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NANJING 2022

Bridges and Structures:
Connection, Integration and Harmonisation

REPORT

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Preface

The IABSE Congress Nanjing 2022 was organized by the Chinese Group of IABSE in co-operation with Tongji University and Southeast University, and was held in Nanjing, one of the metropolises with a 3100-year history that had once been the capital of six dynasties in ancient China.

Bridges and structures are symbols of urban development and expansion. They are not only functional and presentational, but also deeply affect human's lifestyle. The Congress theme *"Bridges and Structures: Connection, Integration and Harmonisation"* reflects the influence of the infrastructure development on the evolving cities and city life. The three sub-themes, i.e., *Future Trends and Innovations in Material, Design and Construction*; *Assessment, Strengthening and Management*; *Sustainability, Durability and Harmonization of Structures* with more than 10 topics for each, explain our understanding of the theme from technical point of view.

This congress proceeding includes a printed version with two-page extended abstracts and an electronic version with the full papers available for download. There were 465 accepted abstracts and 281 papers selected by the Scientific Committee for oral presentation during the Congress.

Eight eminent engineers and scholars recommended by the Scientific Committee and the Chinese Group of IABSE provided Keynote Lectures during the plenary sessions. In addition to the plenary sessions and six parallel sessions, there will also be three special sessions including SS1 (Recent Structures in China), SS2 (Recent Bridges in China) and SS3 (Industrial Session: OVM Technology Forum) in the congress.

The congress was held in a hybrid format (on-site and online). International delegates who were not able to come to Nanjing in person attended the congress online. For technical visits, all participants and accompany persons had the privilege to visit two world record-breaking bridges, i.e., Chang-Tai Cable-stayed Bridge with a main span of 1176m and Zhang-Jing-Gao Suspension Bridge with a main span of 2300m.

We thank all our colleagues for their contributions and support to make this congress possible, especially the Scientific Committee members, the experienced staff of IABSE Secretariat, local Professional Conference Organizers, all the members of the Organizing Committee, the Advisory Committee, the Supporting Organisers, and the Sponsors and Exhibitors.

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IABSE Congress Nanjing 2022

Nanjing, September 2022

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SPECIAL SESSIONS

SS1 Recent Structures in China

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Research on Vehicle-Bridge Interaction Dynamics since 1990s

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Abstract

Impact factors that are more rational for bridges were proposed in 1995 using the vehicle-bridge interaction (VBI) element derived, by which the term VBI first appeared. Resonance and cancellation conditions were proposed for highspeed (HS) railway bridges, by which the optimal span length L was proposed to be 1.5 times the carriage length. Based on the VBI, the vehicle scanning method (VSM) for extracting bridge frequencies was proposed in 2004, which was followed by a huge amount of research not restricted to our research group, but all over the world. Extension was made to construction of mode shapes and detection of damages, damping ratios, etc., of the bridge. Later, pavement roughness was resolved by using the residual of dual vehicles, while vehicle' frequency eliminated by using the vehicle-bridge contact point response. Research continues to grow nowadays on applications to thin-walled beams and railway bridges.

Keywords: bridge; damage; damping; frequency; mode shape; vehicle; vehicle-bridge interaction; vehicle scanning method.

1 Introduction

The journey to research on vehicle-bridge interaction (VBI) problems and vehicle scanning method (VSM) for bridges since the 1990s has been very interesting and rewardable. Partly due to the construction of long-span bridges worldwide and the promotion of high-speed railways in some countries, research on VBI problems continues to grow in a rapid speed.

2 Impact factors for bridges

In bridge engineering, the impact factor *I* to account for vehicle's dynamic amplification is

$$I = \frac{R_{dm}(x) - R_{sm}(x)}{R_{sm}(x)} \quad (1)$$

where $R_{dm}(x)$ and $R_{sm}(x)$ are the maximum dynamic and static responses, respectively, at point *x* of the beam. What attracted us first to this subject is that the impact formula of the AASHTO Specifications (1989) did not look meaningful from the point of physics, in that the impact factor *I* is related to a static parameter, i.e., span length *L*, but not any dynamic parameter of the bridge. In this regard, a dynamic parameter called the speed parameter *s* was adopted instead:

$$s = \frac{\pi v}{\omega L} \quad (2)$$

which is a combination of vehicle speed *v*, frequency ω and span length *L* of the bridge. The span length *L* for simple beams should be interpreted as the characteristic length for continuous beams. Both the non-dimensional impact factor *I* and speed parameter *s* can be related by

$$I = as \quad (3)$$

where *a* is a coefficient specific for each condition. Using the VBI element presented in [1], a set of im-

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Specific Infrastructures in Relationship with the Landscape

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Abstract

The design of specific infrastructures in relationship with their landscapes is a constant challenge, to achieve public acceptance through a harmonious integration. In the last three decades, we chose to work on this topic over a geographical, and technical point of view. This design path is explained over four different projects, in various contexts and at different scales– where consistent attention to the city, landscape, fabric and structural behavior subtly combines into specific designs: how asymmetry orientates the project in Bordeaux; the meeting of two districts over the railways in La Rochelle; a viaduct that offers an urban roof in Paris neighborhood; and a dialog between city and landscape in Linz (Austria).

Keywords: infrastructure, landscape, bridge, specificity, geography, structure

1 Introduction

We take a positive look on the infrastructure. Beyond usage, it is an appropriated and shared space which can always be enhanced.

Our experience and knowledge gained as Architects and Engineers allows us to develop, based on the infrastructure, projects that release themselves from constraints to offer generous urban or territorial situations.

Bridges obviously occupy a significant part of our work. In France, China or elsewhere we identify the local conditions; the site and geographic ones, but also the resources, the knowhow, the local skills which inform our work in order to give priority to local situations and therefore design specific structures.

Every experience adds value to the specific over the generic, the local over the global, and allows to express the location's qualities as well as the work's expertise, by developing an attentive materiality to a world transformed by Architecture.

We always give priority to the capacities that an infrastructure must go beyond its functional characteristics to constitute public realm offered for sharing.

Bridges always magnify the site's environment and offer to everyone shared and appropriable realm. This skill about infrastructures and the technical knowledge on which it is based on, enabled us to expand our projects to specific architectural programs, developing approaches such as inhabited bridges.

Figure 1. Aerial view of the La Rochelle Train Station

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Challenges and Innovations in Design and Construction of Supersized Structural Components for Long Span Bridges

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Abstract

For better cooperating river-crossing highway and railway with waterway transportations, larger spanning capability of a bridges is more demanding than ever before. Larger spans lead to supersized structural components, bringing new technical challenges to the design and construction of bridges. This paper summarizes several recent engineering innovations in the design and construction of supersized structural components for super long span bridges, including thermal-adapting tower-deck restraint system, spatial diamond-shaped tower, steel-box and core-concrete composite anchorage system, scour-mitigating skirted caisson foundation, and vortex-induced-vibration control of the main girder, so as to provide viable solutions for the design and construction challenges brought by supersized structural components of long span bridges.

Keywords: structural scale; thermal-adapting tower-deck restraint system; spatial diamond-shaped tower; steel-box and core-concrete composite anchorage system; scour-mitigating skirted caisson foundation; VIV; long-span bridge.

1 Introduction

Cable-stayed and suspension bridges are two common structural types of long-span bridges in China. The spanning capability of the bridge has significantly increased with the development and construction of bridges in China. In terms of highway cable-stayed bridges, the first cable-stayed bridge is the Yunyang Tangxi River Bridge, which was built in 1975 with a main span of only 76 m. Shanghai Nanpu Bridge was opened in 1991 and adopted the composite girder with a main

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Effects of Subsidence Induced by Tunnelling on Buildings: The Sagrada Familia Temple Case

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Abstract

The paper deals with the controversy that arose over the effects of the construction of a tunnel in Barcelona, for the High-Speed train, on the Temple of the Sagrada Familia. The construction of the tunnel was considered by many as a great structural risk for the temple, as well as for the Casa Milà, both by the famous architect Gaudí. The preventive measures taken, the monitoring implemented, the structural modelling, the control carried out and the results obtained will be explained. It is an example of how to address the risks of a construction which could affect UNESCO World Heritage.

Keywords: tunnelling; world heritage; buildings; subsidence.

1 Introduction

The High-Speed Rail Tunnel Madrid-Barcelona-French Border Line crosses the city of Barcelona connecting Sants and Sagrera Stations. It is a 5.664 Km long tunnel, mostly built by a single EPB shield machine. At both ends of the tunnel, cut and cover stretches were designed for the connection with the stations.

The tunnel crosses a residential area of the city developed at the beginning of the 20th Century called "Ensanche" which is known for its modernist architecture. Most of the buildings are about 100 years old, with brick bearing walls and from 5 to 8 storeys high, being quite sensible to ground displacements. Most of the have very shallow foundations.

The tunnel follows to of the main streets of the district, Mallorca and Provenza. At Mallorca street two of the main buildings designed by world famous architect Antonio Gaudí, are located, Sagrada Familia Temple and Casa Milà. Both of them are included in the World Heritage Catalogue by UNESCO. Figure 1 shows a plan view of the tunnel and Figure 2a longitudinal profile, with the location of the Sagrada Familia Temple.

Sagrada Familia Temple occupies a large block of Mallorca street. The parts built by Gaudi are the crypt, apse and the "Nativity" façade before his death, dated in 1926. The temple is still under construction. The façade facing Mallorca street is the "Gloria" façade, which was started in 2002 and not completed yet.

The tunnel at the Sagrada Familia Temple location is a 11.475 m external diameter reinforced concrete precast lining. Seven segments 0.38 m thick form the lining. The overburden is about 25 m over the crown. The tunnel cross-section is shown in Figure 3.

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Probabilistic Assessment of Vehicle Driving Safety under Strong Winds – Cause Investigations on Two Sea-Crossing Bridges

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Abstract

The strong side winds threaten the stability of running vehicles over the sea-crossing bridges due to the high altitude of the deck and free exposure to the upcoming winds. Therefore, bridge operators control the speed limit or close the bridges when the wind speed reaches predetermined criteria. Since the sea-crossing bridges play an essential role in transportation networks, the traffic control strategy, including complete closure, requires a careful assessment of the critical wind speed at which vehicle instability can occur. As the aerodynamic forces on vehicles depend on several influence factors, including the geometrical shape of the superstructure, the critical wind speeds variate bridge by bridge. This study demonstrates a framework to determine the critical wind speed. This study reports two overturning accidents experienced in a double-deck suspension bridge and a cable-stayed bridge. By applying the proposed framework to the cases, the authors successfully explained the cause of accidents. For this investigation, the authors used a wind tunnel measurement of aerodynamic loads on vehicles and the vehicle dynamics to determine critical wind speed curves. The authors also extended the procedure to the probabilistic risk assessment by adding the long-term wind data analysis of the bridge site. In this way, this study provides a guideline for bridge operators on balancing the driving safety and the continuous mobility of the sea-crossing bridges under hazardous high wind conditions.

Keywords: driving safety; traffic control; strong wind; probabilistic assessment; sea-crossing bridge; short-term wind prediction.

1 Introduction

The Korean peninsula is on the typhoon path, and the sea-crossing bridges are often subject to strong side winds. The total number of cable-supported bridges has increased to reach more than 90. Generally, those bridges are closed at a wind speed of more than 25 m/s on a 10-minute average. However, several bridges also have speed control protocols based on experiences or other benchmarks.

Even though there is a speed control protocol for each bridge, the bridge operators have difficulties taking timely actions for several reasons. The bridge closure requires pre-discussion with the police department in advance and preparation time on site. Also, the wind speed fluctuates all

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Assessment and Retrofitting of Existing RC Buildings – Recent Trends

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Abstract

Most of the existing old structures are vulnerable under seismic actions, due to certain weaknesses that result from poor design knowledge at the time of construction. Critical matters concerning the behaviour of RC structures under earthquake actions were ignored, such as ductility, capacity design, adequate code provisions for detailing of RC elements (minimum number of stirrups, lower limit for compressive and upper limit for tensile reinforcement). A number of approximations and simplifications were adopted in the analysis. Computers were not in use; 3D analysis was impossible and 2D analysis was rarely used. Usually, beams and columns were considered as independent elements. Seismic actions considered in the past were lower than those currently accepted for new structures. In this context, some crucial questions arise: Which structures are more vulnerable and, therefore, have priority to be strengthened and how to identify them? Is it possible (or is it worth) strengthening these structures and to what extent? Is this preferable when compared to the demolition and reconstruction solution? What resources (materials, methods, techniques) are available to intervene and under what standards are they to be applied? Which is the framework to assess the seismic capacity of an existing structure and how to further design the necessary intervention for retrofitting or strengthening? What are the quality control procedures for intervention works?

Redesign of existing structures is a much more complicated task than the design of new ones. Not only there is limited knowledge on this subject, but also existing codes and regulations are relatively new, with the engineering practice not being familiar with them. Furthermore, the configuration of an existing structural system may not be permitted or may be wrong according to our present knowledge, however, it exists and we must deal with this. Usually, there is also a high uncertainty in the general data (geometry, materials, details, hidden errors or faults, etc.). In the present keynote lecture, assessment and retrofitting procedures are analyzed in five stages. In the first stage, the data of the existing structure is documented. Different data knowledge levels define different confidence factors, depending on the extend and detail of the data documentation. Stage two concerns the assessment of the seismic capacity of the structure. The acceptable level of damage is defined through different performance levels or limit states. The third stage involves the decision on whether a structural intervention is required and to what extent. The fourth stage includes the design of the structural intervention, following certain seismic strengthening strategies. The fifth and final stage concerns the construction of the intervention work. Since during this stage new data might arise, frequently the design of the intervention (stage four) should be updated accordingly.

Keywords: seismic assessment; retrofitting procedures; earthquake; RC structures.

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Seismic and Tsunami Resiliency of Bridge and Transportation Structures

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Abstract

Earthquakes can happen in Washington State at any time, and history indicates there may be substantial shifting of land during a seismic event. The State Department of Transportation's manages approximately 18,500 highway lane miles and more than 3,600 bridges on the state's highway system. One of the agencies objectives is to ensure that state highways will be able to provide emergency responders access to damaged portions of the community quickly to provide Recovery life-saving services. State Highways will also need to provide the capability for the state economy and the movement of freight and goods to be re- stored as quickly as possible.

In an earthquake, damage to infrastructure bridges is more closely related to ground motion rather than magnitude. In addition, the ground type can significantly influence ground acceleration. Base on the geographic area and historical data geologists can create seismic hazard maps which show likely earth-quake ground motion zones. This paper discusses the seismic design requirements for bridges and challenges to achieve these requirements for new and existing bridges.

Keywords: seismic; tsunami; resiliency; performance.

1 Bridge Seismic Resiliency

Seismic design of bridges begins with a global analysis of the response of the structure to earthquake loadings and a detailed evaluation of connections between the superstructure and the supporting substructure. Ductile behavior is desirable under earthquake loadings for both the longitudinal and transverse directions of the bridge. Further, the substructure must be made to either protect the superstructure from force effects due to ground motions through fusing or plastic hinging, or to transmit the inertial forces that act on the bridge to the ground through a continuous load path. Plastic hinging is often considered as a mechanism to form and facilitates transverse and longitudinal movement of bridge bents and frames.

Every bridge shall be designed with an Earthquake Resisting System that ensures a load path for gravity loads and provides sufficient strength and ductility to achieve the specified performance criteria.

The plastic hinge ductility or other means of energy dissipation/bridge damping shall be adequate to satisfy the deformation demands imposed by the "design seismic hazards" while minimizing the probability of bridge collapse.

Earthquake Resisting Systems shall consist of the following:

- Seismic critical members – ductile structural members that are intentionally designed to deform inelastic through several cycles without significant loss of strength, thereby limiting the forces

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Innovation and Creation of Recent Bridge Engineering under the Direction of IABSE Outstanding Structure Award

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Abstract

Over recent years there has been considerable development in bridge engineering. Thirty-two bridge projects have received IABSE Outstanding Structure Awards during the past two decades in recognition of the most remarkable, innovative, creative, or otherwise stimulating structures. Several creative structural forms have been created such as two twin-box girder suspension bridges, three spatial main cable suspension bridges, six multi-main-span cable-supported bridges and one cable-stayed and suspension hybrid bridge. Various innovative material combinations have been developed and used in two steel truss and PC flange composite girder bridges, one butterfly web extradosed bridge, one multiple material strength bridge and one long-life concrete cable-stayed bridge. Some remarkable functional technologies have been invented for two remarkable movable bridges, two innovative cable-stayed bridges, two extreme seismic function cable-supported bridges and two environmental coordination bridges. Many stimulating bridge projects have been awarded as Winners or Finalists including three extradosed bridges, four arch bridges, two cable-stayed bridges and four sea-crossing bridges. The innovation and creation of recent bridge engineering has been recognised by IABSE Outstanding Structure Award reflecting the creative structural forms, the innovative material combinations, the remarkable functional technologies and the stimulating bridge projects.

Keywords: Recent bridge; structural form; material combination; functional technology; stimulating structure.

1 Introduction

The International Association for Bridge and Structural Engineering (IABSE) was founded in Zurich, Switzerland on October 29, 1929. After more than 90 years of development, IABSE has become one of the most prestigious institutions dealing with all types of structures, all materials and worldwide membership from over 100 countries. The mission of IABSE is to exchange knowledge and to advance the practice of structural engineering in the service of the profession and society. For this purpose, IABSE established the Outstanding Structure Award (OStrA) in 1998, one of the highest distinctions awarded by IABSE and recognized in different regions of the world for the most remarkable, innovative, creative, or otherwise stimulating structures [1]. During the past 22 years from 2000 to 2021, 28 building structures and 32 bridge structures have been awarded as the OStrAs, including 33 Winners and 27 Finalists [2]. From 2022, IABSE will launch the IABSE Project and Technology Awards for Small Projects, Building Structures, Pedestrian and Cycle Bridges, Road and Rail Bridges, Infrastructure, Rehabilitation,

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Key Technologies of Precast Segment Production for the 4th Ring Transportation Corridor in Zhengzhou, Henan, China

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Abstract

The 4th Ring Transportation Corridor in Zhengzhou, Henan, China (the Project) is implemented in accordance with the design scheme of integral bridge structures and the short-line match casting method. This paper focuses on key technologies of segment precasting used in the Project, involving the design and layout of precast yards, the formwork design for precast segments and the geometry control in the precast yards as well as the application of information technology in precast yards. It can be used as references for projects related to precast segment production in the industry.

Keywords: 4th ring; Zhengzhou; precast bridge; segment; precast yards; geometry control; match cast; short-line; small radius; information technology

1 Introduction

Located in Zhengzhou, Henan Province, the 4th Ring Transportation Corridor in Zhengzhou has a total length of 93.3km. It is an urban transportation mega project with enormous investment and the engineering dimensions are among China's largest urban expressway construction projects.

Situated in the main urban area of Zhengzhou, the 4th Ring Transportation Corridor passes through several administrative districts of the city. Approximately 70% of the total line are elevated viaducts. Both the government and local residents were in urgent need for a bridge construction plan featuring the shortest construction schedule, with minimal construction impact, most convenient transportation of raw material, lowest cost, and minimized maintenance for the future. The innovative design scheme of integral bridge structures and the short-line match-casting method are used for this project, ensuring environmental protection, energy conservation and emission reduction and optimizing economic factors to the greatest extent.

There are 27 interchanges and 39 pairs of on and off ramps along the 4th Ring Transportation Corridor. A challenge was the complicated alignment conditions along the 4th Ring Transportation Corridor, which influenced the layout of the elevated expressway significantly. The general design concept for the elevated expressway was to build the bridges in the center above the existing road with piers in the existing greenbelt. Where, due to space restrictions or utility line interference, it was not possible to build the bridge in the center, the elevated viaducts were constructed at the outsides of the existing road. This led to alignments with the elevated

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Design of Rail Viaducts over the Hajar Mountains

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Abstract

Major railway bridges across the Hajar mountain range belonging to the Etihad Rail Package D of Stage Two of the UAE National Railway Network are built above important wadis and roads.

Standard railway bridges are articulated in 40m long simply supported spans. Tall piers and abutments are required due to the complex terrain and the rail alignment configuration.

Construction logistics and program being key constraints, solutions featuring precast elements have been favoured. The bridge section is made of 7 post-tensioned precast I-girders of 2.50m depth and a reinforced concrete top slab supporting the ballasted track system.

The aim of this paper is to describe the structural system as well as to discuss some important design related aspects related to the precast girder type railway bridges built across the Hajar mountains.

Keywords: railway bridges; heavy freight; precast girders; post-tensioning; rail-structure interaction; scour; seismicity.

1 Introduction

The Etihad Rail Package D of Stage Two of the UAE National Railway Network project (ER2D) comprises the design and construction of the permanent-way infrastructure works carrying dual track freight and passenger trains from Sharjah to the Fujairah Port, through approximately 145km. It will allow completing the first rail connection between the northern ports to the rest of the United Arab Emirates.

ER2D will cross the Hajar mountain range through a succession of 9 tunnels, in addition to the construction of 35 bridges and 32 underpasses. This area is characterized by steep sided mountains with exposed rock surface and marked V-shaped wadis. Detailed hydraulic modelling has been required to capture the complex terrain highly susceptible to flash floods and position the hydraulic crossings appropriately at the location of high flows. Railway viaducts also provide grade separated access for highways, sand tracks utilized locally as well as for camel crossings.

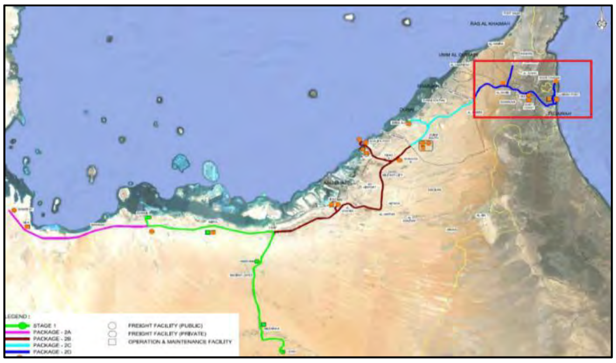

Figure 1. Etihad Rail network

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Important Parameters for Increased Productivity in Bridge Design and Production

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Abstract

There is great potential for increased productivity in the production of bridges in terms of optimizing material use, time and cost for design and production. Hence, the environmental impact and cost can be optimized. To find out how standardisation of parts of bridges and which parameters are of most importance for increased productivity in the production of bridges, a quantitate study was performed on the Swedish bridge construction industry. The questionnaire received 151 responses. The results show in which aspects and parameters the industry's three major actors – engineers, contractors, and clients – see greatest potential in order to increase the productivity. By standardising parts in bridges, there is great potential in making the construction of bridges more productive.

Keywords: bridge building; bridge design; efficiency increase; productivity

1 Introduction

The construction industry in Sweden is behind in becoming more productive [1]. Wodalski et al., [2] even mention that it is documented that the productivity in the construction industry has decreased since the 1960s. Some estimations indicate that the construction industry in Sweden has a cost increase which is twice as high as other industries for the last 20 years [3]. Because of the increased cost of many projects, every project needs to work on reducing their costs [4]. However, the actual productivity is hard to measure [3, 5]. For example, the bridges that are constructed today are designed to carry higher loads than bridges built in the 60s. This increase in load carrying capacity will increase the amount of material which often leads to increased building

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Upgrading the 4th Ring Transportation Corridor in Zhengzhou, China - Optimized Camber Analysis for close to 1,200 Precast Bridge Frames

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Abstract

The City of Zhengzhou is a major transportation hub in the heart of China. The fast-growing city was in need of an additional elevated expressway to increase the traffic capacity from 10 lanes to 18 lanes on the 4th Ring Transportation Corridor. The additional elevated expressway has a total length of 93.3 km and faced complex boundary conditions. 1,200 different bridge-frames were designed for the elevated expressway. The precast segmental bridge frames are continuous girders or rigid frame systems. The short-line match-casting system was utilized for the fabrication of close to 50,000 unique segments. Parameter studies were performed to better understand the influence of the boundary conditions and to optimize the camber analysis. This approach reduced the modeling effort tremendously and allowing the camber data for 1,200 bridge-frames to be analyzed in an accelerated time frame. The largest precast segmental bridge project in the world was partially opened to traffic in 2020 and is now fully operational.

Keywords: Zhengzhou; elevated expressway; precast segmental bridge technology; short-line match casting; fabrication camber; erection camber; optimized camber analysis; geometry control.

1. Introduction

The city of Zhengzhou, with a history of over 5,000 years, is the capital of the Henan Province and a major transportation hub. Zhengzhou has a population of 10.1 million. Due to the poverty-alleviation relocation project, within the next 10 years roughly 5 million more people will move into the city, making large infrastructure projects imperative. To satisfy the needs of the fast-growing city, the 4th Ring Transportation Corridor was developed. This expansion is considered one of the largest transportation projects in China. The 4th Ring Transportation Corridor in Zhengzhou is an elevated viaduct expressway above the existing 4th Ring around the city center. It increased the traffic capacity from 10 lanes to 18 lanes and improved the connection of the inner city with its suburban areas. The industrialization technology of bridge design, fabrication, erection, and construction has been fully implemented to the greatest extent in this project.

1,200 different bridge frames were designed for the entire elevated expressway. The expressway has a total length of 93.3km, with additional 90.0km of interchanges and on & off ramps. The

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Innovations and Breakthroughs in China's Zhangjinggao Yangtze River Bridge

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Abstract

The Zhangjinggao Yangtze River Bridge currently under construction is located in the lower reach of the Yangtze River in Jiangsu Province, China, connecting the cities of Zhangjiagang, Jingjiang, and Rugao. It consists of two river-crossing bridges, one on the south channel and the other on the north channel of the Yangtze river. The south channel bridge is a double-span suspension bridge. In order to minimize the impact of bridge construction on the water traffic and the ecological environment of the Yangtze River, the beam span layout is designed to be 2300 m +717 m, and the cable span layout is 660 m + 2300 m+ 1220 m. When the construction is completed, it will become the world's longest span bridge, which is a veritable world-class mega structure. Since the bridge span breaks the records of all the existing bridges in the world, there is no standard to refer to and no experience to learn from. In order to solve the technical problems brought by the mega long span, the project construction team has utilized technological innovations, proposed six new world concepts, and therefore set six world records.

Keywords: Zhangjinggao Yangtze River Bridge; Longest span suspension bridge; Self-balancing structural system; Steel box and steel tube confined concrete composite tower; Double-loop composite diaphragm wall anchorage foundation; Technological innovation.

1 Introduction

The Zhangjinggao Yangtze River Bridge is a crucial river-crossing link to be constructed during China's 14th Five Year Plan Period as highlighted in both the Yangtze River Principal Arterial River-Crossing Layout Plan (2020-2035) and the Comprehensive Transportation Corridor Plan of Jiangsu Yangtze River Economic Belt (2018-2035). In order to implement the national strategy of integrated development of both the Yangtze River Delta region and the Yangtze River Economic Belt, to optimize the design of the Yangtze River crossing, to improve the layout of the regional road network, and to promote the construction of the Yangtze River city cluster, early completion and operation of the ZhangJinggao Yangtze River Bridge is of great significance.

The total length of the project route is about 30 km, and it consists of two bridges to cross the Fujiangsha channel and the Rugao middle branch channel of the Yangtze River, respectively. For the

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The Construction of Hong Kong-Zhuhai-Macao Bridge

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Abstract

The Hong Kong－Zhuhai－Macao Bridge (HZMB) is located at the Pearl River Estuary on the south of China, It is the longest sea-crossing infrastructure made of island, tunnel and bridge. It links Hong Kong in the east with Zhuhai-Macao in the west with a total length of 55 km. The HZMB was built according to the highway standard of due three lanes. It has a design life of 120 years to meet the Hong Kong standard that is the first in China Mainland. The HZMB has greatly improved traffic conditions on the east and west sides of the coast of the Pearl River Estuary and strengthened the communication, transportation, and economic integration of the three regions, thus accelerating the formation of the Guangdong-Hong Kong-Macao Greater Bay Area. This paper outlines the key construction technologies and strategies used in HZMB to provide references for the design and construction of other mega-projects in China or abroad.

Keywords: Hong Kong-Zhuhai-Macao Bridge; Artificial Island; Immersed Tunnel; Sea-crossing Bridge; Construction.

1 Introduction

The 55-km-long Hong Kong-Zhuhai-Macao Bridge is the longest sea-crossing bridge made of island, tunnel and bridge in the world, which consists of a six-lane highway connecting Hong Kong with Zhuhai and Macao at the mouth of the Pearl River Estuary in China, as shown in Figure 1. The project was completed in February 2018 and was opened to traffic in October 2018. The HZMB had improved traffic conditions on the east and west sides of the coast of the Pearl River Estuary and strengthened the communication, transportation, and economic integration of the three regions, thus accelerating the development of the Guangdong-Hong Kong-Macao Greater Bay Area [1-2].

The HZMB main bridge has a length of 29.6 km， The tunnel is approximately 6.7km in length, with 2 artificial islands approx. 625m long and the immersed tunnel part approx. 5.7km long and at about 20m below the sea bed. The immersed

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ShiZiYang Bridge – Large diameter main cables

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Abstract

The ShiZiYang suspension bridge in the GuangDong province in China will when constructed have a world record main span of 2180 m and carry an impressive 2 x 8 lanes of traffic on the two levels truss girder.

Due to its size, ShiZiYang bridge requires extensive main cable area with diameter nearly 1.5 m representing the largest main cable ever constructed. An option of dual main cables can be considered with smaller main cables including simpler compaction. However the construction time is extended, all adjacent structures such as saddles, anchorages and cable clamps become significantly more complex and the separate cables behave as independent members.

The paper discusses the main key challenges regarding design and construction of large main cables with diameter above 1m and alternatively dual main cables.

Keywords: ShiZiYang bridge; suspension bridge; main cable; high strength cable steel; single main cable; dual cables; cable system erection; cable system structures

1 Introduction

The technological development is pushing the boundaries of span lengths of suspension bridges together with the increasing deck weights carried by the main cables. ShiZiYang bridge in GuangDong province in China is a bright example with the planned main span of 2180 m carrying 2 x 8 lanes of traffic on 2 level truss girder deck. A rendering of the bridge is displayed in Figure 1-1.

Due to the length of the span and the considerable deck weight, the main cable diameter will be significantly bigger in comparison to the current record breaking longest span suspension bridge, Canakkale bridge (Turkey, 2023 m main span, maximum main cable diameter 0,881 m) that has opened to traffic March 2022. The largest ever constructed main cable diameter measures 1,3 m and is applied on the WuFengShan Yangtze River Bridge (road and railway combined with a main span of 1092m) in China. In comparison, the main cable of ShiZiYang bridge is expected to slightly exceed 1,4 m in diameter.

There are several challenges connected to the main cable with size beyond the constructed bridges related to both, design and construction. An option to avoid the main cables of such significant size is to split the single cable into a dual cable which has been previously used in Verrazzano-Narrows Bridge (USA) as the longest span suspension bridge with the dual main cable.

The present paper describes the main design aspects for main cables, discusses use of high strength cable steel, compares the design of main cable system with single and dual cables and identifies possible construction related issues.

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COWI Experiences in Chinese Mega Bridge Projects – Danish Way and Chinese Way

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Abstract

From 20th century, infrastructure in China has experienced rapid development, especially in mega cable supported bridges. COWI had the honour and opportunity to participate in some of the prestigious mega bridge/sea crossing projects, and thus gained in-depth knowledge in the bridge design following Chinese traditions. The mutual corporation on these projects between COWI and the Chinese designers as well as Chinese project owners has closed the knowledge gap of design and construction methods by Chinese tradition and Danish tradition, and also enhanced the technical development and know-how of modern bridge design.

In this paper, some of the challenging issues for mega suspension bridges are presented, where the Chinese way and Danish way in addressing aerodynamic flutter stability, design of hanger system, and anchor block & foundation are described and discussed.

Keywords: cable supported bridges; suspension bridges; aerodynamic performance; flutter check wind speed; flutter critical wind speed; hanger system; anchor block; anchor block foundation.

1 Introduction

From 20th century, infrastructure in China has experienced rapid development, especially in mega cable supported bridges. By 2022, for the bridges completed or under construction, among the world top ten longest sea crossing links, cable stayed bridges and suspension bridges, more than 60% are built in China.

COWI has had the honour and opportunity to participate in some of the prestigious mega cable supported bridge projects in China, and thus gained in-depth knowledge in the bridge design following Chinese traditions. The mutual corporation on these projects between COWI and the Chinese designers as well as Chinese project owners has closed the knowledge gap of design and construction methods by Chinese tradition and Danish tradition, and also enhanced the technical development and know-how of modern bridge design.

Worldwide, COWI has participated in the construction of many world-famous modern suspension bridges, among them are Great Belt suspension bridge, High Coast bridge, Osman Gazi (Izmit) bridge, 3rd Bosporus bridge, Hålogaland bridge, 1915 Canakkale bridge etc.

Although the engineering world is often considered as an exact science, things are not always black and white. In many cases, there could be several solutions which are equally feasible and optimal, all depending on construction conditions, project owner's and designer's preferences towards safety and risks, construction methods, construction cost,

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ShiZiYang Bridge – General Scheme Design Options for Mega Suspension Bridge

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Abstract

The ShiZiYang suspension bridge in the Guangdong province in China will when constructed have a world record main span of 2180 m and carry an impressive 2 x 8 lanes of traffic on the double-deck truss girder. A bridge of this previously unmatched proportion requires innovative design concepts to develop a feasible and constructable bridge. The ShiZiYang Crossing owner organization invited three well-known bridge design companies in the initial design process to develop different options for overall configuration of girder, tower, anchorage, and cable system. Each of the different concepts have their own merits and regardless which one is chosen it will be on the limit to what has previously been achieved. While focusing on minimizing the deck weight, many other items must be taken into consideration such as aerodynamic stability, operation and maintenance, construction, cost, and aesthetic value. Comprehensive comparison of various options was thus carried out to select promising options that can serve as the basis for work of the next phase.

Keywords: ShiZiYang; general scheme design; suspension bridge; truss girder; double deck

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Archimedes Bridge Underwater of BaiYangDian Lake

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Abstract

Based on the concept to build a floating bridge being the mixture of bridges and tunnels on anchored submarines, this paper tells a conceptual design of 3x50 Archimedes bridge underwater of BaiYangDian Lake, and also of prospectives on the same type of Archimedes bridge for TaiWan Strait.

Keywords: BaiYangDian Lake; Archimedes; Underwater Bridge; BIM; Anti-overload Vajra; Anchored Submarine; TaiWan Strait

1 Introduction

The author of the book "Aesthetics of Bridge Design" [1], when introducing the Li River Bridge in Guilin and the Taihu Lake Bridge, which he designed, quoted a famous architecture professor from Tongji University: Guilin is so beautiful that bridges cannot compare with it in any way. The bridge could only be built there "quietly".

In order to realize this concept “quietly” to the fullest extent possible, the author proposed to the author of the book the idea of building an underwater bridge in BaiYangDian Lake. This bridge was named BaiYangDian-Archimedes Bridge by him. According to the Chinese People's Volunteer Army team during the war against the United States [2], the so-called underwater bridge is this bridge to the surface of the water forty or fifty centimetres. It enables the river not to flood the exhaust pipe of the car, but also hides the bridge well. Of course, in the current era of peace, the bridge in the water does not need to be so deep.

The following is the conceptual design of a 3x50m Archimedes (underwater) bridge for a site in BaiYangDian Lake.

2 The bridge position and its hydrological situation profile

According to the website Baidu, the situation of BaiYangDian Lake[3] is as follows. According to the measurement in 2009, BaiYangDian Lake has a water area of 108.8 square kilometres (water level 7.09 meters). The total area is 336 square kilometres (when the Dagu elevation is 10.6 meters), with 102.4 million cubic meters of water storage, and the ground landscape is dominated by water. More than 3700 horizontal and vertical ravines divide the entire lake into 143 small lakes of different sizes. It is also reported that in recent years, the annual diversion of water from the Yellow River 105~200 million m3 of water is injected into BaiYangDian Lake. Its usual water level is maintained at 6.6~7.0m; and 105~200 million m3/108.8km2m.

The form of the bridge deck cross-section, or the corresponding roadway grade, depends on the roadway to be connected at both ends of the bridge. If the existing ground beneath the bridge does not meet the space requirements for the bridge box, the

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Construction Technologies of a large span Railway Suspension Bridge-Wufengshan Bridge

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Abstract

This paper is to introduce construction technologies of a thousand-meter scal high-speed railway suspension bridge in China, Wufengshan Bridge. There are basic principles applied throughout the bridge construction process: 1) To pay attention to innovations in bridge design method and basic theory by emphasizing both life cycle optimization design and durability design; 2) To advance key bridge construction technology; 3) To grasp the state deterioration mechanism and evolution law of the bridge operation and maintenance process in advance; 4) To build a whole life-cycle management framework system. This paper involves the design method, calculation theory, and the corresponding technical standards of high-speed railway suspension bridges in China.
Keywords: railway bridge; suspension bridge; construction; anchorage; cable saddle; steel beam erection

1 Introduction

The Wufengshan Yangtze River Bridge is an essential part of the Lianzhen Railway. The bridge is about 39KM upstream from the Runyang Yangtze River Highway Bridge and 28KM downstream from Taizhou Yangtze River Highway Bridge. The total length of the bridge is 6,408.909M, which includes a 1,432M main bridge for the river crossing, a 1,444.799M approach bridge for the railway and highway joint section, and a 3,532.11M approach bridge for the railway-only section[1-3]. The bridge is shown as Figure 1.

The main bridge is a steel truss suspension bridge of 1,092M with the rise-span ratio of 1/10. The side span of the main bridge is 350M. A total of two main cables are used in the bridge, and the transverse distance is 43M. The stiffening beam uses a continuous steel truss beam with five spans: 84M, 84M, 1092M, 84M, and 84M.

Figure 1. Wufengshan Yangtze River Bridge

The longitudinal design of the bridge is symmetrical. The main towers on both sides of the bridge are comprised of a portal frame concrete

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Overall Design of the Nanjing Jiangxinzhou Yangtze River Bridge

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Abstract: This paper systematically introduces the overall design concept of the Nanjing Jiangxinzhou Yangtze River Bridge. The main bridge is a three-tower cable-stayed bridge featuring a longitudinal diamond cable tower and dual central cable planes. The bridge span is designed to be a total of 80+218+600+600+218+80 = 1796m. A steel-shell composite cable tower design is adopted, with the main girder including a high-performance steel-coarse aggregate reactive powder concrete （CA-RPC） composite girder structure. The cable tower uses cast-in-situ bored pile group foundations, and the stay cables are formed of steel strands. The south and north approach bridges use segmented prefabricated prestressed concrete box girders. The bridge over the river dyke uses a continuous box girder made of prestressed corrugated steel webs for the 78m span and the construction technology of segmented prefabrication has being used for the first time. Nanjing Jiangxinzhou Yangtze River Bridge has become a classic engineering structure which not only environmentally-friendly, but also meets all requirements of industrial construction attributed to the application of a high-performance composite structure for the main bridge, as well as large-scale prefabricated assembly structures for approach bridges and bridges over river dykes.

Key words: Nanjing Jiangxinzhou Yangtze River Bridge; steel shell-concrete composite cable tower; CA-RPC; segmented girder bridge made of corrugated steel webs through prefabricated assembly; industrial construction

1 Overview of Nanjing Jiangxinzhou Yangtze River Bridge Project

Nanjing is one of the four ancient capitals of China, also the economic center and transportation hub of East China. The Yangtze River runs through the city and becomes a natural moat cutting off the city. Nanjing Jiangxinzhou Yangtze River Bridge is in the center of the city and connecting the two banks of the Yangtze River. The bridge improves the regional road networks, greatly alleviates the difficulty of crossing river transportation, and promotes the integrated development of the city on both banks.

Route of this project starts from Wuli Bridge in Pukou District of Nanjing, connects with the reconstructed Jiangbei Avenue, crosses the main channel of Yangtze River, passes through Meizizhou, dives down the south bank of Jiajiang River and connects with the completed Jiangshan Avenue. The total length is 10.334 km, including 4134m Yangtze River main channel bridge, 1754.6m Jiajiang tunnel and about 4.4km other sections. This paper mainly introduces the design of the main channel bridge across the Yangtze River.

2 Main Design Standards

- Highway class: First-class two-way six-lane highway
- Class of vehicle load: Class-I Highway
- Design speed: 100 km/h
- Bridge structural design baseline period: 100 years
- Basic design wind speed: 31.7 m/s
- Basic seismic intensity: Zone VII

3 Design of Main Bridge

3.1 Bridge Span Arrangement

The bridge site finds at the main river surface of the Yangtze River, with 3km in width and of busy shipping. Considering the factors such as navigation, flood control, investment and aesthetics, Nanjing Jiangxinzhou Yangtze River Bridge adopts the cable-stayed bridge with three towers and double main spans (80+218+2×600+218+80)m over the Yangtze River. The two 600m main spans effectively cover the area with a water depth of 10.5m, fully adapting to the shipping development and the requirement for multi-line navigation.

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Trial Design of a New Type of Large-Span Double-Limb Prestressed Concrete Box Girder Bridge with Corrugated Steel Webs

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Abstract

Owing to the buckling problem of corrugated steel webs, up to now the span of prestressed concrete box girder bridges with corrugated steel webs has not exceeded 200m . Based on the analysis of buckling strength of corrugated steel webs, a new type of large span prestressed concrete box girder bridge with double-limb corrugated steel webs is proposed in this paper. It reduces the free height of the corrugated steel webs by filling core concrete between the double-limbed corrugated steel webs, and increases buckling strength of the webs. Additionally, the optimization technique of strong top plate and thin bottom plate is applied to reduce the self-weight of constant load without reducing the cross-sectional stiffness. The result of the trial design shows that this bridge type is applicable and economical, which can achieve a breakthrough in the span of prestressed concrete box girder bridges with corrugated steel webs.

Keywords: girder bridge; corrugated steel web; double-limb; buckling strength; Core Concrete; Thin bottom plate.

1 Introduction

Prestressed concrete box girder bridges with corrugated steel webs are made by replacing the concrete webs of traditional prestressed concrete box girder bridges with corrugated steel webs, which have excellent mechanical properties and efficient material utilization. It is increasingly being used in bridge projects because it overcomes the problems such as web cracking and continuous deflection of conventional prestressed concrete girder bridges. With the development of application, the maximum span of prestressed concrete box girder bridges with corrugated steel webs has been broken through. At present, the world's largest span prestressed concrete box girder bridge with corrugated steel webs is the 179m Yasukawa Bridge in Japan [1-2]. In China, prestressed concrete box girder bridges with corrugated steel webs have made rapid progress although they started late [3]. In 2010, the 120m Juancheng Yellow River Bridge was built in Shandong Province completed [4]. In 2019, the 160m Qianshan River Bridge was completed in Guangdong Province [5]. In 2021, the 185m Feilong bridge under construction in Guangxi Autonomous Region is the largest prestressed concrete box girder bridge with corrugated steel webs under construction at present [6]. Despite the rapid development of prestressed concrete box girder

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Nonlinear Coupling in Cable-Supported Bridges for Non-Analogous Modes

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Abstract

It has been shown that the nonlinear differential equations representing the structural system of a suspension bridge exhibit nonlinear modal coupling that can lead to large torsional vibrations of the bridge deck. Such nonlinear coupling could play a role in the stability of cable-supported bridges under wind effects. Therefore, this paper presents an investigation of nonlinear modal coupling in cable-supported bridges with an emphasis on coupling between pairs of non-analogous modes, i.e., modes having a weak correlation along the bridge deck between the vertical displacement and torsional rotation. A procedure for assessing nonlinear coupling that relies on nonlinear generalized stiffness parameters is utilized for this purpose. Results of nonlinear generalized stiffness analysis for suspension bridges indicate that non-analogous modes have a weaker nonlinear coupling compared to analogous modal pairs.

Keywords: cable-supported bridges; suspension bridge; finite element analysis; nonlinear static analysis; geometric nonlinearities; structural dynamics; modes of vibration.

1 Introduction

The first few decades of the 20th century were marked by a rapid increase in span length for suspension bridges. This went on until dynamic wind effects were observed on some of the suspension bridges designed in this era, even those by prominent engineers like Othmar Amman and David B. Steinman. The collapse of the Tacoma Narrows Bridge is obviously the event that triggered what has been more than 80 years of research on the dynamic effects of wind on bridges. Going from wind tunnel testing, finite element analysis to computational fluid dynamics, this research has made possible super long-span bridges like the Çanakkale Bridge and Messina Strait Bridge. As span lengths are getting longer, nonlinear structural phenomena in cable-supported bridges could play a role on the safety and stability of these bridges when subjected to wind effects. Similar to what happened in the case of dynamic wind actions at the beginning of the 20th century, nonlinear structural phenomena have been omitted in the design process due to a lack of information about them.

Regarding nonlinear structural phenomena, there have been some demonstrations of nonlinear mode coupling made by mathematicians using

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Research on the Connected Effect of Separated Bridges Based on a Large-Span Continuous Rigid Frame Bridge

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Abstract

Prestressed concrete continuous rigid frame bridge is one of the main types of long-span bridges due to its mature construction technology and low cost during construction and operation. The corresponding design theory and construction technology were focused on the control and prevention technology of cracking and deflection. Based on an actual bridge inspection, obvious connected effect of separated structures was found that additional deformation and stress increase of the amplitude structure induced by the influence of the central transverse connection (diaphragm, central guardrail consolidation base, etc.) can not be ignored. Suggestions including raising safety coefficient or adopting refined analysis model are provided.

Keywords: prestressed concrete continuous rigid frame bridge; connected effect of separated structures; spatial grid model.

1 Introduction

Prestressed concrete rigid frame bridge is one kind of the common structural system in construction of long-span bridges due to its mature construction technology and low cost during construction and operation period. It plays an important role in the construction of bridges with a span of 100m~300m crossing waterways and mountainous areas[1].

This type of bridge structural system integrates the force characteristics of continuous beam bridge and T-shaped rigid frame bridge, with a continuous beam which is fixed with the piers. Based on the difference of pier thrust stiffness, the rigid frame system or continuous rigid frame hybrid system can be selected flexibly. The stress characteristics of the superstructure are essentially the same as those of the continuous beam, but the bending moment in the main girder can be adjusted through reasonable pier stiffness. Compared with the continuous beam, the positive moment of continuous rigid frame bridge is smaller than that of continuous beam bridge under live load, and their negative moments are close; under the action of the dead load, their bending moments are also closer. The piers and the girders are fixed together, which can reduce construction and maintenance cost of large-tonnage bearings, and improve the mechanical performance of the structure under horizontal load (such as seismic load). Therefore, this kind of bridge has been widely used all over the world[2][3].

According to the long-term engineering practice and operation tracking, there are some common and prominent defects of long-span PC continuous rigid frame bridges. The most typical defects are structural crack and midspan deflection, which also limit the widespread application of this type of bridges. In the past 20 years, the above problems have become the research hotspots in the

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Conceptual Design of Long-Span Suspension Bridges: Tower Structural Forms

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Abstract

Towers are highly visible and characteristic structural components in long-span bridges. Although several tower arrangements have been proposed for medium-span cable-supported bridges, few solutions have been feasible and optimal for long-span suspension bridges. The most widely adopted form is the H-frame, where vertical (or slightly inclined) legs are connected by one or more cross beams. Another solution is the A-frame in which two inclined legs, not necessarily connected by intermediate cross beams, merge at the tower top. On a few occasions single-shaft towers, often used in cable-stayed bridges, have also been used in suspension bridges. This paper compares alternative tower forms for long-span suspension bridges, based on COWI experience in recent bridge design projects. Different arrangements are investigated, with the objective of improving structural efficiency and reducing material quantities. Finally, constructability aspects and the interaction between the towers and other bridge elements are discussed.

Keywords: suspension bridges; bridge towers; pylons; long-span structures.

1 Introduction

In long-span suspension bridges, aesthetics is often as important as structural efficacy since these structures represent way more than mere crossings. They are landmarks affecting the way people live and interact with the environment. Towers are the most visible element of a suspension bridge, and their form can become as iconic as the whole structure.

Several structural forms have been adopted for cable supported bridges; however, long-span structures impose several constraints on the tower design, thus reducing the available options. This paper investigates the concept design of towers for long-span suspension bridges. First, structural aspects related to design and construction are analysed. Then, advantages and limitations of typical tower forms are highlighted. Finally, some reference projects from COWI portfolio are presented to compare competing solutions in terms of efficiency and aesthetics.

2 Concept design of suspension-bridge towers

This section highlights the key factors driving the conceptual design of long-span suspension bridges.

2.1 Material

As the predominant force carried by the tower is compressive axial load from the cables, combined with bending due to eccentricities and horizontal loads, concrete towers are typically the first choice. However, the considerably increased self-weight over that of an equivalent steel structure may

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Benefits and Challenges of the Twin-box Bridge Girder

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Abstract

The aerodynamics of the twin-box bridge is considered to highlight the reasons for making this type of bridge deck superior to the conventional trapezoidal mono-box for suspension bridges having span lengths longer than 1800 m. The paper proposes a simple theoretical model yielding physical insight into the flutter stability and presents a design example comparing the flutter performance of a 2000 m main span suspension bridge designed with either a mono-box or a twin-box bridge girder. Experience from vortex induced vibration of twin-box bridges is discussed to demonstrate that a twin-box girder can be designed to avoid vortex induced for practical damping levels.

Keywords: flutter instability; suspension bridge dynamics; mono-box bridge girder; twin-box bridge girder; vortex induced vibrations; cross girder connection.

1 Introduction

As the technologies advance and the demands for longer bridge connections arise, additional challenges meet the bridge designer. One being the structural performance of the bridge girder particularly for long span cable supported bridges in areas where the wind climate is harsh and weather extremes will become more frequent and intense because of global warming.

The wind performance of the conventional mono-box girder layout, as used for some of the longest bridges in the world such as the Great Belt bridge in Denmark and the Osmangazi bridge in Turkey, may have reached its limit once the spans approach the 1800 - 2000m mark. The alternative: A twin-box girder.

From the perspective of aerodynamic performance, the twin-box has some merits, as it reduces the self-excited aeroelastic loads in torsion leading to higher wind speeds for onset of flutter. The downside of the twin-box is that vortices shed rhythmically from the upwind girder hull may impact on the downwind girder hull and lead vortex induced vibrations at low wind speeds commonly encountered for every day operation.

From a structural point of view separating the two boxes increasing the lateral stiffness around a vertical axis will naturally be beneficial to some extent, however in doing so cross girders are required to connect the girders to achieve this effect. Herein lies a challenge, since the Vierendell effect of the girder system may impose some localised effects at the connection between the longitudinal girders and the cross beams. This connection will require special attention, and the knowledge of this effect shall be considered in the early phases of the design, since it may have direct impact on the general layout of the bridge girder system.

2 Flutter instability

Aerodynamic instability of long span suspension and cable stayed bridges manifests itself as flutter

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Key Technology for the Design of a Cable-Stayed Bridge in a High-Intensity Area

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Abstract

The background project is Xiyan Bridge, Pingcheng Street, Datong city, Shanxi Province. The bridge crosses both railway marshalling yards and multiple important railway lines. The span arrangement is (41+50+163) m. The overall design, key structure design and calculation of the main bridge are introduced in detail for high intensity areas and for large spans with width and bidirectional asymmetric main girders. The main point is placed on the comparison, selection and analysis of the main tower as an all-steel structure and steel-concrete composite structure for its seismic system design. The linear control, weighing and counterweight scheme are simulated for the main construction process of the whole bridge without setting up the closing section of a rotating body on site. The calculation proves that the structure design is reasonable and that the construction is safe and reliable. It can provide a reference for the design and construction of similar bridges.

Keywords: bidirectional asymmetry structure; hybrid beam cable-stayed bridge; seismic system design; weighing and counterweight; rotation construction.

1 Background project and introduction

The project is located on the west extension line of Pingcheng Street, north of the ancient city of Datong city, Shanxi Province. This line crosses the existing railway marshalling yards and several important railway lines. It is planned as the main urban road with a width of a 50 m red line. Pingcheng Street Road is an east–west street, and the main line viaduct starts from Wuzhouxiyi Road in the west and crosses Wuzhou Road, the Planning Road, the railway marshalling yard (approximately 340 m wide), Xihuan Road and the Yunzhong Road tunnel, ending approximately 150 m west of Weidu Avenue with a total length of approximately 1716 m. To facilitate rapid access to the long-term planning of the West Ring expressway, the planning scheme considered in the west of the west ring road set up two ramps linked with the main line of Pingcheng Street, the near ramp access to the ground of the West Ring Road, through local reconstruction, into the West Ring elevated expressway main line in the long future to achieve rapid interconnection of Pingcheng Street and the West Ring expressway. The engineering plane location is shown in Figure 1.

Figure 1. Geographical location of the background project

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Multilevel Decomposition Model for Optimal Design of Multi-Story Structures

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Abstract

Multilevel decomposition optimization method decomposes a large problem into small subproblems to be solved separately and maintain effects between subproblems effectively by sensitivity derivatives, and it serves as a useful tool for design engineer team to work on a large structural optimization problem simultaneously and effectively. The present paper illustrates the application of this method on the optimization of a portal frame of a multi-story steel structure, and three level of substructure is chosen to solve the optimization problem. The 1st level is the entire structural system constrained to total lateral displacement, the 2nd level is each story frame constrained to story drift, and the 3rd level is related element sizing based on local constrains due to strength, serviceability, and member stability.

Keywords: optimal design; multilevel decomposition model; multi-story structure.

1 Introduction

Structural optimization is one of key aspects of efficient designs, and, with a large numbers of available optimization methods, structural engineer team shall know which approach to adopt in the interest of efficiency in achieving required design goals with limited time and resources. One-level optimization process which requires iterations of the whole structure might be overwhelming, costly, and unmanageable, especially, when it comes to large projects with large numbers of design variables and design constraints.

Multilevel decomposition structural optimization method is the process of partitioning a big problem (a system) into small subproblems (subsystems), solving them independently and simultaneously, coupling effects between different levels, and iterating whole process to a converged point, and, importantly, this method also provides trackability to the problem solving [1]. This method has been adopted in many works such as optimization of prestressed concrete via two-level optimization [2], steel frame optimization [3], and space truss optimization [4].

In structural design application, a system (an entire structures) is seen as a hierarchical system and is decomposed into several levels. Generally, 1st level is always the entire system (a whole structures) while the lower levels (subsystems) are arranged

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Study on Long-term Deflection Control Performance of Long-span Prestressed Concrete Combination Structure Rail Transit Bridges

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Abstract

Rail transit bridges must meet stringent requirements for deflection control throughout the operation period. To provide a reference for the selection of bridge type and structure for long-span rail transit bridges, this paper conducted a comparative study of four PC(prestressed concrete) combination structure bridge types' long-term deflection control performance. The structural configurations of the bridge types under research were trial designed using the same arrangement with a main span of 250 m and design parameters, and the Finite Element models for long-term deflection calculations were developed. According to the findings, all of these bridge types exhibit high vertical structural stiffness and excellent long-term deflection control performance, satisfying rail transit's technical requirements. Additionally, Excess weight and prestress loss have a less detrimental effect on arch-assisted girder bridges.

Keywords: hybrid system； creep effect； influencing factors； long-term deflection prediction.

1 Introduction

Prestressed concrete (PC) girders offer the advantages of high structural stiffness, low vibration and noise, competitive prices, and minimal maintenance, able to meet the smoothness, stability, and reliability requirements of urban rail transit. However, as operation time increases, excessive deflection with cracks is the common issue for long-span PC girder bridges [1].

In comparison to highway bridges, the deformation control for urban rail transit bridges should be more stringent. The deflection of the deck of a rail transit bridge will proportionately increase the acceleration and load shedding rate, affecting the smoothness and safety of train operation [2]. As a result, the long-term deflection effect of the main girder must be strictly controlled. According to Chinese code for urban rail transit bridges [3], the long-term creep deflection of PC girders with a minimum span of 50 m and without ballast should not exceed L/5000. Based on statistics of the deflection of long-span PC continuous girder or PC continuous rigid frame bridges in the world, the aforementioned requirements are no longer suit for the bridges with the main span exceeds 200 meters [4]. While an all-steel main girder structure is feasible in terms of force and long-term

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Study on Mechanical Property of Reticulated Shell Structure Canopy Considering Elevated-effect of Viaduct in High-speed Rail Station

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Abstract

Some high-speed rail stations use reinforced concrete reticulated shell as its canopy structure in China. This structure has advantages of beautiful shape, large span and convenient maintenance. This paper mainly studies the influence of the viaduct structure on mechanical property of reticulated shell structure upper, and establishes the overall finite element model of station including the viaduct and canopy structure. The study results show that due to the relatively large structural stiffness of the viaduct, it can select a separate model of the canopy from the whole station structure to analysis, and can meet the safety requirements of the canopy structure.

Key words: reticulated shell structure; viaduct; elevated effect; rise-span ratio; double-columns.

1. Introduction

Reticulated shell structure belongs to curved space grid structure, which has the multiple advantages of simple construction in beam structure and reliable force of thin shell structure. It can cover relatively large span and has rich and colorful modeling, and can be played freely according to the architect's creative intention. It is deeply favored by architects.

Built in 1957, the Little Sports Palace in Rome (Figure 1) has a spherical dome on its roof and a circular plane diameter of 60 meters. It is famous for its beautiful dome ceiling modeling around the world. The Auditorium of Tongji University was built in 1962 (Figure 2), which is an assembly integrated concrete reticulated shell structure. The hall is 40 meters wide and 56 meters long. The diamond-shaped structure grid in the arched roof is completely exposed, which is very rhythmic, achieve the result by different methods of the Little Sports Palace in Rome.

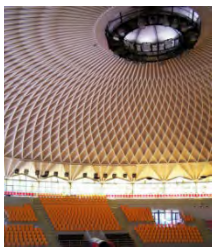


Figure 1. The Dome of Little Sports Palace in Rome
Figure 2. The Auditorium of Toni University

Reticulated shell structure is also widely used in high-speed railway station. For example, the waiting hall roof of Tianjinxi Station built in 2011 (Figure 3) adopted cylindrical single-layer oblique steel

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Investigation on the Flexural Behavior of Reinforced UHPC T-Beams with Different Tensile Strain-Hardening Properties of Base Materials

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Abstract

Ultrahigh performance concrete (UHPC) has been broadly endorsed for many applications in the construction industry due to its superior mechanical properties and excellent durability. Nevertheless, UHPC utilization as full and large structural components is still limited due to the lack of standardized design guidelines and consistent mechanical models. This study presents a numerical investigation on the flexural behavior of UHPC T-beams under the influence of the tensile grade of UHPC, and the reinforcement ratio. The behavior is studied under three conditions relating the UHPC tensile strain to the reinforcement yielding strain. That is, UHPC peak tensile strain is smaller than, equal to, or larger than the yielding strain of the rebar, reflecting the sequence of crack localization and yielding of rebars. Each condition is examined against a reinforcement ratio ranging from low to high ratio. The nonlinear finite element modeling approach is validated by experimental data available in the literature.

Keywords: UHPC; flexural behavior; strain-hardening; multiple cracking; peak strain.

1 Introduction

Ultrahigh performance concrete (UHPC) is one of the state-of-the-art construction materials developed in recent decades that demonstrate outstanding mechanical properties, including compressive strength of more than 150MPa, sustained post-cracking tensile strength and pronounced durability [1,2] . UHPC has attracted worldwide attention from researchers for its high potentials in the construction sector. Even so, its approval as full and large structural components is still limited by several constraints including a lack of consistent and practical design models, low knowledge of the production procedures and quality control, demand for rigorous curing regimes, and the high production cost [3,4]

The inconsistencies and complications in the design models are attributed to the sensitivity of UHPC to

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Wind Induced Response Analysis and Vibration Mitigation Design for Steel Tall Buildings Equipped with Viscous Dampers

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Abstract

The wind induced response of the steel tall building is obvious. Controlling the wind induced response of steel tall building can effectively improve the comfort, stiffness and strength performance of the structure. A large number of studies have shown that equipping damping device is a more effective wind-induced vibration control measure than increasing the structure stiffness. Viscous damps can achieve multi-load and multi-performance structure vibration reduction and have a very broad engineering application prospect. In this paper, the wind induced response of steel tall building and the viscous damper system are studied to ascertain the optimal arrangement and quantity of viscous damps and a 150m steel residential tower is taken as an engineering case, which shows that the integrated viscous damps can effectively improve the structure performance of steel tall building under wind load and reduce the steel consumption of the structure.

Keywords: viscous damper; steel tall building; wind induced response analysis; high-rise buildings.

1 Introduction

Recently, to respond to "dual carbon" strategy, the Ministry of Housing and Urban-Rural Development has vigorously promoted development of prefabricated buildings. The assembly feature of steel structures ensures their wider application in residential building. Steel structure has light mass and high flexibility. Wind load is often the controlling load case for overall performance of the structure. The viscous damper can improve the comfort, stiffness and strength of the structure under wind load. In addition, it has relatively small volume and low price, and is easy to install and maintain. It could be better applied in residential projects.

Since 1990, Makris et al. proposed application of viscous dampers in civil engineering structures [1], and domestic and foreign scholars have continued to promote development and application of viscous dampers. In 1999, TAYCO DEV INC applied invention patent of the toggle brace motion amplification device (patent No.: US5870863[2] and US 5934028[3]), which significantly improved the energy consumption efficiency of viscous damper and achieved wider application of viscous damper. Xin Zhao and Haojia Ma studied

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State of the Art of Concrete Segmental Bridges

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Abstract

The objective of this paper is to summarize current theory, design, and construction methods of concrete segmental girder bridges and to propose future research needs. First, the analytical theory will be overviewed, including concrete creep and shrinkage, bending strength with external tendons and unbounded tendons, web crack control, anchorage, etc. Then, the paper covers design methods regarding corrosion, including the use of Electrically Isolated Tendons (EIT) system, Fiber Reinforced Polymer (FRP) tendons and other corrosion protection techniques. In addition, internal redundance; the use of ultra-high-performance concrete (UHPC); and standardization for expediting the concrete segmental bridge design will be presented. The paper concludes with a discussion of research needs for future development of concrete segmental bridges.

Keywords: concrete segmental bridge; creep and shrinkage; crack control; dynamic allowance; corrosion protection techniques; standardization; new material; construction; research needs.

1 Introduction

Concrete bridges that are built segment by segment or piece by piece are often called concrete segmental bridges. Due to a prevailing desire for expedited construction with minimal traffic disruption, lower life cycle costs, appealing aesthetics and the need for super-elevated to curved roadway alignment, segmental concrete bridges have developed rapidly and become a primary choice for major transportation projects throughout the World. The maximum span length for girder type segmental bridges has reached 330 m. Concrete segmental girder bridges are not only widely used for long span bridges but are also used extensively for elevated viaducts in urban settings.

It has been demonstrated on numerous projects that precast concrete segmental bridges can not only significantly reduce construction time and traffic disruptions, but also can provide the most economical, cost-effective bridge choice. Segmental construction is not only applied to girder type bridges but also widely applied to a variety of complex bridge structures, such as cable-stayed, arch, and rigid frame bridges [1].

To better develop concrete segmental design techniques, this paper summarizes current theory, design, and construction methods of concrete segmental bridges by focusing on the girder type concrete segmental bridges. First, current segmental bridge construction methods are briefly discussed. Then, the analytical theory is

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Wind Induced Vibration Performance of Suspended Double-deck Flat Box Girder Bridge

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Abstract

The paper researches the wind vibration performance of suspended double-deck streamlined bridge deck using the wind tunnel test and numerical simulation. Studies shown that for suspended double-deck bridge, due to the aerodynamic interference of the upper deck, the lower deck is driven by a vertical vibration negative damping, and the vertical vibration is significantly changed. The pressure distribution of the upper deck and the upper edge of lower deck did not change. The wind load acts on the upper edge of lower deck, and the minus attack angle was generated. With the generation, migration and shedding of large-scale vortices at the lower edge of the lower deck, the lower deck occurs the bending-torsional coupling "soft flutter". Moreover, due to the structural static coupling between the upper deck and the lower deck, the bending-torsional soft flutter at the lower deck induces the bending-torsional soft flutter of the double-deck bridge deck.

Keywords: double-deck bridge; wind vibration performance; wind tunnel test; numerical simulation; 'incentive-feedback' mechanism; flow mode; bending-torsional; soft flutter.

1 Introduction

Long-span bridges are extremely sensitive to the dynamic effects of wind loads, and the wind easily induces bridge vibration. Among the various wind-induced vibrations, the flutter of the bridge span structure will cause the overall damage of the bridge structure. Therefore, in the field of bridge wind resistance, the research on the flutter performance of long-span bridges is always at the core.

In long-span bridges, the structural forms of truss girder decks usually include single deck and double deck. Because the large proportion of single-deck layout, the research on the aerodynamic performance of truss girder mainly focuses on the truss girder of single-deck layout. In the study of the aerodynamic performance of the single-deck truss girder, UEDA et al [1]analyzed the flutter suppression mechanism of the central stabilizer plate based on the flow field modal through the PIV flow field display technology and pressure test. MIYATA, YAMAGUCHI [2] and XU H et al [3] studied the effect of lower central stabilizer plate and slotting on the flutter performance of truss girders through wind tunnel tests. LI JW et al [4] conducted an optimization analysis on the effect of various aerodynamic measures such as upper and lower central stabilizer plates and horizontally inclined guide vane on the flutter performance of truss girder through wind tunnel tests. WANG K et al [5] analyzed the effects of upper and lower central stabilizer plates and horizontal guide vane on the flutter performance of truss girders through section model and aeroelastic model wind tunnel tests. TANG et al [6] studied the effects of

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Cable Force Analysis of Extradosed Bridge Based on Comprehensive Optimization Method

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Abstract

In order to determine the rational cable force of the extradosed bridge, a comprehensive optimization method of cable force is proposed. The method is based on the influence matrix method and adopts the data standardization method to change two or more different types of discrete data into dimensionless uniform data, with the objective of minimizing the combined displacement and bending moment of the structural control section. Relying on the extradosed bridge of Nanjing Intercity Rail Transit Ningju Line as an engineering example, the results show that the calculated cable force of the integrated optimization method can reduce the maximum compressive stress at the top and bottom edge of the main girder by 3.3 % and 3.8 %, respectively, compared with the original design cable force.

Keywords: cable force optimization; numerical calculation; extradosed bridge; influence matrix method; rational bridge completion state.

1 Introduction

The extradosed ridge is a combination system between general cable-stayed bridge and continuous girder bridge, with the characteristics of "short tower, rigid beam and concentrated cable" Its cable stress changes little and its overall stiffness is large, and it has outstanding advantages for railway bridges with large load and high standard [1-2]. The optimized design of cable force is an indispensable part of the design of cable-stayed bridges, and a lot of research has been carried out by related scholars. Jie Dai et al [3] reviewed the optimization methods of cable-stayed bridges, analyzed the advantages and limitations of each method and summarized the development trend of cable force optimization at the present stage; Renan Yuan et al [4] proposed a fast and accurate method of cable force adjustment for cable-stayed bridges in the target state by using numerical optimization methods and combining the initial state of cable force calculation; Cunxin Yin [5] developed a set of cable force adjustment calculation for cable-stayed bridges based on the combination of energy method and influence matrix method. Bin can [6] used the standard particle swarm algorithm based on the forbidden search algorithm for cable-stayed bridge force optimization. Liming Zhu et al [7] carried out a secondary optimization of the boom force of a spatial three-cable deck heterogeneous arch bridge by min-max standardization.

Most of the existing cable force optimization studies only aim at a single structural performance optimum, such as bending energy minimization and minimization with cable beams, which is difficult to consider the force requirements of the structure comprehensively. In this paper, we

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Numerical Ward-Type Tornado Simulator and its Application to Transient Wind-Induced Response of Long-Span Bridges

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Abstract

In this study, the tornado-like wind field is simulated by the numerical Ward-type tornado simulator based on computational fluid dynamics (CFD) techniques. To minimize the discrepancy between the simulated and field-measured tornado winds, the optimization strategy is developed to achieve optimal parameters of the numerical Ward-type tornado simulator, namely the inflow angle and translation speed. To facilitate the optimization process, a multi-fidelity surrogate model is utilized to effectively integrate both low-fidelity and high-fidelity data for accurate and efficient simulations. The “best” parameters based on the multi-fidelity surrogate model is input to the numerical Ward-type tornado simulator (using LES technique). Finally, the transient wind field generated using the validated numerical Ward-type tornado simulator is employed as the dynamic inputs to the finite element (FE) model of a long-span bridge.

Keywords: tornado-like wind; transient wind-induced response; optimization; surrogate model; multi-fidelity data; computational fluid dynamics; long-span bridges.

1 Introduction

Tornadoes are the most destructive storm with typical three-dimensional funnel-shaped vortex, and would cause the serious collapse of civil engineering structures due to high wind velocity with short duration. The long-span bridges, constructed as the critical connection for transportation infrastructures, usually play a significant role in emergency transportation and evacuation. Hence the damage or collapse of long-span bridges would cause a substantial hazard to a community. However, there has been relatively scant knowledge on the response analysis of long-span bridges immersed in tornadic wind field. Hao and Wu [1] implemented aerostatic and aeroelastic analysis of long-span suspension bridge under tornado event based on nonlinear aerostatic relationship and two-dimensional (2D) indicial response function.

In order to obtain accurate tornadic wind field input, field measurements of real-world tornadoes would be a useful resource. Unfortunately, direct field measurements are challenging due to the unpredictable, localized and violent nature of tornadoes, and the measurements are usually inaccurate in the near ground region. Therefore, physical and numerical simulations have become

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Effect of Short-Term Shrinkage on Deck Concrete of a Rail-Cum-Road Composite Truss Bridge

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Abstract

Rail-cum-road truss bridges are rapidly developing, and frequent cracking in freshly poured deck concrete is of great concern. For the performance of such a load-bearing deck, it is necessary to understand its stress status due to short-term shrinkage. Taking a newly-constructed rail-cum-road truss bridge as the case project, this paper, by ANSYS finite element simulation, mainly analyzed the stress distribution in deck concrete under short-term action of shrinkage. Shrinkage of one deck panel and two companion specimens shortly after the concrete pouring was measured through in-situ testing. It was found that the free shrinkage of companion specimens at 40 days is 140~150 micro strains, significantly higher than that indicated by the current code. Under the action of short-term shrinkage, tensile shrinkage stress in the magnitude of 1,5~3,5 MPa is present in the deck, triggering potential cracking, and its effect shall therefore not be neglected.

Keywords: short-term shrinkage; composite bridge deck; rail-cum-road bridge; in-situ testing; finite element simulation.

1 Introduction

The early cracking of concrete bridge decks has recently caused rising attention in the bridge engineering industry. Retzepis in Germany reported extensive cracking on the top surface of a typical slab bridge. The cracks appeared, primarily diagonal and surface located, shortly after concrete compacting and smoothing. The crack width mainly was in the range of 0,1~0,55 mm. However, some cracks reached the width of 1,8 mm or 3 mm in the extremity [1]. Similar damage has been reported in Finland and China [2, 3].

It is speculated that such cracking is caused by short-term shrinkage due to dehydration of the concrete surface [4]. Modern concrete tends to develop strength more rapidly, and so could the shrinkage [5]. In continuous testing of shrinkage strain up to 133 days, Zhang et al. demonstrated that shrinkage develops much more rapidly at an earlier stage of the cement hydration process. The portions of shrinkage taking place during 7 d, 7~21 d, 21~42 d, 42~70 d are 72,5%, 19,7%, 5,3%, 2,5%, respectively, of the total amount of 70 days [6].

Although domestic and abroad researchers have gained tremendous knowledge on long-term drying shrinkage [7], studies on short-term

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Study on the Self-Balancing System of 2300m Main Span Suspension Bridge and Relative Mechanical Characteristics

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Abstract

Zhangjinggao Yangtze River Bridge has a main span of 2300 m, and a tower height of 350 m. A huge bending moment at the tower bottom under operation loads would happen if the traditional fixed restraint system between the saddle and the tower top were adopted. In the actual design, a movable saddle was used as a self-balancing device at the tower top, releasing part of the shear force, thus reducing the bottom bending moment. Due to friction, the movable saddle on the flexible tower complexes the structural calculation model and force transmission mechanism. This study established a computational model of the longitudinal movable saddle to analyze the static response and the mechanical properties including the consideration of the influence of friction. The study shows that the self-balancing system significantly reduced the maximum bending moment at the tower bottom under a vehicle load and/or a temperature load. Whereas this system increased the bending moment of the tower under a longitudinal wind load. Large friction coefficients undermined the effect of the self-balancing system.

Keywords: suspension bridge; self-balancing system; flexible tower; saddle; structural response.

1 Introduction

The tower height of Zhangjinggao Yangtze River Bridge reaches 350 m, which needs greater stiffness to ensure structural stability. However, the increase of the tower stiffness will lead to an enlargement of the bending moment at the tower bottom, which creates a great challenge for the tower's design. The use of practical support and restraint devices at the tower top, which partially releases the unbalanced cable tensile force, is

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Design and Experimental Study of Steel Box-Concrete Filled Steel Tube Composite Cable Tower

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Abstract

Steel box-concrete filled steel tube (BCFST) composite tower is a new type of tower structure proposed to be used in super-span suspension bridges. BCFST comprises of four concrete-filled steel tube (CFST) columns inside and a steel box outside. CFSTs and the steel box are connected with each other by steel webs and diaphragm plates. In this study, the combined compressive and bending loading experiments of the BCFST were conducted, and the ability of the composite tower section to deform together was studied. The experiment showed that the bottom section of the composite tower deviated from the plane section after deformation, and the other sections approximately maintained the plane section after deformation. The calculation method of the compression-bending capacity of the composite cable tower was proposed, which can provide a reference for the application of the composite tower in practical engineering.

Keywords: composite tower; concrete filled steel tube; lattice column; plane section assumption; compression-bending capacity.

1 Introduction

Concrete-filled steel tube (CFST) has the advantages of high bearing capacity, good seismic performance, and convenient construction. It has been used more and more in domestic high-rise buildings and long-span bridge towers. However, as the building height and bridge span continue to increase, the size of the components also continues to increase. However, due to the limitations of processing and construction, the size of a single CFST cannot be too large, so the CFST lattice column is gradually applied in engineering. When CFST lattice column is applied to the cable tower of a super-span suspension bridge, the aerodynamic shape of the tower itself needs to be considered. Therefore, this study proposed a new type of cable tower, a steel box-concrete filled steel tube (BCFST) composite tower. BCFST comprises of four CFST columns inside, which

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Analysis on Mechanical Performance of Rail-Cum-Road Double Deck Steel Truss-Arch Composite System Bridge

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Abstract

In order to research the mechanical performance of rail-cum-road double deck steel truss-arch composite system bridge, a rail-cum-road double deck steel truss-arch composite system bridge with 150m main span was analyzed. The overall spatial model of the bridge was established by using the general finite element software, and the structural response under dead load, vehicle load, rail transit load and temperature was calculated and analyzed. Dead load is the main factor causing the internal force of long-span composite system bridge. The stiffness of steel arch rib and steel truss is only 13.5% and 24% of the composite system, so the steel truss-arch composite system bridge has greater overall structural stiffness. In terms of dynamic characteristics, the overall stiffness of steel truss arch composite system bridge is great, the first five natural frequencies are all between 0.3Hz and 1.5Hz, and there is the possibility of simultaneous multi-mode excitation.

Keywords: rail-cum-road; steel truss-arch composite system; structural response; stiffness; dynamic characteristics.

1 Introduction

In order to greatly improve the utilization efficiency of urban traffic and improve bridge traffic conditions within limited land resources and layout space, urban bridge design with double-layer traffic or double-deck is a better solution [1]. At present, simply supported truss bridges, continuous truss bridges or truss arch bridges are commonly used. The truss bridges have high stiffness, sufficient space and good permeability, and are relatively competitive structural forms among such bridges.

Binzhou Huanghe River Rai-cum-Road Bridge is a typical double-deck continuous truss bridge, and its main bridge across the Huanghe River is a continuous steel truss girder with span arrangement (120+3x180+120)m. The main bridge is arranged on the upper and lower decks, with the highway on the upper deck and the railway on the

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Analysis of Reasonable Longitudinal Restraint System of Four-Tower Cable-Stayed Bridge

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Abstract

The four-tower cable-stayed bridge with four towers and three main spans can be set up with various symmetrical and asymmetrical longitudinal restraint schemes for the whole bridge. Different longitudinal restraint systems will directly affect the load transfer path and change the mechanical behavior of the four-tower cable-stayed bridge structure, which in turn affects the structural design of the bridge. Taking a four-tower cable-stayed bridge as the research object, the structural mechanical behaviors of semi-floating system, temperature adaptive system, middle two-tower elastic cable restraint system, and middle single-tower longitudinal fixed restraint system under the effect of temperature load, longitudinal wind load, and load combination are compared and analyzed. The results show that the semi-floating system will cause a larger longitudinal displacement of the main beam, which will increase the internal force of the side towers substantially. Increasing the restraint of the main beam and the middle towers can make the four towers' forces uniform.The temperature adaptive system and the middle two towers elastic cable system have better feasibility.

Keywords: multi-tower cable-stayed bridge; longitudinal restraint system; stiffness; mechanical behaviour.

1 Introduction

In recent years, the growing demand for traffic across straits, valleys, and other terrain has increased the demand for a bridge spanning capacity [1], and the economic and technical advantages of multi-tower cable-stayed bridges make them a highly competitive structural solution [2]. However, compared with the conventional twin-tower cable-stayed bridge, the middle tower of the multi-tower cable-stayed bridge is not equipped with end anchor cables to control the deflection, and there are no auxiliary piers on both sides, thus weakening the overall stiffness of the structure, resulting in a more flexible cable-stayed bridge. Therefore, multi-tower cable-stayed bridges have obvious differences in structural mechanical behavior from conventional two-tower cable-stayed bridges, and for the overall structural stiffness, the contribution of the cable system is reduced, and the overall deformation of the structure is usually limited only by the stiffness of the main beam and the bridge tower, resulting in larger live-load deflections and internal forces in the intermediate tower, and a significant increase in the displacement of the main beam under live load [3]. The structural system is the main factor affecting the mechanical characteristics of multi-tower cable-stayed bridges. A reasonable

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Recent Development and Challenges of Long-Span Railway Cable-Stayed Bridges in China

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Abstract

The main span of railway cable-stayed bridge in China has broken through from 312m in 2000 to 1092m in 2020, with rapid development in recent years. It comes from aspects of new material, new structural form, accelerated bridge construction method, and innovated construction facilities and equipment. New materials mainly include bridge structural steel with higher yield strength, stay cable with higher tensile strength and ultra-high-performance concrete (UHPC), etc. New structural forms refer to three-main truss with three-cable plane, cable-stayed bridge with ballastless track system, multi-pylon railway cable-stayed bridge, etc. Concept of accelerated bridge construction has been also applied in caisson construction, truss girder assembling, truss girder hoisting, etc. Several new facilities and equipment have also been created such as integral bridge expansion joint, hoisting crane, and smart torque wrench, and so on. Challenges have also been discussed.

Keywords: railway cable-stayed bridge; new material; structural system; structural devices; bridge expansion joint; hoisting crane; torque wrench; technological challenges.

1 Introduction

Rapid development has been witnessed in construction of railway cable-stayed bridges in China since completion of Wuhu Yangtze River Bridge with main span of 312m in 2000, within only 20 years [1]. In aspects of material, structural system, construction and equipment, those bridges can be regarded as the milestone such as Wuhan Tianxingzhou Bridge, Tongling Bridge, Husutong Bridge, etc. with main span of 504m, 630m, 1092m, respectively [2]. Now, Changtai Bridge and Maanshan Bridge are under construction, with main span 1176m and 2×1120m, representing a breakthrough of much longer span.

Major innovations have been summarized for railway cable-stayed bridges in China in 21st Century. And main challenges of railway cable-stayed bridges have also been discussed.

2 New material

New material such as bridge structural steel, high performance stayed cable, and UHPC supports the construction of railway cable-stayed bridge with main span over 1000 meters.

2.1 Bridge structural steel

From 1950s, bridge structural steel had been consecutively studied in China to meet the development requirements of railway steel bridges, with different bridge types besides cable-stayed bridge. A3q steel (Q235) was early used in Wuhan Yangtze River Bridge built in 1957 with yield strength of 235MPa and rivet joint. The main span

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Study on Measures to Improve Natural Vibration Characteristics of Three-Towers and Four-Span Suspension Bridge During Construction

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Abstract

In this paper, we take the suspension bridge of Oujiang Beikou bridge in Wenzhou, as the engineering background, the effects of a full rigid connection between segments, adding restraint cables between the stiffening beam and bridge tower, and adding restraint cables between the main cable and bridge tower, addition underwater auxiliary pier and the combination of the above measures on the natural vibration characteristics of the structure are studied and compared, especially the influence of torsional frequency and vibration mode. The calculation results show that when the hoisting quantity of stiffening beams is small, setting cables or a combination of the rigid connection of the beam and setting cables can improve the torsional frequency of the structure. When the hoisting quantity of stiffening beams is large, setting cables or combination setting auxiliary pier and rigid connection of beam

Keywords: three-tower and four-span suspension bridge; construction stage; natural vibration characteristics; measure.

1 Introduction

Unlike two-tower suspension bridges, the main cables of three-tower ground-anchored suspension bridges are vertically supported by saddles at the mid-tower, so the boundary conditions of the main cables at the mid-tower are weaker and the overall stiffness of the suspension bridge will be reduced[1]. Some studies have been done on the static and dynamic characteristics of three-tower ground-anchored suspension bridges. Shen et al. [2]investigated the effects of connection form of tower and girder, connection form of cable and girder connection, and cable system arrangement form on the static characteristics of the structure for a three tower-four span suspension bridge with different main span diameters. Cheng et al.[3]derived the reasonable value range of the longitudinal stiffness of the rigid middle tower. Jia et al.[4]established FEM model to perform a parametric analysis on tower stiffness, sag-span ratio, and side–main span ratio. Liang et al. [5] discuss the mechanical behavior differences between the two-tower and three-tower suspension bridges. Cao et al.[6]propose an analytical model for predicting the structural responses of three-tower suspension bridges with a central buckle under vehicle loads and examines the

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Analytical Methods to Adjust the Distribution of Dead Loads of a Suspension Bridge with Three Cable Planes to Three Cables in The Transverse Direction

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Abstract

Suspension bridges with three cable planes (SB-3CP) provide an excellent solution to the suspension bridges' downwarp problem with ultrawide decks. However, the middle cable bears most of the deck load, which affects the torsional rigidity, and force status of the upper transverse beam on the pylon. It is necessary to adjust the distribution of dead loads to three cables in the transverse direction. In this paper, two analytical methods respectively based on the hanger cross sectional area (Method 1) and unstrained length (Method 2) are proposed. By altering the cross-sectional area of each hanger (Method 1) and increasing the unstrained length of the middle hanger (Method 2), the load share beard by the middle cable reduces. Finally, an SB-3CP was taken as an example. As the results show, the more load the side cable bears, the more torsional rigidity the bridge has, and the less vertical force is applied by the main cable to the upper transverse beam on the pylon.

Keywords: triple-cable suspension bridge; ultrawide deck; dead load allocation; transverse direction of the bridge; hanger cross sectional area; hanger unstrained length; torsional rigidity; tower's top transverse beam.

1 Introduction

Suspension bridges have a long global history and unparalleled spanning capacity among all bridge types due to main cables hanging between the towers and serving as the primary load-bearing parts [1][2][3][4]. With the continuous progress in design theories and construction technologies, the suspension bridge spans reached ultra-large lengths. Several ultra-long-span suspension bridges are currently under construction, including the Çanakkale 1915 Bridge (main span of 2023 m) in Turkey [5], the Zhangjinggao Yangtze River Bridge (main span of 2300 m) in China, and Guangdong Lion Ocean Bridge (main span of 2180 m) in China. In recent years, the designers have preferred to use an ultra-wide bridge deck to accommodate more vehicle lanes in the suspension bridge.

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Stability Analysis of a Super Long-Span Cable-Stayed Bridge in China

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Abstract

With a main span of 1176 meters, the Changtai Yangze River Bridge is a super long-span rail-cum-road cable-stayed bridge under construction in China. The steel truss girder is a transverse asymmetry structure. And the spacial diamond shaped pylon is applied in the bridge to ensure the stiffness of pylon. In this paper, the stability of the Changtai Yangze River Bridge is investigated using finite element method. Dead load, live load and wind load are considered in the analysis. Linear elastic buckling analysis and nonlinear stability analysis, in which both material nonlinearity and geometrical nonlinearity are considered, is performed. The failure mode of the nonlinear stability is presented and discussed. The results show that the minimum stability coefficients are 10,50 and 2,04, respectively for the linear elastic buckling analysis and nonlinear stability analysis. The crushing of concrete at the bottom of the pylon indicates the failure of the structure.

Keywords: rail-cum-road cable-stayed bridge; spatial diamond-shaped pylon; stability analysis; ultimate bearing capacity; failure mode.

1 Introduction

Cable-stayed bridge is one of the most common types of modern long-span bridges due to its advantages of reasonable force and strong spanning capacity. With the continuous improvement of material performance and design standard, the development of cable-stayed bridge presents a trend toward long-span.

For the pylon and girder of cable-stayed bridge are both compression bending members, it is necessary to study the stability of cable-stayed bridges. Many scholars conducted elastic buckling

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Axial Force Transfer Mechanism of Steel-Concrete Joint in Hybrid Girder for Railway Cable-Stayed Bridge

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Abstract

The hybrid girder for a railway cable-stayed bridge consists of the steel-concrete composite girder at the main span and the prestressed concrete (PC) girder at the side span. The two spans are connected by the steel-concrete joint (SCJ) with multiply concrete filled steel cells (CFSC). The mechanical behavior of SCJ is investigated using three-dimensional finite element analysis (FEA). Results show that the internal force can be effectively transferred from the composite girder to the PC girder through CFSC without sever stress concentration. The two bearing plates remain the major force transfer components with the force sharing ratio of 60%, while both the shear connectors and the top concrete slab play important roles with the force sharing ratio of 20% respectively. The unique CFSC with extended force transfer path may improve the mechanical behavior of SCJ and is recommended for the application in the high-speed railway cable-stayed bridge.

Keywords: high-speed railway bridge; hybrid cable-stayed bridge; steel-concrete composite joint; mechanical behavior; finite element analysis.

1 Introduction

The hybrid cable-stayed bridge makes full use of the material advantages of steel and concrete respective. Typically, the main span adopts a steel girder or a composite girder to achieve a large spanning capacity, and the side span adopts a concrete girder to increase the global and local stiffness, stability, and cost-effectiveness [1]. In general, concrete girders have high self-weight and can provide an anchoring effect for the steel girder and improve the aerodynamic response. For this reason, hybrid girder has been used in the cable-stayed bridge worldwide [2-4].

The steel-concrete joint (SCJ) is the key segment of the hybrid girder to bear the force and coordinate the deformation and the abrupt segment of material and cross-section. So, it is necessary to design the connecting structure to reduce the

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The Analysis of the Non-Axial Force Connection for the Earth-Anchored Cable-Stayed Bridge

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Abstract

The Danjiangkou Reservoir Bridge is the earth-anchored light composite cable-stayed bridge with the largest span in the world. The non-axial force connection is firstly used in the composite cable-stayed bridge. This connection mainly consists of the support system, outer and inner box girders. Based on the FE analysis, the stress distribution, load path and deformation of the non-axial force connection are discussed. The results show that the load on the outer box girder is transferred to the inner box girder by vertical and horizontal supports, so as to complete the transmission of shear force, bending moment and torsion of the cable-stayed bridge at the mid-span. The non-axial force connection presents effective mechanical performance and structural deformation response, which indicates that this connection can reduce the unfavourable longitudinal deformation of the earth-anchored cable-stayed bridge.

Keywords: the earth-anchored cable-stayed bridge; the non-axial force connection; support system; longitudinal deformation.

1 Introduction

The cable-stayed bridge is one of the most competitive bridges. Since the advantages of the earth-anchored cable-stayed bridge consist of high stiffness of pylon and earth-anchored cable, larger span, lower side-main span ratio and axial force of the main girder, the earth-anchored cable-stayed bridge shows the priority to be constructed at the wide river, valley and canyon [1]. On the other

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Structural Performance and Cost Analysis of Multi-span Extradosed Cable-Stayed Bridge

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Abstract

To investigate the structural performance and economic applicability of multi-span extradosed cable-stayed bridge, a comparative scheme of composite beam with corrugated steel web was designed based on the Wangjia River Bridge, which was an extradosed cable-stayed bridge with prestressed concrete girder built in Shaanxi. Spatial finite element models of the whole bridge were established by CSIBridge for extradosed cable-stayed bridge with two different sections of girder. Considering the influence of p-Δ effect, the vertical and horizontal deformation and the governing sections of the two forms were analyzed and compared. The material consumption of steel, concrete and steel strand of the extradosed cable-stayed bridge with corrugated steel web was calculated. The material consumption of the two schemes was compared. The differences in structural performance and economic cost for the two structures were explored. It's expected to provide a reference for the tender design of multi-span extradosed cable-stayed bridges with similar span length.

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Punching behavior of a novel steel-UHPFRC composite bridge deck slab

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Abstract

A novel steel-UHPFRC composite deck system, consisting of upper thin reinforced UHPFRC slab, hot rolled sections as longitudinal ribs, and steel strips as transversal reinforcement, is proposed originally in this paper. Considered as more economic and sustainable structure, the new composite deck is a promising alternative to traditional orthotropic steel deck (OSD) in long-span bridge. In this context, due to the relatively thin UHPFRC layer, the punching behavior of new composite deck becomes one of the dominant issues, which determines the spacing of steel trips. Hence, this paper presents the results of punching tests on 12 new composite deck slabs with various spacing of steel strips. All slabs failed in punching-flexure mode with a clearly delimited punching cone and significant flexural cracks on tensile surface. Moreover, the presence of steel strips can increase the punching shear resistance and flatten the inclination of critical shear cracks.

Keywords: long-span bridge; composite bridge deck; UHPFRC; steel strip; punching shear; DIC; critical shear crack; punching cone.

1 Introduction

The conventional orthotropic steel deck (OSD), widely applied in long-span bridges, has suffered awfully from vulnerability to fatigue cracking under cyclic traffic loads. This issue is mainly caused by large stress amplitude and stress concentration, resulting from: (1) insufficient stiffness at local steel deck; (2) initial welding defect and residual stress; (3) inappropriate details.

Nowadays, benefiting from the advantageous mechanical properties and fatigue resistance of Ultra High Performance cementitious Fiber Reinforced Composites (UHPFRC) [1–3], the combination of UHPFRC and steel as lightweight composite structures offer promising alternatives to traditional OSD in long-span bridges. Additionally, UHPFRC is a dense material of optimized compactness, thus providing robust protections as added values against water and chloride iron ingress.

The concept of adding a thin UHPFRC cover (with thickness ≤ 60mm generally), as external stiffener and protection layer to either improve existing OSD or combine with optimized OSD as new deck element (Figure 1), has been developed and implemented extensively over last 10 years [4–6]. Recent researches and applications have demonstrated large improvement of local stiffness of steel-UHPFRC composite deck, leading to considerable reduce (≥50%) of vehicle-induced stress ranges at most of fatigue details, and consequently extension of fatigue life (≥60%), compared with traditional OSD [7–9]. However, for some fatigue details, such as the cross beam

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The Behavior of Long-span Suspended Footbridge Under Wind Load

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Abstract

This study examined the wind resistance characteristics of a 660 m span suspended footbridge using a wind tunnel test and numerical analysis method. The target bridge deck is a hexagonal cross-section beam supported by a three-dimensional catenary cable structure. A wind tunnel experiment was conducted to investigate the wind characteristics in the mountainous valley terrain in the simulated atmospheric boundary layer model. The wind load of the girder was applied to the numerical model considering aerodynamic coefficients and the topographical characteristics. The behavior of the girder according to the wind load was analyzed. Above a certain wind speed, the lateral and vertical displacement increased sharply, and the torsional displacement reversed from nose up direction to nose down direction. This phenomenon was due to the loss of the initial tension of the leeward cables due to the geometrical behavior of the three-dimensional cable structure. This study identifies the behavior of long-span suspended footbridges under wind loads.

Keywords: suspended footbridge; wind load; three-dimensional cable system; mountainous valley terrain; wind tunnel test; numerical analysis.

1 Introduction

Unlike general bridges, the suspended footbridges have a lightweight deck, and the stiffness of the bridge system is low. The main span to bridge width ratio is mainly used as an index to express the flexibility of cable bridges, and a long bridge span lowers the system stiffness. This makes the bridge system vulnerable to wind loads resulting necessarily a detailed review of the displacement control. Additionally, a long-span bridge located in complex terrain contains complicated flow phenomena with mean wind speed-up and variation of turbulence.

Several previous studies evaluated the response of the footbridge due to the wind loads and wind characteristics in mountainous terrain. Taylor et al. [1] and Yoshimura et al. [2] investigated the aeroelastic stability of footbridge according to different deck configurations. Tadeu et al. [3] used Computational Fluid Dynamic simulation to identify elements highly affected by static wind loads in the cross-section of the girder of the suspension footbridge. Flutter wind speed limit with different grating porosity of pedestrian bridge deck was compared by Lee et al. [4]. The wind characteristics in a mountainous valley were studied by Li et al. [5] and Song et al. [6]. Nevertheless, the nonlinear behavior characteristics of a long-span pedestrian bridge on mountainous terrain according to aerodynamic load have not been investigated, and previous relevant studies are limited in scope.

Regarding these challenges, this study focuses on the behavior of a suspended footbridge with three-

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Design and Construction of Chongqing Lijia Jialing River Bridge

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Abstract

To achieve a cost-effective, rational, and efficient structural system, two traditional structural systems—a continuous rigid frame (CRF) girder bridge and a deck arch bridge—are combined to form a new bridge type—arch-stiffened girder (ASG) bridge. This bridge type fulfil the innovative and unique requirements for the Chongqing Lijia Jialing river bridge. The ASG bridge combines the simplicity of a girder bridge with the elegance of an arch bridge. In terms of structural behaviours, the ASG bridge utilizes the arch to assist the main girder and forms a self-balancing system, significantly reducing the mid-span and side-span girder lengths, and thus optimizing structural performance through increased vertical stiffness and effective control of long-term deflection. This article discusses the major components of the Chongqing Lijia Jialing river bridge's design, construction, load capacity testing, and effects upon completion.

Keywords: hybrid structural system; arch-stiffened girder(ASG) bridge; girder-arch combined structure; structural design; construction method.

1 Introduction

Both continuous rigid frame (CRF) and deck arch bridges are suited for use in mountainous environments. CRF bridges has monolithic pier and girder connection which eliminates the need for large tonnage bearings at the main piers. The main girder structure is continuous, which has a more reasonable force distribution, offers smooth riding condition, simple construction, low operation and maintenance cost, and is more economical [1]. But longer span CRF bridges often have less predictable deflection and cracks [2-4] in the girder, this bridge type is best suited for spans not more than 200m [5]. Additionally, the long-span deck arch bridge is economical and attractive in hilly terrain, where it has been frequently utilized [6]. However, due to the considerable force at both end supports, it can only be applied in proper geological conditions. Hence, this bridge type also has limitations.

A hybrid structural system formed by the combination of two or more conventional structural systems may exhibit more complicated mechanical behaviours but provide superior structural performance. The combined bridge system could retain the respective advantages of both bridge systems. As a result, it is novel to study and design a new type of long-span ASG bridge with high spanning capacity, excellent mechanical performance, and a low economic cost index that is based on conventional bridge construction materials, current bridge design codes, and the hybrid structural system design concept [7].

The Chongqing Lijia Jialing River Bridge was selected following a comprehensive study of bridge types, considering the bridge's construction method, long-

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Challenges in Design and Construction of WONJU 404 SKYBRIDGE in Korea

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Abstract

Installed in Ganhyun Park, Wonju-si, South Korea, the 404 Skybridge is the longest pedestrian bridge in Korea, planned as a three-dimensional cable suspension bridge with a main span length of 380m. The location of the installation lies about 100m above from the ground level, on a slope of the mountain which presents very difficult construction condition.

The three-dimensional cable suspension bridge is a challenge to construct but capable to achieve slender girders to have strong horizontal rigidity, without using separate wind resisting cables. By implementing the 3D angle of the cables much larger than the general three-dimensional suspension bridge, the horizontal rigidity of the girders enhanced, and flutter wind speed increased.

At the start of the 404 Skybridge, Skywalk was constructed to provide scenery of the Ganhyun Park.

Keywords: 404 Skybridge; three-dimensional suspension bridge; pedestrian suspension bridge; Skywalk; observatory.

1 Introduction

The 404 Skybridge is a pedestrian suspension bridge installed in Ganhyun Park in Wonju, Gangwon-do, South Korea. Planned to have twice longer span than the previously installed Sogeumsan Suspension Bridge (L=200m) in Ganhyun Park, the bridge was installed to fulfil the hiking course maintenance plan and tourism promotion of the park. As of 2022, the 404 Skybridge is the longest pedestrian suspension bridge in Korea. The construction of the bridge was completed in April 2022, drawing many tourists since its opening. The observatory structure Skywalk, located at the entrance of the bridge is also a surprise to visitors by its rare design and size in Korea.

2 Bridge Plan

The installation location of the 404 Skybridge was 100m above the ground level and the distance from the start to the end of the bridge was more than 400m. To create some uniqueness in the Ganhyun park, a distinctive and iconic characteristic compared to the pre-existing Sogeumsan Suspension Bridge was required. In addition, since the location where the pylon and cable anchorage were restricted at the start and end of the bridge, a bridge plan which overcomes those geographical limitations were necessary. Therefore, a long-span suspension bridge plan which neglects the installation of the high pylons in the valley was selected to satisfy the client's demand and geographical conditions.

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Conceptual Design of 5 km-Class Super Long Span Bridge

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Abstract

In order to examine the feasibility of a 5 km-class super long-span bridge, behavioral characteristics and problems were analyzed in 5K-Bridge technology, and a conceptual design was performed based on the latest and future technologies.

As for the material of the main cable, the applicability of the carbon fiber reinforced polymer (CFRP) with low weight and high tensile strength of 3000 MPa was examined and compared with a steel cable with a tensile strength of 2060 MPa.

For this review, a two-dimensional parametric study was performed for a three-span suspension bridge with main spans from 2000 m to 5000 m with 500 m span length increments. In addition, a conceptual design was performed for a suspension bridge with a main span of 5000 m to evaluate the tension forces, area of the main cables and structural behavior.

Keywords: super long-span bridge; conceptual design; 5K-Bridge technology; carbon fiber reinforced polymer (CFRP); three-span suspension bridge.

1 Introduction

1.1 Why 5K-Bridge technology

With the use of the current material, design and construction technologies, the recognized main span length limit is about 3300 m which was applied for the Straight of Messina Bridge.

Various future bridge types such as submerged, floating, and multifunctional bridges are being considered for deep-water crossing projects. As connections between continents or equivalent important connections are predicted due to demand for human and material movement in the future, it is necessary to secure next-generation technologies for super long bridges.

5K-Bridge technology is a study of very long-span bridges with main spans up to 5000 m. 5K-Bridge technology covers ultra-high-strength material technology, new structural systems, wind resistance and seismic performance evaluation technology, and construction and maintenance technology.

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Measures to Control Vortex-induced Vibration for Shangba Branch Channel Bridge in Nanjing

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Abstracts

An all-steel cable-stayed bridge with steel towers, steel box girders and cables for a main span of 500m is rarely seen at home and abroad. Due to the low damping ratio of all-steel structure, wind-induced vibration is likely to occur, especially for a single column steel tower, and twin-box girder with a total width of 54.4m is also more susceptible to vortex-induced vibration. In this paper, the aerodynamic shape of the main girder is optimized by sectional model wind tunnel test, and an aerodynamic configuration as the combination of wind fin plate and wind baffle plate to control the vortex-induced vibration (VIV) has been found. The damping effect of the main girder was also studied. The VIV and buffeting performance of the freestanding steel tower and its combined system with tower crane and construction platform were also studied.

Key words: separated steel box girder; cable tower; tower crane; free-standing state; vortex-induced vibration; wind deflection angle; wind tunnel.

1 Project overview

Pukou-Yizheng Highway Shangba Branch Channel Bridge, an important control project on this highway, is a cable-stayed steel box girder bridge with two towers and two cable planes in full floating structure system, with spans of (50+180+500+180+50) m, as shown in Figure 1. For this bridge, twin-box girders are used, with girder height of 4.0m and width of 54.4m, the steel cable towers are composed of single column of box section, with a total height of 166m and a height of 130.7m above the bridge deck.

Figure 1. Photo of the main bridge of Nanjing Shangba Branch Channel Bridge

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Prediction of Aerodynamic Coefficients using Artificial Neural Network in Shape Optimization of Centrally-Slotted Box Deck Bridge

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Abstract

Aerodynamic shape optimization of bridge deck is a very important task in the wind-resistant design of long-span bridges and often carried out via wind tunnel tests of sectional model or CFD simulation, both of which commonly need heavy workload, thus are time-consuming and costly. In this paper, an artificial neural network (ANN) model was developed to predict aerodynamic coefficients of a central-slotted box deck of a 1600m main span cable-stayed bridge during the aerodynamic shape optimization to enhance its performance of wind-induced static stability. The ANN model was built and trained with a data set of aerodynamic coefficients obtained from limited cases of wind tunnel tests. The effect of neuron numbers in the hidden layer on prediction accuracy was discussed. The results show that the built ANN model can accurately predict the aerodynamic coefficients and significantly reduce the workload of wind tunnel tests.

Keywords: long-span bridge; centrally-slotted box deck; aerodynamic shape optimization; aerodynamic coefficients; artificial neural network.

1 Introduction

Over the last decades, with the application of new materials and the progress of construction technology, the span length of modern bridges has considerably increased. The demand for super long-span bridges with a main span of 1500 -3500 meters is growing. There are many super-long span bridges under construction or design in China, including Jiangsu Zhangjinggao Yangtze Bridge, Nanjing Wenjin Yangtze Bridge, Nanjing Xianxin Yangtze Bridge, Lingdingyang Shenzhen bridge, Changtai Yangtze Bridge, Hutong Yangtze River Bridge, with expect to be finished with five years. With the increasing span length, modern long-span cable-supported bridges become more and more susceptible to strong wind, and the wind-induced static instability and flutter are considered as critical factors that control the construction and design of bridges.

Flutter is generally treated as a sudden aeroelastic instability phenomenon caused by negative aerodynamic damping. Once the wind speed exceeds the critical wind speed, the system damping will be negative, and the structural vibration diverges rapidly with the increase of

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Tendon Distribution Optimization Method of Prestressed Concrete Bridges Based on Consistent Safety Degree of Stress Index

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Abstract

The traditional tendon distribution method of prestressed concrete bridges is mainly based on trial calculation. The existing optimization research of structure and tendon distribution mostly takes the least material consumption or total economy as the optimization goal, but the stress of the structure may not be reasonable. Therefore, considering the rationality of structural stress, the optimization method has a large research space. This paper puts forward the tendon distribution optimization method for the prestressed concrete bridge. This method takes the principle that the safety degree of stress indexes at different positions of the whole bridge is as consistent as possible. On the premise of meeting the codes and construction feasibility, this method realizes the optimization of the amount of prestressed steel tendons in the bridge. Finally, a three-span continuous bridge is used as the optimization example to verify the rationality and feasibility of the method.

Keywords: prestressed concrete bridges; tendon distribution optimization; consistent safety degree; stress index.

1 Introduction

Reinforced concrete(RC) structure is composed of reinforcement and concrete according to certain principles. The strength advantages of the two materials are brought into full play in this structure, which has the advantages of good durability, fire resistance and integrity. However, the self-weight is large and the crack resistance is poor in this structure. In order to further develop RC structure and improve its crack resistance, it is necessary to overcome the defect of poor tensile resistance of concrete. The use of prestress can solve this problem, resulting in prestressed concrete structure. Before the external load is applied to the structure, apply pressure on the concrete, in which tensile stress will be produced under the external load. In this way, it needs to overcome the pre applied compressive stress before the concrete can be tensioned. The pre applied compressive stress can reduce or even offset the tensile stress

Tianhu Wang, PhD student from Tongji University, is responsible for writing and calculation..
Dong Xu, professor from Tongji University, is responsible for proposing theory.

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Advantages of New Type of Steel Box Coarse Aggregate Reactive Powder Concrete Composite Continuous Beam Bridge

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Abstract

Coarse aggregate activated powder concrete (CA-RPC) is a new modified material for the large-scale application of existing ultra-high-performance concrete (UHPC), which can improve the technical difficulties of existing materials such as harsh materials selection, high construction viscosity, large self-shrinkage, etc., and has the characteristics of ultra-high strength, low viscosity, low shrinkage, high toughness and high elastic modulus. Nanjing Lvdu Road bridge over New QinHuai River innovatively introduced coarse aggregate activated powder concrete and formed a new composite continuous beam bridge system with steel box. Through comparative analysis with the steel box- conventional concrete composite continuous girder bridge, prestressed concrete continuous girder bridge and other structural systems, the advantages of the new structural system such as large span lightweight, prefabricated assembly, and ecological environmental protection are expounded.

Keywords: coarse aggregate active powder concrete; Ultra-high-performance concrete; Steel box-coarse aggregate active powder concrete composite continuous beam bridge.

1 Introduction

Ultra-high performance concrete has excellent properties such as ultra-high strength, high toughness and high durability, which can meet the requirements of lightweight, large-span and high durability of civil engineering structures, and is one of the important directions for the development of concrete science and technology.

In order to achieve UHPC ultra-high performance, UHPC preparation techniques typically include rejecting coarse aggregates, optimizing fine aggregate gradation, adding ultra-fine active mineral blends, autoclaving curing, and incorporating steel fibers[1]. However, the high raw material cost and complex preparation process of PREPARING UHPC limit its large-scale promotion and application. Therefore, in order to reduce the production cost of UHPC, scholars have successfully prepared coarse aggregate active powder concrete (CA-RPC) by selecting gradation-optimized ordinary river sand (tail sand) instead of ground fine quartz sand or using standard

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Experimental Study of the Post-Tensioned Prefabricated Retaining Blocks with Mortise-Tenon Joint

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Abstract

Conventional sacrificial shear keys in both bridge abutments and pier cap beams have been proved to be helpful to limit the over displacement of the superstructure under the designed earthquake event. However, the advantage of the sacrificial shear keys depends on the severe damage of the shear key itself or the stem wall, which would completely break off the mechanical connection between one concrete component and another. In addition, it is time-consuming and costly to repair and reinforce the conventional shear keys once it is severely damaged in huge earthquake event. Therefore, this paper proposed a novel post-tensioned prefabricated concrete retaining block with mortise-tenon joint. Four retaining block specimens were designed and tested to study its anti-seismic effectiveness and basic mechanical properties. The influence of the structural material and forms on seismic damage mode of the proposed retaining blocks were investigated.

Keywords: bridge; retaining block; post-tensioned; mortise-tenon joint; test; UHPC.

1 Introduction

Conventional sacrificial shear keys in both bridge abutments and pier cap beams have been proved to be helpful to limit the over displacements of the superstructure under the designed earthquake event. Meanwhile, they also can be used as a seismic fuse to protect the bridge abutments or piers from severe damage in potential huge earthquake event[1, 2]. Therefore, these sacrificial shear keys have been used widely around the world. In order to better understand and predict the seismic behavior of the sacrificial concrete shear keys in actual earthquake, lots of researchers have studied the seismic performance of this shear key. These researches have investigated the seismic failure modes and shear strength of different concrete shear keys by conducting a series of laboratory tests, which have enriched the knowledge of seismic behavior for the concrete shear keys and highlighted the significant of the rational design of concrete shear keys in bridge design. Especially, the isolated shear keys with a smooth construction joint is recommended by SDC [3]. However, the advantage of the sacrificial shear keys depended on the severe damage of the shear key itself or the corresponding cap beam. It is time-consuming and costly to repair and retrofit the conventional shear keys once they are severely damaged in huge earthquake. Especially in China,

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Experimental Study on Shear Performance of Steel Shear Key Dry Joint in Precast Segmental Bridges

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Abstract:

The joints between segments represent weak points and introduce discontinuity into structures, therefore they are particularly significant in precast concrete segmental bridges (PCSBs). In this study, a new steel shear key was designed, and 3 full-scale tests were conducted. Various shear keys were taken as experimental parameters to study crack development, failure mode, shear slip, ultimate bearing capacity, and the residual bearing capacity of various joints under direct shear force. The results show that the stiffness and bearing capacity of steel shear keyed joints is higher than concrete key joints, and the structural system is more stable than concrete key joints at the moment of cracking.

Key words: bridge engineering; steel shear keys; direct shear experiments; shear keys; construction methods.

1 Introduction

A large number of post-tensioned precast concrete segmental bridges (PCSB) have been constructed, as a result of the demand for practical construction designs which are economical, safe, fast, versatile, aesthetically pleasing, and possess excellent serviceability[1-3]. The joints that characterize discontinuity sites are the prominent factors affecting overall PCSB behavior [2-4]. Under direct shear loading, shear failure will occur parallel to jointed surfaces [4, 5]. It is therefore necessary to understand the shear behavior and shear capacity of the joints.

To simplify joint type, improve joint shear force transmission, and enhance joint bearing capacity and ductility, a steel shear key was designed for precast segmental bridges. To study the mechanical properties of the steel shear key, three samples were designed,

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Corresponding Force Matrix: A Bridge Connecting Refined Analysis and Reinforcement Design of Box-section Girders Based on Shells

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Abstract

Benefitting from the development of computing power, box girders can be analysed in a more refined way by discretizing cross-sections into shell elements. However, how to take full advantage of the analysis results in the reinforcement design process remains a problem. To solve this problem, the concept of "corresponding force matrix" is proposed in this paper. The matrix has 6 columns corresponding to the key unit force resultants of a specified location, and 12 rows corresponding to all the possible unfavourable cases. For each row, only one force resultant reaches its maximum (or minimum) under loads while the others take the corresponding values. Then the construction method of the proposed matrix under live loads and load combinations is described, respectively. After that, two reinforcement design methods with the use of the matrix were introduced and compared. Finally, discussions and preliminary conclusions are made.

Keywords: concrete bridges; box-section; shells; reinforcement design; sandwich model; corresponding force matrix.

1 Introduction

The behaviour of box-section bridges is more complicated since the plane section assumption does not strictly apply. To simplify the design process and make it consistent with the current guidelines, several amplification factors are employed to envelop the "spatial effects", such as effective net area of flanges, partial loading amplification factor, etc [1,2]. However, this simplified design method neglects the real structural response of box sections and will potentially result in two extremes, i.e., a significant waste of steel or safety problems [3,4].

Benefitting from the development of finite element theory and computing power, elaborate finite element models such as shell element models can be established for box-section concrete bridges. By performing a linear elastic

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Slipping Behavior and Relaxation Characteristics of Thin-Walled GFRP High-Strength Bolted Friction Joints for Sound Barriers on Bridge Viaducts

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Abstract

This study aimed to clarify the performance of high-strength bolted joints for thin-walled glass-fiber-reinforced polymer (GFRP) members by conducting slip tests and long-term relaxation tests. The parameters of the slip test were the FRP surface treatment, bolt axial force, and bolt hole diameter. Relaxation characteristics might also be affected by variations in fiber content based on differences in production lots. Hence, samples from different production lots were taken. However, in these tests, the influence of all parameters was relatively minimal. One year after tightening, the axial force reduction gradually subsided and tended toward convergence. However, because it is difficult to determine convergence based on temperature changes, long-term measurements will continue. In the slip tests, the highest slip coefficient was obtained when the GFRP was coated with fluoroplastic and the connecting plates were treated with phosphate. This study proposes a design slip coefficient for GFRP high-strength bolted friction joints.

Keywords: GFRP; high-strength bolted friction joints; slipping behavior; relaxation.

1 Introduction

Glass-fiber-reinforced polymer (GFRP) has excellent material properties such as corrosion resistance, high strength and light weight. Moreover, laminated structures made from GFRP can be easily molded to form single parts. This reduces cost and simplifies manufacturing processes [1]. This has the advantage of simplifying the structure of bridge appendages such as GFRP wall railings, which are complex structures with many components. Therefore, the number of components can be reduced and workability improved, which has led to its application to bridge appendages. High-strength bolted friction joints, which have a proven track record in steel structures and are highly reliable, are commonly used.

However, in GFRP members with these joints, creep deformation occurs after a certain period of time owing to the viscoelastic behavior of the matrix resin after axial force is introduced. Therefore, the bolt axial force may be reduced to a greater extent than that in general steel.

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Numerical Analysis of Flexural Behaviour of High Strength I-Shape Steel Composite Girders with Corrugated Webs

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Abstract

With the high out-of-plane stiffness and shear buckling strength, the number of stiffeners and the thickness of the web can be reduced when using corrugated webs in composite girders. The finite element model is established according to the existing experimental results. The flexural behaviour of I-shape steel composite girders with the corrugated web was investigated by numerical analysis. From the numerical results, the flexural behaviour of I-shape steel composite girders can be improved by increasing the strength of materials. The concrete slab grade range of C50 to C60 was recommended to ensure full use of concrete and high strength steel material properties. The high strength steel grade with nominal yielding strength between 420MPa and 460MPa were suggested for bottom flange with priority, while steel grade no less than Q345 was suggested for corrugated web to avoid the safety risks caused by the premature reaching of the yield strength of the web.

Keywords: high strength I-shape steel composite girder; corrugated web; flexural behaviour; finite element analysis; material matching.

1 Introduction

The I-shape steel composite girder with corrugated web consists of the corrugated web welded with the flange, and the upper flange and the concrete slab are combined with studs. In recent years, composite girders with corrugated webs have been used more and more widely in bridge construction due to their lightweight, large spanning capacity, apparent stress, and elegant appearance. The I-shape steel composite girder with corrugated web appropriately combines the two different materials of concrete and steel, which improves the structure's stability, strength, and material efficiency. As of 2018, more than 80 composite girders with corrugated webs have been made in China [1-2]. With the increase of traffic volume, the continuous accumulation of engineering experience, and the continuous innovation of construction technology, the composite girders with corrugated webs have gradually developed in the direction of large-span and complex bridge types. Therefore, bridge construction has higher requirements for steel and other materials. It is essential to study how to improve the mechanical property and material utilization of the composite girders with the corrugated webs [3].

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Numerical Simulation of Longitudinal Shear Behavior of High Strength Steel and Concrete Composite Girders

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Abstract

Longitudinal shear failure is a typical failure mode for composite girders. Based on experimental study, the finite element model was calibrated and numerical studies were carried out to analysis the longitudinal shear behaviour of high strength steel and concrete composite girders. It was analysed the effect of transverse reinforcement ratio, concrete strength, and steel grade on the longitudinal shear behaviour of high strength steel and concrete composite girders. Based on the current specifications, the transverse reinforcement area and longitudinal shear strength of the test girder were verified. Learn from the analysis results, the concrete strength grade no less than C60 was suggested with priority for concrete slab, for composite girders using steel with nominal yielding strengthen above 420 MPa. To prevent the longitudinal shear failure for the high strength steel and concrete composite girders, the transverse reinforcement ratio no less than 1,18% was suggested.

Keywords: high strength steel and concrete composite girders; longitudinal shear behaviour; numerical simulation; design criteria.

1 Introduction

The longitudinal shear failure is a typical failure mode for steel and concrete composite girder, which will result in the reduction of loading capacity. The longitudinal shear failure would occur when adopting improper design, like insufficient transverse reinforcement, inadequate arrangement of shear connector, etc. High performance composite girder is encouraged nowadays to acquire superior structural performance, including high strength, high toughness and improved durability. Thus, the longitudinal shear resistance for high strength composite girder needs to be focused. In order to make full use of the material properties of high strength materials, the requirements for the resistance of longitudinal shear failure need to be stricter for high strength composite girders.

Mattock proposed the theory of shear transfer in concrete slab in 1972, and found that transverse reinforcement was the main part of the longitudinal shear resistance of concrete slabs [1]. Oehlers conducted experiments and finite element analysis for composite girder, which revealed that the cracks in the concrete slabs with double-row studs would extend forward in a herringbone pattern or along the centre of the stud as

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Track Transition on Bridges or Switch-Over Ramps: Rail Based Urban Transport

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Abstract

With rapid urbanisation, pressures on the urban transport facilities have increased manyfold for reasons of ever increased population and demands for better living. Rail based Mass Rapid Transit Systems (MRTS) be it elevated or underground was the first choice of the Indian Cities, which is changing now with more and more interest coming from 2nd and 3rd Tier Cities, Light Rail Transit System (LRTS) and trolley bus is gaining momentum and this become preferred choice in tier 1 cities as well to provide last mile connectivity, in sync with multi-modal integration to for door-to-door service. In order to control cost, it is now more and more explored to adopt to At Grade Section in such light transit systems. But at junction of such at grade section with Elevated / Underground stretch, it becomes inevitable to provide transition section. This paper aims in elaborating approach to design such transition zone for trackwork.

Keywords: rail based transportation; light rail transport; transition of railway track; bridge to ballasted track transition; track deflection under railway load.

1 Introduction

In present day, more and more Cities are leaning towards adopting Mass Transit System termed as "Metro", be it Metro Lite / Metro Neo or full fledged Metro Rail System. Second and Third Tier Cities like Nashik, Thane, Gorakhpur, Jammu, Srinagar and Coimbatore, are becoming more and more interested about getting light rail based system to ease the traffic load. In order to make the projects viable, it is of utmost importance to reduce the Capex of the project and the effective way to reduce the cost is by eliminating the need of construction of heavy infrastructure and bring the alignment down to at grade wherever possible.

In addition to reduction of cost, the at grade sections bring inevitable interfaces with elevated / underground sections as there are need to decongest crowded places and some unavoidable obstructions like waterbodies etc. In such locations, different types of tracks are provided and as a result transition zone is needed to be provided in such junctions.

Although at present, there are standard practices for providing such transition zone (like for conventional rail, this is provided since long at junction of bridges with ballasted sections, or in practice for long running LRT systems (like in European countries / Singapore), in countries like India, where the system is just picking up pace, there is either option for adopting any of the

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Effect of steel diaphragms on girder performance of simply supported T-girder bridges with wide girder spacing

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Abstract

A promising system for accelerated bridge construction is the simply supported T-girder bridge with wide girder spacing and steel diaphragms. However, the influence of steel diaphragms on this system is unclear. A space grillage model was presented to conduct a parametric study. Three forms of the number of steel diaphragms were considered: with three diaphragms, with two end diaphragms only, and without diaphragm. It is found that the reduction of the number of steel diaphragms reduces the stresses of girders under dead load; under eccentric vehicle load, the removal of steel diaphragms changes the load transfer coefficient and leads to uneven load distribution. However, under load combination conditions, the removal of steel diaphragms has a modest positive effect of reducing stress and deflection envelop values for girders and can bring the most adverse situation of each girder closer.

Keywords: assembled T-girder bridge; space grillage model; diaphragm; main girder performance.

1 Introduction

With the development of accelerated construction, a promising system is proposed, which is the simply supported T-girder bridge with wide girder spacing and steel diaphragms. This type of bridge allows girders prefabricated in the shop and the adjacent girders connected on field by longitudinal wet joints as well as steel diaphragms. However, the installation of steel diaphragms causes inconvenience, and the influence of the diaphragms on the performance of each girder is unclear. Lungui Li et al [1] investigated the effect of intermediate diaphragms on the deflections and flexural strains of girders at the midspan of decked bulb-tee bridges and recommended one intermediate diaphragm at midspan be used. Tedesco et al [2] showed that the removal of diaphragms has only a modest effect on the response of the bridge while reducing the maximum negative bending moment of the slab, leading to improved deck performance through the finite element method. Tanya Green et al [3] analysed the effect on the overall stiffness and deflection of main girders at different inter-section angles between the intermediate diaphragm and the main girder by considering the effects of temperature differences, bearings, and other

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The Qilihe Street Pedestrian Bridge in Nanjing, China

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Abstract

In order to build a complete pedestrian access area in the wetland park, a curved steel structure pedestrian bridge has been built approach to the lake, extending one span of beam from both ends of the second link of the bridge, which is connected with the landscape road in the park. Stairways are set up at the side span to provide an open and diverse viewing experience. Section of partial pentagon girder is provided with half of the glass bridge deck. The piers are consolidated on the inclined web of the box girder on the other side, which provide a stable support for the curved bridge. Assembled high strength screws are used at the pier bottom to anchor the pier to the pile cap to provide sufficient stiffness. The finite element models were established to calculate and analyze the overall structure and local structure of the bridge to prove its applicability.

Keywords: footbridge; design analysis; local optimization.

1 Introduction

Qilihe Street Pedestrian Bridge is one of the two pieces of infrastructure recently built in Nanjing Jiangbei New Area to create a complete pedestrian access area in the Qinglong Green Belt Park. This strip-shaped park is located in the core urban area of Jiangbei, adjacent to Yangtze River in the South and extending to Laoshan in the north, which is separated by multiple urban arterial lines. It is expected to develop into a new urban landscape in the next few years. The three park areas connected by this bridge are positioned as natural ecological landscape areas in the central of the city, bearing part of the functions of a sponge city, with artificial lakes, wetlands and hillsides. From the top view, the bridge adopts the shape of Yuruyi, a traditional Chinese ornamental symbol of auspiciousness and beauty, which harmoniously integrates with the natural landscape of the park.

Designing a structure to be part of a group of bridges that will be perceived together is, visually, more challenging than designing a bridge in isolation[1]. Another Hengjiang Avenue Pedestrian Bridge which is also a traffic node in this scattered park has been planned as a commanding height in the park for viewing the panorama of the green ecological corridor, locating in a block not far from the south of the bridge. Therefore, this bridge

Vibration Control of Simply Supported Beam Bridges Equipped with an Underdeck Adaptive Tensioning System

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Abstract

External post-tensioning offers significant potential to improve the load-bearing performance of bridges. However, typical external post-tensioning systems are effective for a specific load case. This work investigates the application of an external adaptive tensioning (EAT) system for high-speed railway (HSR) bridges. The design of HSR bridges involves strict acceleration constraints, which typically results in oversizing. The EAT system comprises under-deck cables deviated by linear actuators, which enable controlling the bending moment as the load changes. Simulations are carried out on simply supported beam bridges. Results show that active control through the EAT system allows satisfying vertical acceleration limits for mid-span HSR bridges, which cannot be met otherwise without incurring a weight penalty. In addition, the cyclic stress range is significantly reduced showing the potential for fatigue-life extension.

Keywords: adaptive structures; bridge engineering; vibration control.

1 Introduction

External post-tensioning is an effective solution to improve the structural performance of beam bridges [1]. The tension force from the external cables is applied eccentrically to the neutral axis through deviators, which produces a bending moment opposite to that caused by the external load. However, passive external post-tensioning systems are effective only under a specific load case. This work investigates the performance of beam bridges equipped with an active external tensioning system comprising under-deck cables that are deviated by vertical compressive struts acting as intermediate supports. Each cable end is anchored to the corresponding end of the beam nearby the support. The structural system comprising beam and cable-strut behaves as an underdeck cable-stayed bridge [2]. However, linear actuators are employed to adjust the length of the struts, which changes the tension in the cables, thus allowing the manipulation of the bending moment as the load changes. This system is referred to as external adaptive tensioning (EAT) system. Previous work has shown that similar external adaptive tensioning systems are effective to reduce the response of beams under quasi-static [3, 4] as well as dynamic loading [5].

The demand for high-speed railways (HSR) is growing since it is considered a strategic and

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Effects of Axial Compression Ratio in Socketed Precast Pier-Footing Connection

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Abstract

A socket connection is one of the emerging and most recommended joint connections in prefabricated substructures. At present, a large number of researches on socket connections has been carried out and most of them deal with pier-spread footing in the shallow foundation. This paper aims to study the effect of axial compression ratio using quasi-static tests of 2 specimens with socket connections. Specimen M1 is subjected to vertical and horizontal loading, whereas Specimen M2 is subjected to horizontal loading only. The experimental results showed that the axial compression ratio has a huge influence on the socket wall stress, i.e., the greater the axial compression ratio, the greater the socket maximum wall stress. But under the same horizontal force, the greater the axial compression ratio, the smaller the socket wall stress. And during increment of axial compression ratio, horizontal bearing capacity and horizontal stiffness of pier increase significantly.

Keywords: socket connection; axial compression ratio; socket wall stress; precast; pier-footing.

Introduction

Bridge construction is one of the most important sectors for any country's infrastructural development. Recently, Accelerated Bridge Construction (ABC) has focused on the development of bridge substructures because of its vulnerability to seismic activities. Generally, the connection region of precast members is critical in the high seismic area as the structural integrity under large cyclic deformation is hard to maintain. Therefore, various methods have been developed and evaluated to connect precast members, such as bar couplers, grouted ducts, and socket connections [1].

In prefabricated bridge construction, a socket connection is vastly emerging and most recommended joint connection with both precast pier and footing or with precast column and cast-in-place (CIP) footing. Socket connections can be classified in different ways according to the types of joint (dry and wet), geometrical shapes (internal, embedded, and partially), socket interface (smooth and rough), and the energy dissipating materials (grout, sleeves, etc.) used [1]. Among all types of connections, the socket connection that is constructed by embedding a precast element inside another member offers numerous benefits

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Buckling behavior of stiffened plates in concrete-filled steel tubular bridge towers

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Abstract

The steel panels on concrete-filled steel tubular bridge towers are large aspect ratio stiffened plates subject to unilateral restraint from concrete, whose local stability performance can be improved by setting multiple longitudinal stiffeners. In this paper, the elastic buckling coefficient of such a unilaterally restrained stiffened plate was derived using the Ritz method. Then, the critical relative stiffness of the stiffeners was proposed to identify the buckling mode of the plate. Further, the effective area method was proposed to evaluate the ultimate strength of the stiffened plates. The numerical simulation of the unilaterally restrained stiffened plates under axial compression was conducted using the verified finite element models. The results show that the buckling coefficient and effective area method proposed in this paper can evaluate the ultimate strength of unilaterally restrained stiffened plates under axial compression with high accuracy.

Keywords: local buckling, concrete-filled steel, bridge tower, stiffened plate, Ritz method, finite element, effective width

1 Introduction

Concrete-filled steel tubular (CFST) bridge towers consist of steel box sections welded by stiffened plates and concrete infill, which are characterized by high resistance, construction convenience and good economy [1, 2]. It has become increasingly popular on cable-stayed and suspension bridges in recent years in China, such as Lichuan Bridge (2017), the Fifth Nanjing Yangtze River Bridge (2020) and Yuanshuo Bridge (2021).

Due to the huge width-to-thickness ratio of the plates in steel bridge towers or CFST bridge towers, it's common practice to set longitudinal stiffeners to avoid local buckling. However, the plates in CFST bridge towers are unilaterally restrained by the concrete infill, which cannot buckle freely on both sides outside the face like the plates in steel bridge towers, resulting in an increase in local stability. In addition, the stiffeners are embedded in the concrete, which will not suffer from torsional instability like stiffeners in steel bridge towers. Hence, the design method of stiffened plates in steel bridge towers cannot be directly applied to those in CFST bridge towers.

The plates in the CFST bridge towers can be simplified to a rectangular stiffened plate with four fixed edges and unilateral constraints. The local buckling performance of unilaterally restrained flat plates without stiffeners has been extensively investigated by Wright [3], Uy et al. [4-6], Azad et al. [7, 8], Sun et al. [9, 10]. Tao, et al. [11-14] conducted a series of experimental studies on the buckling performance of square CFST columns with single or double longitudinal stiffeners on a single panel and proposed a

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Property Analysis of Link Slab in Long-span Steel-Concrete Composite Bridge

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Abstract
The expansion joint of simply supported bridge makes the driving uneven and maintenance inconvenient. Therefore, it is the best way to reduce or cancel it. Link slab is a favourable substitute. At present, it is mainly used for small and medium span bridges. This paper attempts to introduce the link slab into long-span simply supported steel-concrete composite bridge. The numerical model of the whole bridge is built, and the influences of bridge span, debond length of link slab and thickness of link slab on the mechanical property of continuous bridge deck structure are studied. The results show that as the bridge span increases, the longitudinal tensile stress on the upper surface of the control section increases significantly.

Keywords: Long span simply supported bridge; Debond Link Slab; Debond length; Thickness of DLS

1 Introduction
Steel structure and steel-concrete composite structure bridges have outstanding advantages such as large span capacity, and easy assembly construction. They are widely used in Bridge Engineering in developed countries such as Europe, America and Japan. As of 2015, the proportion of steel structure bridges in China is still less than 1%[1]. In recent years, under the guidance of national policies, the adaptability of steel-concrete composite structures in long-span bridge, mountain bridge, prefabricated bridge and other structures has attracted more and more attention[2].

Simply supported bridge has the advantages of good economic benefits, simple structure and fast construction speed. So it occupies an important position in the construction of modern bridges in China. However, there are many expansion joints in simply supported bridge, which reduce the flatness of the bridge deck. In addition, the expansion joints

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Experimental Design of Link Slab in Long-span Steel-Concrete Composite Bridge

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Abstract

Link slab makes the steel girder simply supported and the bridge deck continuous. Therefore, it is a fine substitute for expansion joint in simply supported bridge. However, the application of link slab in long-span simply supported composite bridge is rarely reported. This paper attempts to introduce the link slab into long-span simply supported steel-concrete composite bridge. In order to study the static performance of the link slab, this research designs a full-scale I-shaped segment specimen and conducts a numerical analysis on it. The calculation results are compared with the full bridge model to verify its feasibility, preparing for a follow-up test.

Keywords: Long span simply supported bridge; Debond Link Slab; Full-scale specimen design.

1 Introduction

In 2016, the Ministry of transport of China issued the guiding opinions on promoting the construction of highway steel structure bridges. After that, more and more importance has been attached to the adaptability of steel-concrete composite structures in long-span bridge, mountain bridge, and prefabricated bridge [1].

Simply supported bridges have the advantages of good economic benefits and simple structure. Therefore, it is the most widely used bridge type. However, there are many expansion joints of simply supported bridge, which makes the driving uneven. In addition, the expansion joint is easy to damage, difficult to maintain, and need to be replaced frequently.

In order to solve the above problems, in the late 1970s, engineers put forward the concept of Continuous Bridge Deck, which means that two adjacent spans of simply supported bridge decks (all or part) or deck pavement are connected

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A Comparison Study of Reinforcement Design Methods of Concrete Box Girder Bridges Considering Spatial Effects

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Abstract

At present, typical reinforcement methods of box girders able to consider spatial effects are known as the amplification factor method, "panel element model" method, and the "spatial grid model" method. However, the differences between these methods have not been investigated.

In this paper, these methods are compared in terms of the full spatial resistances of box-girders, by evaluating the reinforcement results in an example. A surplus indicator in different directions in terms of the ultimate bearing capacity and normal section crack resistance is defined. The results show that in the mid-span section, the amplification factor method is prone to over-limiting the principal tensile stresses at the bottom panel near the web, and the other two methods have the good load-bearing capacity and crack resistance in all directions, but the reinforcement (especially for the spatial grid model method) is too conservative at the web and bottom panel.

Keywords: box girder; design method; spatial effect.

1 Introduction

Concrete box-girders possess the merits of high availability and strong bending, and torsion resistance, and are thus comprehensively applied in the bridges of span lengths of more than 40m [1]. Meanwhile, the mechanical features of box-girder bridges are also more sophisticated than any other structures with an open section, such as the T beam bridges. The spatial effects in the top, bottom, and web slabs of a box-girder, as well as the connections between them, are so remarkable that a very precise design is difficult to implement. Then inappropriate consideration of these spatial effects in the reinforcement design analysis happens, which might introduce cracks and structural risk [2,3].

To solve this issue, the codes worldwide started to use an amplification factor approach for the

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Desirable Geometrical Configurations of The Web/Flange Splices for Enhancing the Frictional Slip Resistance of an I-Girder

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Abstract

The present study focuses on the major slip behavior of high-strength frictional bolted connections in an I-girder. Bolted girder connections resist the applied bending moment through the cooperation of flange and web resistances. Flange and web splices are individually designed following practical design codes, such as Eurocode 3 and the Japanese Specifications for Highway Bridges. In the present study, FEA of various cross-sectional dimensions of the web splice in girder bolted connections, having various bolt arrangements of the web splice, and various number of bolts in the flange and web splices have been conducted to quantitatively evaluate the cooperative slip behavior of the girder connections. It has been found that the frictional force of the web splice was small compared to the design resistance. Moreover, as the bolt spacing of the web splice increased and the number of bolt rows of the web splice decreased, the ratio of the frictional force to the design slip resistance increased.

Keywords: girder bolted connections; high-strength frictional bolted joints; slip limit state; cooperative resistance mechanism

1 Introduction

Flange and web splices of girder connections are designed separately, following general design codes such as Eurocode 3 [1], Japanese Specifications for Highway Bridges [2], and the AISC Steel Construction Manual [3]. The ultimate and slip resistance of web splice is obtained by determining the ultimate and slip strength of the bolt is farthest from the center of gravity. This is because the implementation of the simplified design procedure and the web splices of the beam and girder connections are generally evaluated using the instantaneous center (IC) of the rotation method [4,5].

However, actual girder connections resist the applied bending moment through the cooperation of flange and web resistances [6,7] (herein cooperative resistance mechanism). Moreover, the slip resistance of the girder bolted connections is attributed to the flange and several web bolts [8,9]. Although the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications [10] include the cooperative resistance mechanism; due to the lack of data on the influences of the various structural parameters, the details of the cooperative resistance mechanism are not clear.

It was found that the cooperative resistance mechanism had a significant effect on the slip limit states. Furthermore, clarifying the cooperative resistance mechanism enhances the slip resistance and reduces the number of bolts in bolted girder connections.

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Experimental Study on Tension Mechanisms of UHPC Link Slab

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Abstract

The ultra-high performance concrete (UHPC) link slab has been proposed to provide a suitable solution to the cracking problem of conventional reinforced concrete (RC) link slab. This paper presents an experimental study on the tension mechanisms of UHPC link slab under monotonic tension loads. The experimental results of load-displacement curves, crack development and strains of UHPC link slab were investigated and compared with those of RC link slab. It can be found that in the elastic phase, the tension stiffness and ultimate loads of the UHPC link slab were respectively 2.6 and 2.4 times those of the RC link slab. Compared with the RC link slab, the number of cracks on the top surface of the UHPC link slab was larger, but the average crack width was significantly smaller. The concrete and reinforcement strains of UHPC link slab were smaller than those of RC link slab.

Keywords: jointless bridge decks; link slab; ultra-high performance concrete; tension mechanisms; load-deflection response; tension stiffness; crack development.

1 Introduction

Deck joints are installed at each end of simple-supported girders to accommodate the cyclic longitudinal thermal movements of the superstructure [1, 2]. However, a large number of investigation data showed that the deck joints are expensive to maintain and easy to be damaged due to the influences of unconservative set of design temperature parameters and overloaded vehicles [3-7]. In order to resolve the problems caused by deck joints, the concept of jointless bridges have been widely studied and used [1, 3-6, 8]. Link slab, i.e. a continuous slab installed between adjacent simply supported girders, is one solution to eliminate deck joints over the piers to form a jointless bridge deck [9-12].

However, the conventional reinforced concrete (RC) link slab is subjected to a complex stress state due to the combination of: a) the girders longitudinal deformation induced by the average effective bridge temperature variation; b) the concrete creep and shrinkage; c) the rotational deformation of the girder ends caused by vertical traffic load. Due to the previous reasons and to the low tensile strength of the concrete material, it is easy to be cracked causing deterioration [11-14].

Compared with RC material, the ultra-high performance concrete (UHPC) has larger tensile strain, higher compressive strength and better

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Short Stud Arrangement Effect on Flexural Behavior of Steel-UHPC Composite Decks

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Abstract

To investigate the effects of short stud arrangement on flexural behavior of steel-UHPC composite decks, a static bending test was conducted on a full-scale segmental specimen and a parametric analysis was executed based on a validated finite-element model. The test results showed that when UHPC crack width reached 0,10 mm, the measured strain of UHPC was 1568 με, accounting for 47% of the material ultimate tensile strain. And the corresponding nominal stress of UHPC was largely over the material cracking stress. The parametric analysis results showed that increasing stud spacing from 200 mm to 300 mm increased the UHPC cracking load by 9,7% because of a lower composite action; compared with the normal arrangement, studs arranged in groups with the same amount could increase the UHPC cracking load by 11,1% while maintaining the combined effect. However, this was under the condition that the steel and UHPC partially interacted.

Keywords: steel-UHPC composite decks; short stud arrangement; flexural behavior; finite element simulation; parametric analysis

1 Introduction

Combining an ultra-high performance concrete (UHPC) slab with an orthotropic steel deck by shear connectors can significantly enhance the bending stiffness of the deck, reduce the cracking risk of fatigue-prone details, and ameliorate structural diseases of the pavement [1,2,3]. The cubic compressive strength and tensile strength of UHPC are normally more than 120 MPa and 7 MPa, respectively. Besides, excellent post-cracking behavior can be observed on the material under tension due to the strain-hardening feature [4].

In the last decade, application cases of the steel-UHPC composite deck increased rapidly among new projects and reconstructions of aged bridges. The shear connector is crucial to achieving a satisfying combination between the steel deck and the UHPC slab. Main structural forms of the shear connector include headed stud, section steel, reinforcement mesh, etc., among which headed stud is most commonly adopted because of constructional convenience and mechanical reliability. However, since the thickness of the UHPC slab is usually small, the headed stud used in the steel-UHPC composite deck typically has a height of 40 mm and a diameter of 13 mm, leaving

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Thermal Spray Zinc Coatings for Protecting Bridges from Corrosion

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Abstract

Metallic zinc coatings are recognized as environmentally friendly, sustainable, and low maintenance, providing the lowest life cycle cost corrosion protection. Various case studies illustrate that the corrosion protection of steel bridges with thermal spray zinc (TSZ) duplex coating are very good in the environmental corrosivity of class 4 or 5 without any maintenance for a long time. Meanwhile, TSZ coatings on the exposed surface of the concrete of reinforced concrete structures can be electrically connected to the steel reinforcement and provide corrosion protection to the steel. The lives of iconic bridges have been successfully extended by using TSZ coatings for use as anodes in ICCP systems.

Keywords: thermal sprayed zinc; corrosion; steel bridge; reinforced concrete bridge.

1. Introduction

Steel is a strong, versatile and inexpensive material with uses in many different construction industries, the bridge industry amongst others. It has the highest strength to weight ratio of all construction metals and is recyclable. However, in order to enhance and protect this vital asset, corrosion prevention is essential. Metallic zinc coatings are well established and recognized as the most cost-effective corrosion protection available for steel structures. Zinc coatings protect steel from atmospheric, marine and in-soil exposure conditions, and can be applied either by hot dip galvanizing or by thermal spraying [1,2]. Hot dip galvanizing involves the full immersion of the steel into a bath of molten zinc, ensuring complete coverage over all surfaces with a zinc coating. However, some structures can be too large to galvanize. With thermal sprayed zinc coatings, there is no size limitation to the part to be coated, and the technology is fully portable, allowing easy field applications.

Road steel bridges are typically designed with a lifetime of 100 years. However, lifetime extensions are normal and there are many bridges that are older than 100 years. Bridges are most likely to be replaced or decommissioned due to increased traffic capacity or the closing of the road than for

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Continuous Galvanized Reinforcing Steel in Concrete Structures

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Abstract

Corrosion of steel reinforcing bar (rebar) is the most significant cause of concrete failure, resulting in expensive repairs, reduced load carrying capacity and premature replacement of concrete structures. This paper will discuss continuous galvanized rebar now available for concrete structures. The properties of this zinc coated rebar and its contribution to improvement of concrete performance will be presented together with the status of related national and international standards and applications in China. The Continuous Galvanized Rebar (CGR) coating process improves product consistency, increases through put and reduces costs. The zinc coating is durable and resistant to abrasion that is routine during transport and construction but is also highly ductile and can be formed after galvanizing to further reduce cost and speeding construction schedules. Once in the concrete, the zinc coating protects the rebar both as a barrier coating and with the well-known sacrificial properties of a galvanized coating.

Keywords: corrosion; galvanizing; rebar; reinforcing steel bar; zinc; continuous galvanized rebar.

1. Introduction

Hot dip galvanizing is by far the most effective way to protect steel from corrosion. The zinc coating acts first as a barrier protection, isolating the base steel from corrosive elements, and secondly by cathodic protection, acting as a sacrificial anode to protect the steel from corrosion should the coating be compromised.

The excellent corrosion protection provided by zinc will also extend the life of steel-reinforced concrete structures exposed to aggressive environments that promote corrosion of steel reinforcement. Galvanizing increases resistance to chloride corrosion both by increasing the threshold chloride level where corrosion begins and by slowing the rate of corrosion after that threshold is exceeded and is also very effective in combating the effects of carbonization-induced reinforcement corrosion [1].

Field studies highlight the excellent performance of galvanized reinforcing steel as a successfully

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Effect of SFRC Composite Deck on Negative Bending Behavior Steel Box Girder

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Abstract

To investigate the failure mode and effect on a steel girder negative bending behavior of an SFRC composite deck, eccentric tension tests and numerical simulations were conducted on C50 concrete composite deck and SFRC composite deck specimens. Furthermore, parametric analysis via girder segment finite element models was carried out for summarizing the influences of the composite deck on the steel box girder performance. The test and simulation analysis results showed that the residual contribution of SFRC slab to the axial tensile stiffness of composite deck was 36% as cracking up to 0,10 mm, while that of C50 concrete slab was only 15%. Moreover, the parametric analysis results showed that the residual contribution of SFRC slab to the bending stiffness of steel girder was twice that of C50 concrete slab. When SFRC crack width reached 0.10 mm, the bending stiffness of the main girder was reduced by 11% compared with the intact state.

Keywords: SFRC composite deck; eccentric tension test; parameter analysis; bending stiffness.

1 Introduction

Combining steel fiber reinforced concrete (SFRC) with orthotropic steel deck by shear connectors can significantly reduce cracking risk at fatigue-prone details and ameliorate pavement deteriorations. SFRC can be classified as normal steel fiber reinforced concrete, high performance concrete, and ultra high-performance concrete according to the compressive strength. Besides, excellent post-cracking behavior can be observed on the material under tension due to the strain-hardening feature. For medium span continuous municipal bridges, ordinary or high-strength SFRC can meet the engineering demands and the cost is relatively low. Therefore, making efficient use of the mechanical advantages of SFRC can improve the mechanical properties and economy of the bridge structure.

The previous studies on bridges with a composite bridge deck mainly focused on the bridge deck mechanical behavior. Shao et al.[1] conducted transverse bending tests on steel-ultra high performance concrete (UHPC) composite bridge decks and found that the local effect of transverse stress on the bridge deck is significant. Su et al.[2] proposed a crack width calculation method considering the residual stress of SFRC cracking through a static bending test of full-scale segmental composite bridge decks. Ye et al.[3]

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Effect of Concrete Thickness on Fatigue Performance for rib-to-diaphragm in steel-concrete orthotropic composite decks

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Abstract

In order to study the effect of thickness of rigid pavement on the fatigue performance of orthotropic deck, the shell-solid finite-element model was established to analyze the stress on the opening area of diaphragms in orthotropic deck under different concrete thickness. The results show that with or without rigid pavement, the stress distribution of the bridge deck and the hot-spot stress at the opening area of the diapragm are significantly different. The stess amplitude at the diaphragm-opening area of the orthotropic steel bridge deck with rigid pavement is only half of that in orthotropic steel bridge deck without rigid pavement. The thickness of the concrete has a great influence on the fatigue strength of the opening area of the diaphragm in orthotropic steel bridge deck when the concrete thickness is no more than 100 mm.

Keywords: Steel-concrete orthotropic decks; Finite-element method; rib-to diaphragm; Fatigue strength assessment approach.

1 Introduction

Orthotropic steel bridge decks have been widely used in long-span bridges due to their overall light weight, convenient construction, high strength and easy transportation. A typical tranditional orthotropic steel deck usually consists of a bridge deck plate、longitudinal and transverse stiffeners[1]. Despite inherently possessing excellent structural properties, orthotropic steel decks are prone to initiate cracks as a consequence of high cyclic stresses by wheel loads in conjunction with inevitable fabrication defects. Meanwhile, Orthotropic steel bridge decks usually use asphalt concrete as the pacements. Because of the insufficient stiffness in the deck and severe overloading, the pavements are always found damaged in long-term operation, which seriously limits the application and development of orthotropic steel bridge decks[2].

Relevent data shows that fatigue cracks of orthotropic steel bridge decks are mostly discovered in the conjunction of longitudinal ribs and transverse diaphragms. It has been found that when the opening height of the diaphragm is 1/3~1/2 of the height of the longitudinal rib, and the opening position is treated by a smooth transition, the diaphragm has better mechanical properties[3]. While Zhang[4] obtained the relationship between the thickness of the longitudinal rib and the shape of the opening by finite element analysis. In the fatigue tests of the welding forms of longitudinal ribs and transverse diaphragms conducted by Tsakopoulos[5], the test results indicated that the

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Seismic Response Analysis for Engineering Structures Equipped with Double Viscous Damper Toggle Brace System

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Abstract

The toggle brace viscous damping system has been proved to be an effective motion amplification device, which can amplify the deformation of the damper under wind load and earthquake action, thus significantly improving the energy dissipation efficiency of the damper. In the existing viscous damping system of elbow joint, the damping force will act directly on the floor beam, which often leads to unsatisfied performance of the connected floor beam. Therefore, a double-damper toggle brace device is proposed in this paper, and a mathematical model of geometric parameter optimization of double-damper toggle brace device system is established. According to this mathematical model, a larger displacement amplification factor can be obtained, which is far superior to the existing toggle damping system. Finally, a two-story steel frame model is taken as an example to verify the effectiveness and applicability of the proposed double-damper toggle brace device system.

Keywords: viscous damping device; double-damper toggle viscous damping device; seismic response.

1 Introduction

Viscous damper is a kind of velocity-dependent damper with no stiffness. It has the advantages of strong energy dissipation, no additional stiffness, and the displacement and damping force are out of phase. A large number of engineering practices have proved that viscous damper is a kind of energy dissipation device that can effectively absorb and dissipate seismic action and wind load [1], such as Huntington Building 111 in Boston, Yintai Center in Beijing, International Trade Center in Tianjin, Four

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Practical Use of UHPC As a Main Material for Superstructure of Pedestrian Bridges

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Abstract

The main topic of paper is practical use of UHPFRC as main material for superstructure of pedestrian bridges. Three practical examples of real pedestrian bridges are presented – first is segmental single span bridge (completely made by UHPFRC segments), the second is cable stayed pedestrian bridge also with superstructure made by UHPFRC segments and the last one is low raised arch with external prestressing tendons. Information about design (material and structural analysis, details solutions and construction stages) are described and presented.

Keywords: UHPFRC; pedestrian bridge; structural analysis; precast segments; cables; construction.

1 Introduction

UHPFRC or UHPC is a new promising high-quality cementitious material. Its mechanical properties (compressive strength 120-180 MPa, flexural tensile strength approximately 20-40 MPa) and workability make it possible to design new constructions of specific parameters and shapes. At the same time, a very high durability many times higher than ordinary concrete is essential for practical use. Methodologies were also developed under the leadership of the CTU in Prague to further expand the possibilities of designing and applying UHPC and UHPFRC in the Czech Republic.

2 Segmental bridge in Pribor, Moravia

2.1 Basic Information

This relatively modern cement composite material was used in this case to build a footbridge designed as a simple supported girder with length of the span 35 meters and total structure length 36 meters from UHPFRC C 110/130 with dispersed steel reinforcement. The general view of the bridge is shown in Fig. 1. The bridge is placed on the reinforced concrete substructure (abutments) by means of four cylindrical steel bearings with a diameter of 200 mm. The surface of the structure is directly walkable (without additional waterproofing and covering surfaces) with water drainage realised by cross section slope of 1.0%. The bridge is equipped with a railing system - 1.1 meters high, formed by optically subtle circular posts with a diameter of 22 mm. These posts are longitudinally connected by a solid lacquered acacia handrail. Inside the handle is integrated footbridge lighting, including the necessary accessories.

2.2 Structure arrangement of the bridge

The superstructure with a depth of 800 mm is divided in the longitudinal direction into five segments with a length of 7.2 meters and a cross-section according to Fig. 2. The slenderness ratio of the structure is therefore 1:44.

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Review on Flow Characteristic and Pumpability Prediction of Pumping Concrete

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Abstract

Pumping is the most commonly used construction method for modern concrete transportation and pouring. This paper summarizes the theoretical and experimental research results on the flow behavior characteristics and pumpability prediction of pumped concrete. The formation mechanism of lubrication layer based on shear induced particle migration theory is introduced, and the distribution of concrete shear rate and flow rate in the pipeline is analysed. This paper discussed three prediction methods of concrete pumpability, including empirical judgment, coil test and pumping resistance calculation. Thus, the cognition of concrete pumping process can be improved and reference for engineering and technical personnel in pumping construction can also be provided.

Keywords: concrete; pumping; lubrication layer; velocity distribution; pumpability.

1 Introduction

Pumping has gradually become the main construction method of modern concrete transportation and pouring since the first use of pumping in the United States in the 1930s. According to statistics[1], in 2020, the output of ready mixed concrete in China has reached 2.94 billion m^3, and most of the ready mixed concrete is transported and poured by pumping. Pumping technology directly affects the quality of concrete construction. At the same time, with the development of Chinese construction industry, lightweight, long-span and other construction objectives require concrete to have high strength and high constructability, which puts forward new requirements for pumping technology. For example, Guangzhou Chow Tai Fook financial center project requires that C80 high-strength concrete be pumped into the 530m high shear wall[2], and the complex double-layer rigid steel plate shear wall requires that the concrete has low shrinkage and self-leveling characteristics.

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Experimental Study of Curved SFRC and ECC Composite Beams

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Abstract

In order to investigate the cracking behavior of curved steel-concrete composite mechanical behavior under a hogging moment, two composite box girders with a central angle of 9º were designed and tested under static loads. In the reported test program, the CCB-1 was designed with steel fiber reinforced concrete (SFRC) slab and shear studs. In contrast, the CCB-2 was designed with Engineered Cementitious Composites (ECC) and Uplift-Restricted and Slip-Permitted (URSP) connectors for enhanced crack resistance. The load-displacement curve, strength and displacement ductility, failure mode, and strain distribution were reported in detail. For the test small curvature beams loaded under the hogging moment, the flexural critical failure mode was observed for both specimens, which was governed by compressive yielding of the top steel plate and tensile yielding of the concrete slab. The URSP connectors effectively reduce the stiffness of the interface slip of composite girders, enhance the interface slip capacity, and reduce the crack width of concrete compared with traditional shear studs.

Keywords: Curved composite beam; steel fiber reinforced concrete; Engineered Cementitious Composites; Uplift-Restricted Slip-Permitted connector.

1 Introduction

The steel-concrete composite beam combines the steel beam and the concrete slab through shear connectors. The compressive strength of concrete and tensile strength of the steel plate can be fully achieved in composite beams. Therefore, the composite beams have been widely adopted in many large-scale complex composite structures and ultra-high-rise buildings with reduced self-weight and enhanced mechanical performance. Significant experimental and finite element (FE) simulation has been reported in the existing literatureto investigate the mechanical performance of composite beams as well as concrete beams [1-4]. Recently, in order to reduce the concrete cracking in the continuous composite beam, Nie et al. [5] proposed Uplift-Restricted and Slip-Permitted (URSP) connectors. The URSP connectors were composed of traditional shear studs and low-elastic modulus material. In order to further verify the cracking resistance behavior of URSP connectors, a significant experimental study has been conducted. These tests include hysteretic shear test and pull-out tests [6], two hogging moment tests on steel truss-concrete composite beams [7-8], three continuous composite beams [9], suspension bridge tests [10], and a series of FE simulation of composite frame [11]. Existing test and simulation results showed that the application of URSP connectors at the hogging moment region of the composite beams significantly reduced the cracking behavior of composite beams. In addition, the URSP connectors have been widely adopted in many bridges in China, including the Tianjin Haihe

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Study on the Bearing Capacity of Grouted Connections with Shear Keys

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Abstract

Grouted connection (GC) is an important part of the offshore wind turbine (OWT) support structure. There are a lot of axial compression tests of GCs. But in order to thoroughly study the effects of different parameters on GCs, it is necessary to carry out the numerical study with the finite element method (FEM). In this study, the local models of GC were established by using the FE software ABAQUS. The numerical results were verified by the experimental results. A parametric study was carried out to investigate the influence of grout thickness, lateral compressive stress, shear key spacing, and the number of shear keys. The study shows that increasing the lateral pressure and the number of shear keys can significantly improve the bearing capacity. While increasing the grout thickness within a certain range will reduce the bearing capacity. And increasing the shear key spacing within a certain range will improve the bearing capacity.

Keywords: grouted connection; axial bearing capacity; finite element simulation; parameter analysis.

1 Introduction

Wind energy has a huge scope of utilization and value utilization. The connection is an important part of the OWT support structure. Because of its many advantages, a large number of OWT support structures are currently connected by grouting.

There were many experimental studies on the axial load capacity of the GCs. The experiments can be divided into scaled-down experiments and local experiments. Due to the large size of the OWTs, it is difficult to conduct prototype experiments. So, the scaled-down experiments were widely used. Billington[1][2] conducted about 60 static load loading experiments of scaled-down models based on five factors. Lamport[3][4] conducted six sets of scaled-down experiments to study the effect of four factors. Since the scale-down experiments have many limitations in the process of physical reduction, they cannot simulate the real force states of large diameter OWTs, so local experimental studies are needed. Under the premise of large pile diameter, the local equivalence of the circular tube can be a flat plate, which can be directly simplified to a double shear experiment of flat plates by symmetry. Wang et al.[5] used this model for the test.

In addition to experiments, many scholars have carried out FE simulation studies. Two typical models are still used for the establishment of the FE model. Wang et al.[6] used the flat plate double shear model to develop FE analysis of GCs. Chen et al.[7] used FE analysis to investigate the compression-bending performance of the GCs.

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Finite Element Analysis of Local Pressure Failure Mechanism of RPC

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Abstract

Reactive powder concrete (RPC) has been widely used due to its high tensile and compressive strength and excellent durability. However, the failure mechanism of RPC local pressure is still unclear. Therefore, reasonable structural dimensions of the finite element model (FEM) and the relevant parameters of the RPC were selected to deeply explore the local pressure of the RPC under the local loading. The FEM of the axial local compression of the RPC with different constitutive models was built. The whole nonlinear analysis process of the local pressure of RPC was completed, and the failure mode, stress distribution, and maximum plastic principal strain of the specimen were analyzed. The model shows that the local pressure performance of RPC is improved due to the increase of ultimate tensile strength, the local pressure failure mode of RPC conforms to the wedge split theory, and the orthogonal ties can uniformly distribute the pressure stresses.

Keywords: Reactive powder concrete (RPC); finite element model (FEM); local pressure; constitutive models.

1 Introduction

Reactive powder concrete (RPC) [1] is a new type of cement-based composite material. Compared with Ordinary Concrete, RPC has been widely used in high-rise structures, nuclear reactor waste storage containers, long-span bridges, and other practical projects [2].RPC has significantly improved mechanical properties and durability [3, 4]. For bridge engineering [5], the improvement of compressive strength [6] and bending strength of RPC can effectively reduce the size of the structure under the same bearing capacity, thereby significantly improving the spanning capacity of the bridge structure itself. However, when the RPC is combined with the prestressed structures, it can achieve a smaller cross-sectional size than the conventional prestressed concrete structural members [7]; it also makes the local pressure problem of the RPC structural members under the post-tensioned prestressed anchors more difficult, prominent, and complicated. The applied force on the steel strands will be transferred to the concrete through the bearing plate. The pressure transmitted by the bearing plate will cause vertical compression inside the concrete. In addition, due to the relatively concentrated pressure area of the bearing plate, the high compressive stress will cause lateral expansion inside the concrete. However, this local lateral expansion will be

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Numerical Simulation on Seismic Performance of HPS-UHPFRC Composite Pier-foundation Embedded Joint

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Abstract

The assembled composite bridge pier with high performance steel (HPS) and ultra-high performance fibre reinforced cementitious composite material (UHPFRC) possess the advantages of factory production and good seismic performance. In order to improve the connection degree and seismic performance of pier-foundation embedded joint in HPS-UHPFRC composite pier, PBL shear connectors and UHPFRC were adopted in the embedded part. Numerical simulation was carried out on the seismic performance of the joint with PBL shear connectors and without the connectors. Besides, the parametric analysis of the main influencing factors was conducted, including the construction of PBL shear connector, embedded depth of the pier and material types of the joint. The influence laws were obtained through the comparisons, and reasonable suggestions were provided for the design of HPS-UHPFRC composite pier-foundation joint.

Keywords: HPS-UHPFRC composite pier; embedded joint; seismic performance; PBL shear connector.

1 Introduction

High performance steel (HPS) and ultra-high performance fibre reinforced cementitious composite material (UHPFRC) possess the advantages of high compressive, tensile and toughness properties, which can be applied to assembled concrete filled steel tube (CFST) composite pier to form assembled HPS-UHPFRC composite pier, so as to improve the bearing capacity and ductility of the bridge pier, and meet the stress requirements of assembled substructure of bridge in strong earthquake areas. The connection joint between the pier and the foundation is the key part of the assembled HPS-UHPFRC composite pier, which controls the overall performance and safety of the structure.

In order to improve the seismic performance of pier-foundation joint, relevant scholars have carried out experimental and theoretical studies. Pertold et al. [1] researched on two groups of embedded steel footings, and showed that the bond strength between the steel and concrete and the punching strength of the concrete base were conducive to vertical load transmission. Hsu et al. [2] proposed a connection method of CFST column foot by adding stiffeners in the embedded part, and verified the superiority through quasi-

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Analytical Study on Tubular Flange Girder Bridges Using High Strength Steel

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Abstract

Twin-I girder bridge systems are representative structures used in bridge industrialization construction. They have advantages including structure simplification, material save and accelerated construction, but the system using two main girders limits the span and makes the lateral effect more significantly. The general suitable spans range from 25m to 45m, which limits the use of twin-girder bridges. To increase the span limit, the use of tube as top flange and high strength steel can improve structure behavior and increase bridge spans. In the paper, parametrical study and structure optimization were conducted to investigate the behavior of tubular flange girder bridges using high strength steel. Parameters including cross-beam arrangement, stiffeners, tube size were studied. Comparisons between the systems using ordinary steel and that using high strength steel were conducted.

Keywords: high strength steel; tubular flange girder; span limit; lateral torsion bulking; stability.

1 Introduction

Nowadays, the industrialized operation mode has gradually penetrated into bridge construction. Since 2016, China's Ministry of Transportation has been vigorously promoting the industrialized construction of highway steel bridges (including steel truss girders, steel box girders, and Steel-concrete composite girder bridges) to promote the construction of highway bridges and to make full use of the performance advantages unique to steel bridges. The industrialized construction of bridge structures requires simple cross-section, uniform segments and simplified lateral connection (crossbeams). For the twin-I girder bridges that are used for industrialized construction, currently I section is mostly adopted, which is convenient for industrialized construction but has some problems meanwhile[1]. Firstly, in order to improve the stability and torsional resistance, a large number of crossbeams need to be arranged between the main girders, which increases construction time and cost. Secondly, the main girders made of ordinary steel are heavy, which has more requirements for construction equipment. Finally, the span of twin-I girder bridges is up to 40 m, which is not suitable for longer span bridges. Therefore, based on the demand of industrialized bridge construction, a tubular flange girder using high-strength steel is

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Flexural Behavior of a New Steel-UHPFRC Composite Beam with In-Built Steel Dowel as Connector

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Abstract

A lightweight steel-UHPFRC composite beam structure, consisting of a half rolled section with in-built steel dowels as connectors and a T-shaped UHPFRC component, is proposed originally in this paper. The excellent properties of steel and UHPFRC materials can be exploited fully and properly, and the presence of in-built steel dowel is expected to allow effective force transmission between steel and UHPFRC components, benefiting from its higher shear resistance and ductility. Two composite beams with various heights of UHPC web are tested by 4PBT method, aiming at validating this concept and investigating the flexural behavior under sagging moment. And a high resolution Digital Image Correlation (DIC) system is applied during testing, in addition to conventional measuring techniques. Moreover, the sectional analysis method considering the tensile properties of UHPFRC is applied to predict the flexural.

Keywords: composite beam; UHPFRC; rolled section; steel dowel; in-built connector; flexural behaviour; sectional analysis; DIC.

1 Introduction

Benefiting from the outstanding mechanical properties and durability of Ultra High Performance cementitious Fiber Reinforced Composites (UHPFRC) [1], the combination of UHPFRC and steel in composite structure allows more elegant and slender filigree element compared with conventional steel-concrete composite member in bridge engineering. The challenging tasks of the concept include: (1) proper geometry and arrangement of UHPFRC and steel components to fully utilize both materials; (2) efficient interaction between two components to ensure overall structural performance.

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Design and Application of New Steel-UHPC Composite Slab Girder Bridge

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Abstract

A project is located in the core area of the high-speed railway station, subject to large traffic volume and various controlling factors. A new steel-UHPC composite slab girder bridge is adopted based on and taking into account the characteristics of the project. Compared with the conventional structure, the self-weight of the bridge superstructure is greatly reduced; meanwhile, the size and weight of the lower part of the bridge are further reduced due to the fact that the prestressed concrete bent cap with large volume and weight is replaced by steel box beam; the fact that longitudinal and transverse beams are connected by high-strength bolts speeds up the on-site construction progress. Furthermore, components of the project have light self-weight and are easy to transport and install, which further reduces the impact of the construction on the environment. This paper introduces the design scheme and stress analysis of the new steel-UHPC composite beam structure, with the aim of providing reference for similar projects in the future.

Keywords: new steel-UHPC composite slab girder bridge; light self-weight; steel box beam; high strength bolt connection; stress analysis.

1 Introduction

The development of steel bridge has a history of more than 100 years, and the steel-concrete composite beam bridge has a history of nearly 70 years. Since the reform and opening up, China has built many steel bridges and steel-concrete composite girder bridges, which have made important contributions to the national economic and social development. However, long-term engineering practice shows that the steel bridge deck pavement is very easy to be damaged, and fatigue cracks are easy to appear at various joints of orthotropic steel bridge deck; For steel-concrete composite beam bridge, tensile cracking is easy to occur in the negative moment area of the structure, and due to large self-weight and large amount of materials, the structural applicability and economy are getting worse and worse with the increase of span and structural complexity [1].

A project is located in the core area of the high-speed railway station. There are dense buildings on both sides of the road, heavy ground traffic, many existing buildings and structures, and there are many intersections with the subway. The complex construction conditions have made the conventional bridge structure design scheme no longer applicable. In this paper, a new steel-UHPC composite slab girder bridge structure is proposed based on ultra-high performance concrete, so as to carry out its application technology research, further strengthen the application and promotion of UHPC materials in bridge engineering, and make an important contribution to the construction of infrastructure and technical progress of bridge engineering in our country.

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Creep Effect and Time-Varying Reliability Analysis of Prestressed Continuous Rigid Frame Bridge

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Abstract

This paper studies the long-term shrinkage and creep performance of C60 low shrinkage and low creep high performance concrete used in the main bridge of continuous rigid frame box girder bridge. The finite element model of the bridge is established by finite element simulation software. Firstly, the shrinkage and creep effect of the main bridge over a long time is calculated and analyzed by using the shrinkage and creep model of C60 low shrinkage and low creep concrete and different specification models of ordinary C60 concrete. The effects of shrinkage and creep on the internal force, stress, deflection and prestress loss of the main beam of the bridge under different loading ages are studied. Finally, combined with the prior information of concrete materials and data sample information, bayes method is used to predict the service reliability of the bridge. The research results can provide guidance for the long-term shrinkage performance and creep reliability of the bridge.

Keywords: C60 low shrinkage and low creep high performance concrete; Shrinkage creep effect; Bayesian updating method; Failure probability; Bridge reliability

1 Introduction

Concrete shrinkage and creep is a unique time-varying characteristic of the material itself. Concrete creep is a phenomenon that the creep increases with the increase of load holding age under the action of long-term load [1-3]. Concrete shrinkage and creep will increase the prestress loss, long-term deformation and internal force redistribution of concrete bridges after long-term operation [4]. Therefore, many studies began to carry out relevant research represented by C60 high-performance concrete and put relevant research into real bridge application [5-10]. With the construction and use of a large number of prestressed continuous rigid frame bridges, the phenomena of bridge deflection, prestress loss and cracking caused by concrete shrinkage and creep are common [11-13]. Therefore, the research on the ultra long-term shrinkage and creep effect and long-term reliability of C60 low shrinkage and low creep prestressed continuous rigid frame bridge has certain theoretical value and economic significance.

In recent years, a large number of scholars have studied the shrinkage and creep effect of concrete used in long-span bridges. Liu et al. [14] analyzed the shrinkage and creep effect of Hong Kong Zhuhai Macao Bridge over a long period of 30 years by carrying out the shrinkage and creep test of high crack resistant dense homogeneous concrete used in Hong Kong Zhuhai Macao Bridge; Pan et al. [15] proposed a modified shrinkage and creep prediction model through the shrinkage and creep

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Research on wind field characteristics measured in U-shaped valley at bridge site by Lidar

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Abstract

Currently, research on wind fields of U-shaped valleys is rarely reported. In order to study the wind characteristics in a mountainous U-shaped valley, a lidar was placed at a bridge site located in a U-shaped valley. Then, nearly 6 months of original data ranging from 0 m to 810 m were analyzed statistically. It was found that the wind parameters are correlated among different virtual wind towers (VWTs). The wind speed profile is divided into three categories: disordered, linear and nonlinear. The wind direction is consistent with the main wind direction at the bridge site and the average wind direction of different VWTs has a high consistency. The concept of wind-direction deflection rate is put forward to describe the variation of wind direction with height. These measured wind parameters could be used as a reference for bridge wind-resistant design.

Keywords: bridge engineering; wind characteristics; field measurement; U-shaped valley; lidar; bridge site

.

1 Introduction

Many long-span bridges have been built in mountainous valley areas, for example, Royal Gorge Bridge, (1929, 384 m), Cañon City, Colorado, USA; and Yachihe Bridge (2016, 800 m), Guizhou Province, China; and more will be built in the future. The requirement for long-span bridges in mountainous valley areas also enhances the performance standard of long-span bridges. Among them, the influence of wind on the long-span bridges cannot be ignored, and is even one of the critical factors. At the same time, the distribution of wind parameters in mountainous valley terrain is complex and different from that in flat terrain. Although much research has been conducted in this field, due to the impact of topographic relief and elevation changes, the spatio-temporal distribution of wind speed in mountainous valley areas has its own unique patterns, which are generally analyzed on a case-by-case basis and are difficult to be described by a unified mathematical model. At present, the study of wind parameters in mountainous valley areas is one of the hot topics in wind engineering research.

Wind tunnel terrain model test, numerical simulation, and field measurement are the mainly method to study the wind parameters. Wind tunnel terrain model test is widely used, but there is room for improvement in accuracy because of characteristic flow simulation and scaling model making [1]. With the development of computer technology and computational fluid dynamic (CFD), numerical simulation methods have been applied more and more widely, and their reliability has also been verified [2]. However, further research is needed in calculating domain size and setting boundary conditions. In spite of the time consuming, huge investment and limited measured

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Advances in and Benefits of Rapid Steel Connections

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Abstract

Pairing of robotic arms with precision cutting in the form of laser, plasma, and water jet cutting has opened the door to entirely new forms of structural steel connections that can be assembled with no field welding and minimal (if any) bolting. Such connections can offer increased erection speed, decreased safety issues, and in some cases the opportunity for rapid disassembly, thereby creating a pathway for direct reuse. This paper provides an overview on the testing, numerical modeling, and field assembly of one such connection – the Intermeshed Steel Connection (ISC). This paper highlights features and behaviors of this connection when simulated, tested, and erected in a beam-to-beam connection and focuses on compliance, ability to be designed reliably, load transfer between the side plates and the main member, and the relatively rapid speed of erection compared to a traditional fully bolted connection. Because of its limited number of pieces, the connection may enable in-situ robotic assembly.

Keywords: steel connections; digital manufacturing; steel fabrication; steel erection; quick steel connections; design for disassembly; robotic assembly.

1 Introduction

Steel structures are assembled from many small parts connected together to create the final configuration. Part sizes are usually maximized to the extent possible within manufacturing, transportation, and erection limitations. Those limits result in the need for many connection pieces. Steel connections have been a major factor in the design, costing, and construction of the structural steel industry, since its earliest day of its mass production in the 19th century [1] Currently most

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Analysis of local compressive behaviour of concrete bed under an embedded cast iron cable saddle

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Abstract

The cable saddle on top of pylon not only helps the main cable pass through the summit of design form, but also transmits the tremendous force to the pylons. An imbedded cast iron cable saddle is proposed for a single pylon and two spans cable stayed bridge. Due to the arched shape of the cable saddle, the local compressive pressure on concrete bed may not be uniform. A plain strain FE model and A solid FE model is adopted to investigate the stress distribution in concrete foundation. The reduce factor for nonuniform local compression is about 0.73. This cable saddle structure can meet the local bearing capacity via theoretical verification, which could provide an example for the similar type of structures.

Keywords: concrete local compressive behaviour; embedded cable saddle; nonuniform local compression; finite element method

1 Introduction

The main cable saddle is a specific structural member installed on top of pylons for suspension bridges. It not only helps the main cable pass through the peak of design cable form, but also transmits the tremendous vertical force to the pylons. In order to reduce the bending stress in the main cable in the cable saddle, the radius of the groove casted in the cable saddle is usually at the range from 8 to 12 times of main cable's diameter. Moreover, the cable saddle structure should guarantee that bundles of wires are fixed in it, where there is enough friction between main cable and cable saddle.

For the suspension bridges with two or more pylons, the cable saddles usually are offset to the side span a certain amount of distance before the girder segments are lifted. This approach has advantage of cutting down the bending moment at the root of pylons, generated by the unbalanced forces on both sides of the cable saddles during construction. Then the cable saddles will be propelled step by step towards the main span direction in accordant with the girder segments lifted and installed. These cable saddles would eventually arrive at the centre of top section of pylons just when the girders are totally installed in right place under the main cable. In this research the background involves a single pylon suspension bridge that is a symmetric hybrid of suspension and cable stayed structure. However, comparing with the common suspension bridges just mentioned, the bending moment in pylon is not going to be influenced by the unbalanced forces of main cable, thus the cable saddle needs to be offset no longer.

With respect to saving material and keeping simple for the structure, an imbedded cast iron cable saddle is proposed in this paper. Compared with the common cable saddle structure, the amount of material for the alternative can be reduced by approximately 40%. It should be noted that the imbedded cable saddle is not an original innovation around the countries, the Hardanger bridge in Norway has adopted the similar

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Investigation on the Unsteady Aerodynamic Force on a 3:2 Rectangular Section under Accelerating Airflow

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Abstract

Unsteady characteristics of aerodynamic force and wind-induced pressure on a 3:2 rectangular section under accelerating airflow are investigated through wind tunnel experiments. Three aerodynamic coefficients, drag coefficient $C_d(t)$, RMS of lift coefficient $C_l^{rms}(t)$, Strouhal number of the rectangular section in the accelerating airflow with or without initial velocity are compared with those of the steady flow. Results show that in the cases of airflow accelerated from the static state, significant unsteady feature appears in all three aerodynamic coefficients, $C_d(t)$ and $C_l^{rms}(t)$ decreases and *St* number increases in the early accelerating stage. For accelerating airflow with an initial velocity, the three aerodynamic characteristics fit well with steady flow values, indicating negligible impact on any of these variables.

Keywords: accelerating airflow; rectangular section; unsteady aerodynamic force; wind tunnel test.

1 Introduction

Accelerating airflow is a distinguishing feature of extreme wind hazards such as tornadoes and downbursts. Unlike the atmospheric boundary layer wind environment, the wind speed of the above two disasters increases intensely in a short time, resulting in significant unsteady features of the wind force on the structure. Among them, the rectangular section is widely used in bridge members, such as stiff hangers and support columns of arch bridges, and pylons of cable-supported bridges. Efforts have been made by many researchers [1-7] on wind tunnel experiments and numerical simulation of aerodynamic characteristics of the rectangular section in uniform flow, such as lift coefficients, drag coefficients, Strouhal number, wake region et al. Nevertheless, relatively fewer studies are carried out on unsteady wind force of rectangular section under accelerating airflow.

Sparyaky firstly studied the development of vortices around the section of an accelerating bluff body in a water tunnel [8, 9]. Matsumoto simulated accelerating airflow by suddenly switching a louver-shaped device installed downstream of the wind tunnel test section, and found the maximum drag force coefficient is 1.14-1.25 times of that under steady flow [10]. Takashi investigated the force on the ellipse and rectangle section prism under the 0.2s accelerating time airflow generated by the actively controlled rotation of the horizontal plate blades in the wind tunnel [11]. Yang investigated the effect of the accelerating flow on the aerodynamic forces of three two-dimensional rectangular prisms through a series of unsteady wind tunnel manometric experiments [12]. Zhao and Cao [13] simulated the

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FE Modeling of the Interfacial Behaviour of Precast Multi-box Girder

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Abstract

To facilitate the reuse of the internal mold of precast multi-box girder and accelerate bridge construction, the torsional crossbeam at the end of precast simply supported multi-box girder needs to be changed to post-cast in-situ. Finite Element Modelling package ABAQUS 2021 was used to model the interfacial shear behaviour of the three-dimensional Z-shaped straight shear specimens. The models took into account the bond-slip relationship between the old and new concrete interfaces and the interaction between the concrete and the shear key. The models were validated and calibrated based on the experimental results. The study shows that the rigid shear key can improve the shear load capacity of the specimen at the new and old concrete interface. The difference between the model and experimental results is relatively small and therefore it shows the capability of the finite element modelling to carry out parametric analysis.

Keywords: precast multi-box girder; concrete interface; shear performance; new-to-old concrete; anchors; shear key.

1 Introduction

Simple-supported continuous small box girder bridge is a typical medium-span bridge which is very economical and applicable, and is favored by the engineering construction and construction parties[1]. Because the two ends of the small box girder need to set a diaphragm to ensure the torsional performance, the internal model uses a disposable wooden template, which is time-consuming and expensive[2]. The integral pull-out steel internal formwork technology is introduced into Shanghai Jiamin Viaduct. However, this construction technology requires that the precast part of the small box girder cannot contain the end diaphragm, and the joints of the precast-cast-in-situ structure need to be moved in to the support span. Because the shear force near the fulcrum of the small box girder is the largest, it results in precast - cast-in-place joint shear problems.

Numerous scholars have carried out studies on the shear resistance of new-to-old concrete interfaces. The results show that without reinforcement, the main factors affecting the interface shear capacity are the direction of the bond surface, the roughness of the interface, the type of interface agent, the concrete strength, the curing age and the dimensional effect[3–8]. The joints in the precast-cast sections form a natural weak surface and there are no prestressed steels passing through, which is not conducive to shear resistance (see Figure 1). However, the anchoring of prestressed steel bars at the interface constitutes a rigid shear key that is beneficial to the shear resistance of the interface.

Therefore, in this paper, numerical models are established to analyse the factors affecting the interface shear load capacity, based on Z-type direct shear experiments in conjunction with the

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Modal Analysis and TMD Design of the Wing-spread Bridge: A Pedestrian Bridge along the Binjiang Avenue, Shanghai

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Abstract

Wing-spread bridge is an innovative stress-ribbon arch pedestrian bridge expected to be built along Binjiang Avenue, Shanghai, China. Human-induced vibration is an important factor that needs to be considered in the operation period of pedestrian bridges. However, there is a lack of research on this new structure's dynamic characteristics and vibration reduction measures. In this paper, the finite element (FE) model of the Wing-spread Bridge is firstly established, and the modal analysis is conducted based on the FE model. Subsequently, the maximum acceleration of each mode under pedestrian dynamic load is calculated. The result shows that the maximum acceleration of the first-order lateral bending mode exceeds the best comfortable indicator. Finally, two tuned mass dampers (TMD) are designed to be installed at the top of the arches, and the vibration amplitude of the bridge with TMD meets the requirements.

Keywords: stress ribbon arch bridge; FEM; modal analysis; vibration control; TMD.

1 Introduction

Wing-spread bridge is an imaginary 164m stress-ribbon arch bridge built in Shanghai. The arch and the main cable overlap in the middle of the span. A back-cable partial double-layer suspension-arch combination system is proposed in creating the entire bridge, and several innovations are realized. The rigid frame effectively connects the flat arch and the sling in the middle of the bridge. Under the lifting action of the sling, the overall bending moment of the flat arch is improved, the cross-section is lightsome, and the span of the whole bridge is increased. Bridge decks are set on the main arch and suspension belt, and the double bridge decks bring different walking experiences to pedestrians. The tower and foundation are the significant components of the bridge. We adjust the position and the cable force of the back cable, and the cable force of the main cable to achieve better structural performance. In this state, the structure has almost no horizontal thrust on the foundation, and the bridge tower is only subject to axial force under the action of dead load. At the same time, the bridge tower adopts the shape of a

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Numeric Analysis of Creep Effects on Steel-concrete Composite Structure with Equivalent Temperature Field Method

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Abstract

The analysis of creep effect on steel-concrete composite structure is very complex. In this paper, the numeric analysis method of creep effect on steel-concrete composite structure with equivalent temperature field method is deduced, including transformation of initial creep strain to nonlinear equivalent temperature field along composite section, and also the reduced elasticity modulus of the concrete deck is taken for solution by computer. Based on this method, the programs for analysis of creep effect on steel-concrete composite structure with elements of integrated section without need of building models as divided separate layer have been developed, which has been used to analyse the creep effect on a long-span pre-stressed steel-concrete composite bridge. The conclusion has been drawn that creep effect is remarkable on pre-stressed steel-concrete bridge even if the reduced equivalent modulus of elasticity is considered.

Keywords: creep; steel-concrete composite beam; equivalent temperature field; reduced modulus of elasticity ;numeric analysis.

1 Introduction

Steel-concrete Composite Structure is a type of structure widely used in bridge and civil engineering. As its section is composed of two different kinds of material of concrete and steel, and creep caused by concrete is more evident than steel that the creep of steel can be neglected, and so the creep effect analysis of this composed structure become more complicated. The statically determinate composite structure can also cause self-stress due to the strain re-distribution of creep, which complies the plain section assumption. As the statically indeterminate composite structure, secondary super-static stress should be caused by creep, besides the self-stress. Self-stress effect of creep from static for example simply supported composite beams can be solved by manual calculation or with equations given in textbook[1], but creep effect of super-static composite beams is far more complicated than that of static ones that it can not be analysed accurately only if by programs. There is great need for suitable and numeric analysis method and effective software. In some cases we may build models by two separate layers that represent respectively different material of steel and concrete, and connect them with additional rigid element. But this method increase the element numbers, and bring the result that is not continuous where the node points connect, and so is usually not ideal.

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Numerical Simulation of Overall Marine Transportation of Bay Bridges under Complex Hydrographic Environment

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Abstract

Although more and more research achievements have been obtained in offshore engineering in recent years, there are few studies on transportation of bridge under marine condition. In order to explore the response characteristics of bridge transportation under the action of marine environment, this paper conducts numerical simulation of the transportation of a butterfly arch bridge by a semi-submersible barge. In this paper, the software based on potential theory has been used to analyze the swing motion of the transportation of bridge. The motion response of the combined float has been calculated under the action of wind, waves and currents with the varying of frequencies and directions. The results show that the swing motion amplitude of the combined float in the condition determined by the local code is relatively small, and the action of waves are the main factor of the swing motion compared to wind and currents.

Keywords: marine transportation; AQWA; semi-submersible barge; butterfly arch bridge.

1 Introduction

In recent years, the construction of offshore projects such as cross-sea bridges and sub-sea tunnels has been increasing in order to alleviate the problem of insufficient urban land resources in developed areas. Therefore the application of technology related to the marine transportation and installation of bridge sections is becoming more and more significant. Marine transportation of bridges is a fluid-structure coupling problem. There are usually two research methods to solve the problem of barge transportation, CFD method and potential flow theory method. Although the CFD theory method present high calculation accuracy, it requires huge computational power and running time, while the potential flow theory analysis method is fast and meets the accuracy requirement of most shipping project and occupies an important position in the ship transportation engineering. Therefore, the most used commercial software in the marine field such as AQWA, MOSES, WAMIT, etc. are based on the 3D potential flow theory. For the above reasons, this paper uses AQWA as the main analysis tool for bridge marine transportation.

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Case Study On a Nonlinear Static and Dynamic Behavior of a 2D-Story Steel Frame with Different Configuration

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Abstract

This paper investigated the seismic performance of steel frames under earthquake motion. Two-story steel frames were designed based on a code-design method for a medium and high-risk seismic zone. The frame's nonlinear static and dynamic analyses have been performed using OpenSees software and sap2000. We consider diverse configurations, concentrated plasticity, and fiber-model were employed. The results obtained in the analytical study concluded that the user design method was reasonable and the mean maximum drift of the frames under the ground motion sets was in an acceptable range.

Keywords: nonlinear static analysis; dynamic analysis; earthquake motion; steel frame; concentrated plasticity model; fiber model.

1 Introduction

A.Elnashai et al. (1) Presented how stiffness is the most pertinent parameter in responding to serviceability requirements under the frequent small earthquake. Strength is utilized to control the level of inelasticity under the infrequent medium-sized earthquake; finally, collapse prevention under the large rare earthquake is most affected by ductility. A.Chopra(2) explain the theory and application to earthquake engineering. Two-story steel frames were designed for a seismically active area using the Chinese Seismic Design Code (3) to address this issue. OpenSees software (4) was employed for nonlinear static and dynamic analyses.

2 Elastic Analysis

The 2-story steel frame structure is to be designed. The seismic design of the frame is carried out. The structure is assumed to be located on medium-stiff soil ($500 \geq V_S > 250$) (class II), in Sichuan Province, a region with a Seismic Fortification Intensity of 8 (basic acceleration of ground motion of 0,20g). The seismic loads and seismic design criteria used for the structure were established according to "GB 50011-2010 Code for Seismic Design of Buildings".

2.1 Loads Assumption

Considering two uniformly distributed loads (Live load, superimposed dead load) and a span between planar frames of S = 4,00 *m*, the linearly distributed loads acting on beams were summarised in Table 1.

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Numerical Analysis of Bolted Connectors in Prefabricated Steel-Lightweight Aggregate Concrete Composite Beams

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Abstract

This paper presented a three-dimensional (3D) numerical model to explore the shear behavior of bolt connections embedded in steel-lightweight aggregate concrete composite beams (SLACCBs) by utilizing the ABAQUS software. Nonlinear geometric effects and material nonlinearities were considered in the finite element (FE) modelling. The accuracy and reliability of the FE modelling were validated against the push-off tests initially. Subsequently, the basic shear properties of the bolted connection embedded in SLACCBs were studied and compared with that of the bolted connection embedded in the normal concrete (NC) slab by applying the verified FE modelling. Meanwhile, the effects of the concrete strength, concrete density, bolt diameter, and bolt tensile strength on the shear behaviour of bolt connection embedded in SLACCBs were also investigated by extensive parametric studies.

Keywords: bolt shear connector; lightweight aggregate concrete (LAC); push-off test; finite element model; shear bearing capacity.

1 Introduction

Steel-concrete composite beams (SCCBs), which combine full advantages of two materials (tensile strength of steel and compressive strength of concrete), have long been employed in buildings and bridges [1-2]. Reliable shear connectors that resist the relative slip between the steel-concrete interface are the critical feature to guarantee the composite behaviour [3]. Traditional connectors (e.g., steel studs and Perfobond ribs) with outstanding mechanical performance and the ease of construction have been adopted and investigated extensively in SCCBs in recent decades [4-5]. However, dismounting and reusing the elements (i.e., steel beams, shear connectors and concrete slabs) is challenging when conventional SCCBs reach the end of their service life because the connections are not only welded to steel girders but embedded into the cast in situ concrete slabs. To achieve this challenging goal and to improve construction sustainability, high-strength bolts are applied in SCCBs to substitute traditional connections as the shear connection.

Dallam [6] first reported the shear behaviour of high-strength bolts embedded in the NC slab by push-off tests. Test results showed that the shear resistance of high strength bolts was twice that of steel studs with the same dimensions. Subsequently, Dedic and Klaiber [7] elucidated the possibility of utilizing the high-strength bolts in rehabilitation work with older bridges by push-out

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Experimental and Numerical Study of Welding Residual Stress Distribution in Shear Keys

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Abstract

Welding technologies are widely applied in all kinds of steel structures. No matter what kind of welding is used, the welding residual stress is always inevitable. So, in this research, a semi-destructive experiment and a numerical simulation are conducted to study the welding residual stress distributions of shear keys in the grouted connection section. The experiment uses the blind hole method on 3 flat-plate specimens of the sleeve section, to measure the welding residual stress distributions of them, which gives an approximate distribution of the real grouted connection section. Based on the experiment, a FEM numerical simulation is performed to estimate welding residual stress distribution. During the numerical simulation, EBD (Element Birth and Death) and Dflux subroutine are applied to maintain a better precision. Through the experiment and simulation, a comparison is done and a good correlation between welding residual stresses was found.

Keywords: steel structure; welding residual stress; blind hole method; finite element method; element birth & death.

1 Introduction

Welding is a widely used joining method in industry because of its advantages such as low price and ease of operation. However, extra stresses, namely welding residual stresses, are introduced due to the great localized heat input and rapid cooling of the steel structure during the welding process, which is inhomogeneous for the whole structure [1]. This is no exception in some offshore wind turbine structures, where different parts of the structure are connected by sleeves and grout in grouted connection sections. In order to increase the friction between sleeves, the sleeves are equipped with multiple shear keys. The fabrication of these shear keys is done by welding [2], and these welding actions inevitably bring additional welding residual stresses and initial defects to the whole sleeve, which have an impact on the fatigue life of the whole structure [2–4], hence many studies are done on the welding of offshore steel structures.

Jacob et al. [5] adopted the contour method of residual stress measurement to map residual stresses in the welded mock-up as well as in the CT specimens extracted from the weld region of the plate. Through the experiment, residual stresses above yield stress were found in the core region of weld specimens. These results indicate that welding residual stresses should be taken into consideration in OWT structures.

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Analysis and Optimization of Single Cable Plane Prestressed Concrete Extradosed Cable-stayed Bridge

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Abstract

Extradosed cable-stayed bridge has been used more and more in practical engineering because of its superior structural performance, good economic efficiency and good appearance. In this paper, taking a single cable plane prestressed concrete extradosed cable-stayed bridge as an engineering example, finite element analysis (FEA) is applied to complete the static analysis and stability analysis of the bridge during the construction stage, completed bridge stage and operation stage. In addition, the characteristics of stress distribution of the anchorage zone are analysed by using FEA software and the space finite element method. Finally, FEA software is used to output the cable force influence matrix, and the cable force adjustment and optimization are carried out based on the calculation principle of cable force optimization and combined with Matlab programming. The results can be used as reference for the design and construction of similar bridges.

Keywords: extradosed cable-stayed bridge; finite element analysis (FEA); global analysis; local analysis; adjustment and optimization of cable force.

1 Introduction

With the development of bridge technology, the type of bridge structure has gradually formed two obvious trends. One is the lightweight structure, which reduces the self-weight through the use of new materials and more rigorous calculation; One is the combination of bridge types, that is, the beams, arches and cables, etc. as the basic structure are combined with each other to form a more diversified composite bridge type [1]. Extradosed cable-stayed bridge is a relatively new cable-beam composite structural type, which is between continuous beam bridge and cable-stayed bridge [2]. As a transitional bridge type, it has been used more and more in engineering practice for its superior structural performance, good economic benefit and good aesthetic effect.

Extradosed cable-stayed bridge not only has the stress characteristics of the beam of continuous beam bridge, but also has the flexibility and spatial triangle stress of conventional cable-stayed bridge, but it is significantly different from them in cable arrangement, size and stress characteristic [3]. The vertical load of extradosed cable-stayed bridge is borne by the main girder and the cable. The form of its main girder is similar to that of continuous beam bridge, and its stiffness is less than that of continuous beam bridge with the same span. The number of stay cables is less than that of conventional stay cables, and the inclination angle is smaller. Its vertical component plays the role of elastic support, and its horizontal component plays the role of external prestress. The cable only plays a partial role in the overall resistance of the structure, and the proportion of bearing load is less than that of the main girder [4].

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Numerical Simulation Analysis of the Connection Structure Between the Pier and Pile Cap of Precast Concrete Bridge Piers

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Abstract

The precast concrete bridge pier in Ganzhou City, Jiangxi Province, China, was used as the research object to compare the longitudinal and transverse force differences of the bridge pier and further analyze the force characteristics of the bridge pier connection structure. The refined nonlinear finite element model with the load direction and axial pressure ratio as the variation parameters was established to analyze the horizontal force-displacement curve, anchor force, shear force of notched perfobond connector, strain distribution of steel jacket and notched perfobond connector-concrete relative slip. The results show that the concrete damage, anchor bolt action, strain distribution of steel jacket and notched perfobond connector-concrete relative slip are different in the longitudinal and transverse direction of the bridge pier. The bearing capacity of large axial pressure piers is larger than that of small axial pressure piers. The compression side damage of precast piers occurs at the concrete interface above the connection device. The shear force of outer notched perfobond connector is less than that of inner notched perfobond connector.

Keywords: precast concrete pier; pier-pile cap joint; load direction; notched perfobond connector; finite element analysis.

1 Introduction

Precast assembly bridge pier has the advantages of high components quality, short construction time and green environmental protection [1]. Various connection methods have been developed such as grouting sleeve connection and grouting bellows connection [2]. However, the connection strength of grouting sleeve and other connection methods is closely related to their quality of construction, which is prone to grout uncompacted, grout leakage, and grout quality is difficult to detect [3], thus affecting the normal performance of the precast pier. Therefore, the connection structure of precast pier needs to be studied.

Nzabonimpa [4] et. al and Kim [5] et. al adopted the metal plates to carry out column-column connection of precast concrete column and precast concrete pier-pile cap connection, and verified that the structure with metal plate connection has a good structure performance through pseudostatic test and nonlinear finite element analysis. Xie [6] et al. performed the assembly of piers with outsourced steel plates and steel flanges, and experimentally demonstrated that the outsourced steel plates enhanced the traditional plastic zone.

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Parametric Study and Design Method of Compressed Steel-Rubber Composite Anti-Collision Device

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Abstract

The compressed steel-rubber composite anti-collision device is a new type of self-floating device protect bridges from ship collision, which can significantly reduce the structural damage caused by ship collision. The use of compressed tires recycles the old tires and increases the elasticity of the device. Based on experimental analysis, the paper continued to develop detailed finite element model to investigate the behavior of the anti-collision device. Besides the comparison with the test results, parametrical study was developed including the thickness, position, number of the diaphragms to evaluate the sensitive parameters, so as to determine the design parameters for different collision conditions. Finally, a simplified design method including the key parameters was proposed to simplify the design process of anti-collision design.

Keywords: anti-collision device; parametrical study; ultimate load capacity; simplified formula

1 Introduction

The compressed steel-rubber composite anti-collision device is a kind of self-floating bridge anti-collision device with the advantages of high anti-collision efficiency, good durability and low consumption (environmental protection and low cost). Previous and current research mainly focus on the ability to protect bridge abutment structures. Chen et al.[1] investigated the effects of material strength, number of roll-slip components and yield strength of energy-consuming steel cylinders on the anti-collision performance of self-floating collision avoidance devices. The results showed that self-floating anti-collision devices could prolong the impact time and significantly reduce the peak impact force. Fan et al.[2] carried out numerical simulations of a new steel-concrete combination anti-collision device, and the numerical analysis results showed that the protection performance of the device was better than that of the traditional steel fenders. Luo et al.[3] investigated the protective capability of a steel-composite anti-collision device and showed that it could effectively mitigate the severity of ship-bridge collisions and significantly reduce the structural response of bridge columns. Zhou et al.[4] proposed a new type of assembled ultra-high performance concrete (UHPC) anti-collision device, and found that the collision prevention device had a very strong energy absorption capacity. Pan et al.[5] studied the collision process between a ship

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Finite Fault Source Model for Ground Motion near Fault Zone

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Abstract

Ground motion is categorized into near fault zone and across fault zone where impulsive component is included. The impulsive component usually causes larger damage than that by far-fault ground motion. To build a Benchmark model platform for cable-stayed bridges across-fault region for comparative analysis, the paper proposes a way combining the finite fault source model. In the paper, the finite fault source model was conducted based on the site Qiongshan earthquake. After the geological structural parameters were determined, forward modeling of near site earthquake was carried out, and the observation points were obtained using numerical simulation. Then, the analysis results were compared with the pulse characteristic parameters of similar grade of recording ground motion. Additionally, the ground motion near-fault region was analyzed to validate the finite fault source model.

Keywords: finite fault source model; impulsive component; structural parameters; forward modelling; ground motion.

1 Introduction

The earthquake poses a huge threat to bridge safety. During Jiji Earthquake in Taiwan, Beifeng Bridge with three spans across the fault collapsed, and Wuxi Bridge with two spans across the fault collapsed [1]. During Arifiye Earthquake in Kocaeli, Turkey, falling off girders occurred for bridges across the surface fault zone [2]. In the seismic design code for bridges in China, it is required that the site selection of bridges should avoid the main fault zones as far as possible with a long distance [3]. However, the layout of China transportation network will be located in the dense areas of fault

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Influence of Uniform Thermal Cycles in Reducing Rail Stresses Induced by Creep and Shrinkage Built over Time in Concrete Railway Bridges

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Abstract

In railway bridges supporting a continuously welded rail, the friction induced at the location of the fasteners generates an increment of axial stress in the rail, to be controlled to maintain its integrity. The adequacy to consider creep and shrinkage effects along with the thermal effects in rail structure interaction (RSI) studies is often debated over. A widely accepted analysis approach in the industry is to model the fastening system as reversible bi-linear elastic-plastic. The present article exposes the conclusions of a study which, instead, adopted a realistic hysteretic law for the fastening system to demonstrate, through adequate time-dependent analysis, that the cyclic nature of temperature over time tends to eliminate the gradual increase in axial stress in the rail due to creep and shrinkage, potentially rendering the consideration of concrete rheologic effects in RSI analysis unnecessary, or to be accounted for adequately in order to avoid unnecessary conservatism.

Keywords: RSI; CWR; creep; shrinkage; temperature; railway bridge; fasteners; UIC; hysteretic; longitudinal restraint.

1 Introduction

On railway bridges, the use of "Continuously Welded Rails" (referred to thereafter as "CWR") has become very common because of advantages such as, amongst others, user's comfort, ease of maintenance and installation cost. Since the tracks and the bridge structure are connected, the behaviour of one element affects the other and generates forces and displacements. The study of this interaction is often referred to as "Rail-Structure Interaction" (thereafter referred to as "RSI"). The global context of codes and norms is not very abundant and the UIC 774-3 code is often cited as reference to provide guidance on the axial stress that has to be controlled in the rail.

1.1 Principles of rail structure interaction

When the supporting structure contracts of expands, its contraction or expansion entrains the rails through the connection of the fasteners connecting the structure and the rails. The simply supported beam example shown in Figure 1 is used to illustrate the phenomenon. Under thermal effect, the structure contracts along the x-axis of the beam with a boundary condition in A where no displacement is possible: and Point (B) where the beam is free to displace. The simply supported beam contracting under the rails then tends to compress the rails in the region of Point (A) while it tends to put the rail in tension in the region of Point (B).

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Design of pre-stressed intersecting cable string steel bridge

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Abstract

The article presents the methodology for designing an innovative pre-stressed cable-stayed steel bridge structural system using intersecting cables and string. The behavior of this new structural system under the effect of permanent and temporary loads is also taken into account. The article also discusses the design of the components of this new type of structure and presents the calculation methodology of this structural system taking into account geometrical nonlinearity. Installation sequence variants of such a bridge are also considered as well as the influence of string and cable pre-stressing on bridge displacement and component stresses. Equations for calculating bridge string stresses and displacements are presented. The article shows how to design this new steel bridge system which is more effective than the typical cable-stayed bridge structure according to the mass criterion.

Keywords: steel bridge; cable-stayed bridge; pre-stressed string; intersecting stay cables; nonlinear analysis; analytical model; numerical modelling.

1 Introduction

Cable-stayed bridges are exceptional structures due to their form and architectural appeal [1,2]. Bridges of this type of structure not only cover record spans [3,4] but are successfully implemented for shorter spans, too [5,6]. Nevertheless, we have to mention their disadvantages: e.g. sensitivity to asymmetrical or local loads and the relatively big mass of stiffening girder and pylons [7,8]. Additional cables, branched stay cables, pylon connection with stringers, etc. could be used to work around mentioned issues [9,10,11]. Intersecting cable stays could be one of the way to stabilize bridges initial form. They can not only control displacements, but shorten required pylon height as well. Such cable-stayed pedestrian bridges were built in the United Kingdom - Royal Victoria Dock Bridge [12] and the Forthside Footbridge [13], and in France - Passerelle du Grand Large bridge [14].

Stress ribbon bridges are well known for their light weight [6,15]. However, such bridges are also marked by high deformability [16] and certain initial sag [5,6]. Different approaches have been developed to reduce the kinematic-type displacements of this type of bridge [17,18,19]. However, many of them are costly and complex.

To keep the straight deck shape suitable for the usage, additional structures are designed. A pre-stressed string functions as the main supporting element [20]. This supporting element has no kinematic displacements, i. e. they are not sensitive to the effects of asymmetrical loads. Using high strength materials could be one of the solutions confronting high stresses and relatively small cross-sections. [20,21]. The main disadvantage of these systems – they can only cover small spans.

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Implementation of Neural Networks for the Calibration of a Macroscopic Model of a Lead-Core Bearing Device

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Abstract

The increasing popularity of the lead-core bearing devices motivates the research efforts devoted to a more accurate behavior assessment. The contribution provides details of an accurate finite element model of the bearing device. The geometry is reproduced in great detail. Material models are defined for the rubber layers, steel elements, and lead core. The output of the finite element simulations provides an insight into the bearing response, for example, through the numerically obtained 'Restoring force- displacements' relationship. The definition of a less demanding model of the lead-core rubber bearing about an implementation into the finite element analysis of a base-isolated structure might be an attractive option. Some elements of the implementation of a neural network for the identification of the model parameters based on results obtained by finite element analysis are discussed.

Keywords: seismic isolation; lead-core rubber bearing device; finite element modelling; neural network.

1 Introduction

Lead-core Rubber Bearings (LRBs) are widely used hardware for seismic isolation of buildings and structures. Typically, elastomeric isolators consist of rubber layers separated by steel shims. The low horizontal stiffness of the bearing device, needed to lengthen the fundamental natural period of the base-isolated structure, is provided by the total thickness of the rubber layers. At the same time, the steel shims provide to LRBs with considerable vertical stiffness. Vertical stiffness assures the load-carrying capacity for vertical loads transferred from the superstructure. The lead, mounted in the center hole, yields relatively quickly under transverse Loads, which results in a well-pronounced hysteresis response of the LRB.

Due to their large energy dissipation capacity, they are often employed in the base isolation of important structures: nuclear power plants, hospitals, bridges, etc. A considerable research effort has been devoted to the study of the mechanical [1, 2] and the thermo-mechanical [3, 4, 5] behavior of the lead-core rubber bearings. Despite the recent advances in this field, some mechanisms involved in the complex response of

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Numerical Fatigue Simulation of Access Hole Detail in Orthotropic Steel Bridge Deck

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Abstract

In order to investigate the fatigue crack mechanism of growth and propagation at access hole detail in the orthotropic steel bridge deck, welding numerical model and multi-scale whole bridge numerical fatigue model were established. Based on linear elastic fracture mechanics and eXtend finite element model (XFEM), numerical fatigue simulation and mechanism analysis were carried out under the multi-filed coupling effect. Welding residual stress analysis results show that the high residual tensile stress exists at welding hole edge, of which the maximum value located at the middle of the edge. The numerical simulation results show that stress intensity factor (SIF) range at access hole detail exceeded the fatigue crack propagation threshold under the multi-filed coupling effect. And fatigue cracks at access hole detail are mode I cracks.

Keywords: orthotropic steel bridge deck; access hole detail; numerical simulation; XFEM; welding residual stress; fatigue crack.

1 Introduction

The orthotropic steel bridge deck is wildly applied in modern steel bridges, especially in the long-span bridges and urban bridges, because of its convenient construction, excellent mechanical properties, and light weight [1]. However, the fatigue problem of the orthotropic steel bridge deck is serious, and the fatigue cracks will generate after using merely several years, which constraint the safety operation and health service of steel bridges. Since the 1960s, many fatigue cracks have been observed at daily detection in the orthotropic steel bridge deck [2]. Therefore, the fatigue problem has been the worldwide technical challenge [3], and it is necessary to investigate the fatigue problem of the orthotropic steel bridge deck.

With the development of fracture mechanics theory and finite element method, the fatigue crack numerical simulation is made excellently progress. Xiao et al. [4] carried out fatigue stress analysis under vehicle load based on linear elastic fracture mechanic theory, and estimated the life of joint details between deck and longitudinal rib. Wang et al. [5] found that the crack was grown in the weld joint toe between rib and diagram which was under pressure stress in the orthotropic steel bridge deck full scale fatigue test, because there existed high welding residual tensile stress. Zhao [6] and Berg [7] et al. calculated and tested the residual stress values of U-rib stiffener, and verified that there existed high welding residual tensile stress near weld joint at rib-deck detail of orthotropic steel bridge deck. Wang et al. [8] carried out welding numerical simulation of rib to deck weld joint and rib to diagram weld joint, then analysed the fatigue crack propagation mechanism and carried out numerical simulation of the fatigue crack propagation behaviour at typical fatigue details based on linear elastic fracture mechanic and XFEM. Wang et al. [9] made

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The First Step Towards BIM Models in Major Bridge Design

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Abstract

The design of the world record 1915 Çanakkale Bridge is an example of the first steps towards using a BIM for a major bridge design. The model developed by COWI has been used to create 2D drawings and bar bending schedules, to manage interfaces and to check constructability, as well as health and safety related checks for working in congested space. Furthermore, it has proved to be an effective tool in communication with the project's stakeholders.

This paper describes where BIM has been applied in the design of the 1915 Çanakkale Bridge. Here special focus is on the construction of the plinth of the tower foundations where the contractor prefabricated the reinforcement cage for each plinth onshore, including all cast-in items and the steel form work and then lifted the whole assembly (18m in diameter) into place off-shore using a floating crane.

Keywords: Çanakkale Bridge; BrIM; BIM.

1 Introduction

In the design of buildings, coordination between many different parties and disciplines is required (e.g. owner, architects, structural design, facade installation, plumbing, heating, sanitation etc.). Building information modelling (BIM) has been commonly used in the building industry during the past decade. BIM collects information about the building relevant before, during and after construction. BIM has proven to:

- Improve constructability
- Lower the construction risks
- Help in communication between the parties involved

In bridge engineering the counterpart to BIM is called "BrIM" (Bridge Information Modelling). However most often people use the term "BIM" also for bridges, tunnels etc. and hence this paper will use the term "BIM".

For major bridges it is not common to apply BIM in design yet. The main reason is that it has not been requested by contractors and bridge owners. One reason could be that the advantages with BIM do not counterbalance the cost in time and money to establish the model for a major bridge design. Another reason could be that for a bridge fewer disciplines and interfaces need to be coordinated compared to a complex building and for that reason does not need this level of detailing. Finally, it is also a question of what requirements there should be for such a model. For instance, for reinforced concrete structures, the ideal world would be a reinforcement model without any clashes. As it is explained later in this paper, this is not always practical. What is needed for a BIM model is an agreement between the involved parties about the level of detail.

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Numerical Analysis of Top-Down Construction Method of High-Rise Buildings and its Effects on Substructures with their Corresponding Heights

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Abstract

The Top-Down construction method has been used widely in urban areas, particularly in high-rise buildings with basements. This paper presents the Nanjing Jinmao Plaza II Tower in Nanjing-China as a case study, which consists of 68 floors with a height of 283.6 m and five basements with a depth of 27.5 m. A numerical finite element simulation in PLAXIS 3D was performed to analyze the construction of soil excavation and basement structure and their corresponding heights. The study concluded that the effect of adding floors to the superstructure had little effect on the underground excavation process. Likewise, the condition of column piles is in different stages of construction. In view of that, this paper has analyzed and summarized construction guidelines for the top-down construction method to ensure safety, optimize design, and provide recommendations for this promising construction technique.

Keywords: top-down construction method; high-rise building; deep foundation excavation; deformation; displacement.

1 Introduction

Currently, the process of urbanization in the world has been accelerated, urban construction has been well developed, and the super high-rise buildings in the commercial center area of cities have become more and more crowded. The height of buildings continues to rise, and the use of underground space becomes more complicated [1]. That led to an increase in the depth of the excavations and the complexity of the construction, so the related technology was constantly applied and innovated, Including Top-down technology [2-5]. The top-down method has been widely used in the deep foundation pit supporting structure, which has produced significant results [6-8]. Because of its advantages, that can be used in the construction of narrow construction sites, complex surrounding environments, short project periods, the low safety level of foundation, high settlement, and deformation requirements of surrounding structures [9]. In addition, it has good economic savings. Therefore, the Top-Down method has been widely used and developed in many parts of the world since it came into being [5, 10]. The Estimation of displacement caused by excavation is always the main problem in deep excavation pit. Several techniques were advanced in knowledge of the displacement mechanism of deep excavation [11,12]. Among these methods, numerical methods are the most effective ones which could take each geotechnical and structural detail in deep excavations, so it is more and more popular [13]. Depending on the case study of Nanjing Jinmao

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Structural Detailing of Bridges, Making Use of the Brim Methodology (Bridge Information Modeling), through the Creation of Parametric Models and As-Build Plans

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Abstract

Within a project related to the area of bridges, we work with different tools and between this information is usually managed through the use of CAD drawings made basically in 2D.

Today, a new concept of BIM applied to bridges called Bridge Information Modeling (BrIM), which well implies being a methodology with different uses and being the solution in helping the different parties to work more collaboratively, effectively and simultaneously.

This paper presents the experience of applying one of these uses in the phase of analysis and structural diagnosis of ten bridges in Chile, which demonstrates that this technology becomes a valuable tool for information management through the virtual model worked between the different parties involved in the maintenance and operation of a project.

Keywords: bridge; BIM; BrIM; modeling of bridges; modeling projects.

1 Introduction

Around the world, many ancient and historic bridges are still in operation. Deterioration and failures have increased in already aged bridges due to various factors throughout their service life. Therefore, the importance of bridge management systems has increased to ensure operational safety through good maintenance [1]. At the international level, research has been developed for the implementation of new technologies that allow the full management of specific projects related to the area of bridges. Making these recent technological improvements a great contribution to this problem [4].

These investigations result in methodologies focused directly on the integration of all parties involved in a bridge project, ranging from design and construction to the maintenance and operation of the structure. This process of generation and management of data during the life cycle of the bridge is known as BrIM (Bridge Information Modeling), this concept that emerges from the term BIM (Building Information Modeling), applied to buildings.

The use of BrIM is based on the generation of an intelligent representation of the components of the structure that host detailed and necessary information of all stages of the life cycle of the bridge.

As a case study, in Chile more specifically in the city of Viña del Mar, ten bridges were affected by the earthquake of February 27, 2010, however, they also had previous damage due to lack of maintenance [2]. This is how the project "Analysis and Structural Diagnosis of Viña del Mar Bridges"

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Pseudo-Static Tests of Precast Bridge Pier with Half Grouted Sleeves

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Abstract

The seismic performance of precast bridge piers with half grouted sleeves is studied by quasi-static test and compared with precast bridge pier with full grouted sleeves. The main failure modes of the precast bridge pier with half grouted sleeves are concrete crushing failure at the joint of column-to-footing and bond-slip failure of the longitudinal reinforcements in the half sleeves, there is no obvious crushing and spalling of the pier concrete. The ultimate horizontal strength of the precast bridge pier with half sleeves is small and shows a rapid decline trend after reaching the ultimate strength, hysteresis loops are flat and narrow while the residual displacement is small. On the whole, the seismic performance of the precast piers connected by half grouted sleeves is weak due to the bond-slip of the longitudinal bars in the half grouted sleeves. further researches are needed for precast bridge piers with half grouted sleeves without bond-slip behaviour.

Keywords: bridge pier; half grouted sleeves; pseudo-stasic test; seismic performance.

1 Introduction

With the development of economy and the progress of society, the construction method of substructure of bridge has gradually changed from high pollution, high noise and low efficiency to green, environmental protection, high quality and high efficiency of precast construction method. A reasonable and reliable connection method is an important part of precast bridge piers. The main connection methods existing include grouted sleeve connection, prestressed reinforcement connection, socket connection etc[1-4]. Among them grouted sleeve connection is widely used in many countries and regions due to its economic and reliability.

Grouted sleeve can be divided into full grouted sleeve and half grouted sleeve. As for the full grouted sleeve, both ends are connected by grouting. At present, many scholars have carried out researches on the seismic performance of precast pier connected by the full grouted sleeves.

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Advancements in Timber Construction: A Review of Prefabricated Mass Timber Floor Assemblies

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Abstract

This paper provides a state-of-the-art review of prefabricated mass timber floors, with a focus on composite floor assemblies for common residential and long-span office applications. The discussion relates to different design aspects, including connection systems and methods of assembly. Also, design methods and code provisions for the floor assemblies comprising ultimate limit state design, vibration control and long-term behaviour are expounded. A life-cycle overview of floor solutions is also presented to highlight their sustainability potential. The paper demonstrates how the building industry can leverage the structural performance, light weight and prefabrication capabilities of these innovative floor solutions for a better-built environment.

Keywords: sustainability; mass timber; composite floors; lightweight floors; prefabricated construction.

1 Composite floors: Overview

Composite floors are structural assemblies where composite action is developed through connectors that transmit shear and inhibit slip between structural floor components. These components are often slab and beam elements, or two joined slab elements. The most common forms of connectors used in composite floors are mechanical fasteners, adhesives, and interlocks. Composite floors are often characterized by some degree of slippage between the components leading to a partial composite behaviour.

Having been extensively studied for many decades, steel-concrete composite flooring systems are well-established in the building industry, having design provisions that are well-detailed in codes and standards internationally [1-3]. Whereas prefabricated timber-based composite floor alternatives examined in this study are still emerging. The focus herein is on timber-concrete composites (TCCs), timber-steel composites (TSCs) and timber-timber composites (TTCs)

Other composite solutions built with timber and glass, or aluminium are beyond the scope of this paper. Experimental and numerical investigation of the structural performance of composite beams made of glass webs and timber flanges have been published in [4-6], while research into the behaviour of aluminium-timber composites has been reported in [7-9].

2 Timber-based composite floors

Figure 1 shows common section types and material combinations for prefabricated timber-based composite floors that have been studied and with published works. The T-shape arrangement, which is sometimes flipped to form an upstand beam, is

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Shrinkage and Fatigue Performance of Novel Post-Combined Steel-UHPC Composite Decks

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Abstract

Considerable UHPC shrinkage has an enormous impact on steel-UHPC composite deck. To this end, a novel post-combined orthotropic steel-naturally cured UHPC composite deck was proposed in this paper. Two full-scale segmental steel-UHPC composite decks, one normal while the other post-combined, were fabricated for shrinkage monitoring and fatigue loading tests. The monitoring results showed that shrinkage-induced secondary stress on the steel deck of the post-combined specimen was lower than that of the normal one. And the fatigue loading test results showed that there was no significantly worse damage on the rib-deck weld detail in the post-combined specimen. In other words, the post-combined method mitigated UHPC shrinkage restraint without obvious deterioration to fatigue resistance. It contributed to establishing an economical alternative that could effectively address the adverse shrinkage effect on a steel-UHPC composite deck.

Keywords: steel-UHPC composite deck, post-combined method, shrinkage effect, group studs, fatigue damage

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Design and Construction of the West Kowloon Cultural District Artist Square Arch Footbridge

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Abstract

The West Kowloon Cultural District Artist Square Bridge (ASB) is a part of Hong Kong's new art and cultural district development. It forms a primary pedestrian link between the adjacent MTR station and the new development. ASB is a design-and-build project consisting of a 78m clear spanning, 8m wide footbridge, an access lift tower and a 30m long staircase and escalators. The footbridge is a covered, dual steel arch and Vierendeel truss footbridge, that crosses an existing flyover, connecting the station shopping mall to the new development. During construction of ASB, very limited space was available on the new development site to accommodate the construction of ASB. These posed engineering challenges to the design and construction team. This paper presents the design of the ASB structures with particular focus on the main footbridge, and the challenges encountered during the design and construction of ASB and how incremental launching solution was developed to tackle these challenges.

Keywords: arch footbridge; incremental launching; erection analysis; modular construction; steel design.

1 Introduction

The West Kowloon Cultural District (WKCD) is one of the largest cultural development projects in Hong Kong. Its vision is to create a vibrant new cultural quarter for Hong Kong on the approximately forty hectares of reclaimed land located alongside Victoria Harbour in Hong Kong. The district will feature the new museum of visual culture "M+", several theatres including the Lyric Theatres Complex, Artist Square, concert halls and other performance venues under the management of West Kowloon Cultural District Authority (WKCDA).

The Artist Square Bridge project is a design and build project consisting of a footbridge crossing the existing Austin Road West flyover and roads, an access lift tower and a staircase and escalators. The project was funded by the Civil Engineering Development Department of Hong Kong (CEDD) and managed by WKCDA. The completed footbridge is maintained by Highways Department of Hong Kong (HyD). The objective of building ASB is to provide barrier free connection from the MTR Kowloon Station through Elements Mall to WKCD.

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Innovative Design and Materials for Seismic Resilient ABC

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Abstract

Earthquakes can happen in Washington State at any time, and past history indicates there may be substantial shifting of land during a seismic event. The State Department of Transportations manages approximately 18,500 highway lane miles and more than 3,600 bridges on the state's highway system. One of the agencies objectives is to ensure that state highways will be able to provide emergency responders access to damaged portions of the community quickly to provide Recovery life-saving services. State Highways will also need to provide the capability for the state economy and the movement of freight and goods to be re- stored as quickly as possible.

In an earthquake, damage to infrastructure bridges is more closely related to ground motion rather than magnitude. In addition, the ground type can significantly influence ground acceleration. Base on the geographic area and historical data geologists are able to create seismic hazard maps which show likely earth-quake ground motion zones. This paper discusses the seismic design requirements for bridges and challenges to achieve these requirements for new and existing bridges.

In recent years the ultra-high performance concrete (UHPC) has been tested for bridge columns to improve to improve the performance of the connection within the plastic hinging regions. UHPC with its superior properties of higher compressive strength and modulus, and very low permeability, can provide improvements over conventionally build bridge columns.

Keywords: Bridge, Innovation, Design, Construction, Materials, ABC, UHPC, CFST

1. Bridge Seismic Resiliency

Seismic design of bridges begins with a global analysis of the response of the structure to earthquake loadings and a detailed evaluation of connections between the superstructure and the supporting substructure. Ductile behavior is desirable under earthquake loadings for both the longitudinal and transverse directions of the bridge. Further, the substructure must be made to either protect the superstructure from force effects due to ground motions through fusing or plastic hinging, or to transmit the inertial forces that act on the bridge to the ground through a continuous load path. Plastic hinging is often considered as a mechanism to form and facilitates transverse and longitudinal movement of bridge bents and frames. Every bridge shall be designed with an Earthquake Resisting System that ensures a load path for gravity loads and provides sufficient strength and ductility to achieve the specified performance criteria.

The plastic hinge ductility or other means of energy dissipation/bridge damping shall be adequate to satisfy the deformation demands imposed by the "design seismic hazards" while minimizing the probability of bridge collapse.

Earthquake Resisting Systems shall consist of the following:

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In-Situ Test and Simulation of the Web-Self-Supporting Construction for the Composite Bridge with Corrugated Steel Webs

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Abstract

In order to improve the safety and economics of the construction for long-span composite bridges with corrugated steel webs(CSWs), the web-self-supporting construction method with the characteristic of using the CSWs to carry the construction load is one of the effective ways. In this paper, a composite bridge with CSWs with a span of 55+100+55 m is taken as the research object. The stress distribution of main components and the stability of the CSWs in each segment during the construction process are analyzed by finite element simulation. The applicability of the construction method is verified by comparing the simulated with the test results of the practical bridge, and corresponding optimization measures are proposed. The results show that the stresses and stability within the scope of specification requirements, and the web-self-supporting cantilever construction method is safe. The transition sections between the concrete slabs and the cantilever CSWs are critical positions, which should be appropriately strengthened during construction. The arrangement of transverse braces can effectively prevent the lateral-torsional buckling of the CSWs.

Keywords: corrugated steel web; web-self-supporting construction; finite element simulation; in-situ test; optimization measure

1 Introduction

Composite bridges with corrugated steel webs (CSWs) have been widely used in China for the advantages of light weight, avoiding web cracking and superior seismic performance[1-3]. The construction methods are gradually enriched with the increasing number of these bridges. A new type of cantilever casting method is reported in [4], which is called the web-self-supporting construction by the authors. This method uses the CSWs to carry the construction load and improves the construction efficiency[5-7]. The CSWs are directly used as the main load-bearing components

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Parameterized Analysis of Guide Beam in the Incremental Launching Construction of Five-span Steel Box Girder Bridge

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Abstract

The parameters of the guide beam have a great influence on the structural behavior of the incremental launching construction bridge. Based on an incremental launching construction engineering of a five-span steel box girder bridge, this paper established the finite element model. The influence of the length, stiffness, and weight of the guide beam on the behavior of the main beam was analyzed, and the original design scheme was optimized and compared. Finally, some suggestions were put forward for the design and parametric analysis of the incremental launching guide beam.

Keywords: the incremental launching construction; guide beam; analysis of the parameters.

1 Introduction

The incremental launching construction is a common method in modern bridge construction. Due to its early origin, the modern incremental launching construction technology is advanced, the construction accuracy and the launching ability have been significantly improved, and the applicability has been expanded. The incremental launching construction can be used for various bridge types such as continuous girder bridges, cable-stayed bridges, suspension bridges, rigid frame bridges, and arch bridges. It is not only suitable for constant-height beams but also variable-height beams; Suitable for curved and inclined bridges. The incremental launching construction method has many advantages, such as simple construction equipment, without large lifting equipment, fewer temporary supports, a small construction site, high construction efficiency, and does not affect the traffic under the bridge. Therefore, the incremental launching method is ideal for valley bridges or overpass bridges.

In the incremental launching construction stage, the boundary conditions of the beam will change many times, and the structural behavior of the beam is also quite different from the post-construction stage. The analysis of the incremental launching construction process is very important. As assistant equipment, the guide beam plays a key role in the structural behavior during the construction stage. Optimized guide beam parameters (length, stiffness, weight, etc.) can make the performance of the main beam in the construction stage close to the post-construction stage, but unsuitable guide beam parameters will lead to the increase of negative bending moment and support reaction force. With the development of new construction methods such as intelligent construction, modern construction technology has gradually become intelligent and digital. The parametric analysis of guide beams is the general trend of modern bridge construction technology.

About the calculation and optimization of the guide beam parameters in the incremental launching

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Innovative Construction Technique of Two Bridges in Hong Kong

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Abstract

The multi-storey Yuen Long Town development in Hong Kong is separated by a live Light Rail Track. To connect the two sides of the development, a footbridge and vehicular bridge has been constructed using a novel construction technique. The footbridge is a 45m long fully enclosed steel warren truss bridge located at a lower level and the vehicular bridge is a 50m long steel concrete composite bridge located at the top of the podium.

The erection of each bridge took 3 days. Both bridges were in turn assembled on top of the adjoining podium of the development. They were then connected to a turntable constructed at the edge of the podium and temporarily made into a cantilever cable stay bridge. In an overnight rail possession, the bridges were rotated 120 degrees over the railway. Temporary cables were then removed, and each bridge were lowered by strand jacks to the final level over the next two rail possessions.

Keywords: innovative construction bridge construction; live railway.

1 Introduction

1.1 Location

Yuen Long Town development is a residential development comprising of 6 residential towers, two club house podium and a shopping mall on top of the existing West Rail Yuen Long Station (Northern Site) and an adjacent plot of land (Southern Site).

A live Light Rail Track (LRT) separates the two portions of the site. To provide connection between them, a footbridge (FB1) and a vehicular bridge (VB) have been constructed at different levels (Figure 1).

FB1 is a fully enclosed steel warren truss bridge located at a lower level and VB is a steel concrete composite bridge located at the top of the podium.

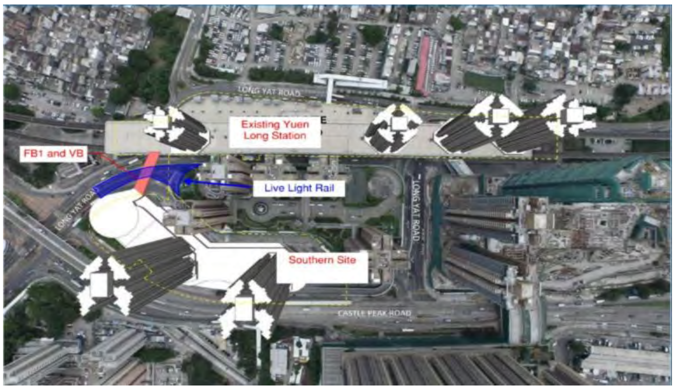

Figure 1 Map of YLTL510

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Automatic Production Process and Quality Control of Large Bridge Component Factory

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Abstract

In order to meet the needs of rapid bridge construction and structural reliability, this paper studies the automatic production technology of bridge components from three aspects: production process, quality assurance and information management based on small and medium-span bridge components. In the production process, in addition to the necessary automatic pouring of components, high-temperature steam curing and secondary tensioning are used to achieve intelligent and rapid production of components. Quality Assurance ensures a reliable build by analyzing concrete maintenance needs and subsequent quality issues that may occur. Information management improves the production quality management control of assembly parts by establishing an automated production information framework for bridge components.

Keywords: bridge component factory; automatic production technology; process flow; key technical index; quality management and control.

1 Introduction

The factory production of components avoids the complex construction environment on the construction site, which significantly improves the precision and quality of components. Quality management digitizes construction projects through construction project information management.

The arrangement of the production line and the arrangement of the production plan are the primary issues in the automated prefabrication of large-scale bridge components. At present, at home and abroad, the research on the layout of the construction site has been relatively systematic. In the early stage of the research, the expert system and artificial intelligence methods were used, and the corresponding computer software was developed to assist with the layout of the construction site, introduced the prefabricated beam yard facilities for specific bridge projects in detail, and proposed the method and scheme of the prefabricated beam yard layout. Cheng Min-Yuan[1] et al. studied the reasonable stacking method of building materials based on the GIS platform and the reduction of the secondary transportation cost in the building material field.

In terms of production process, the informatization and intelligence of pre-stress tension can overcome the shortcomings of traditional

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Key Technology for Planning and Construction of Automated Production Lines in Large Bridge Factories

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Abstract

Prefabricated bridges are one of the key means to realize industrialized bridge construction. Traditionally, bridge components are produced in temporary prefabricated girder yards serving a single specific project, which produce prefabricated components with limited use and low utilization rate. Therefore, the construction of permanent prefabricated production bases has gradually become the trend of the highway bridge industry. This paper discusses the planning method and construction technology of permanent precast production plants for different concrete members of highway bridges. The construction method of bridge precast plants in terms of production line selection, equipment selection and application is introduced. Eventually, the key technologies for the automated production lines and construction of large bridge precast factories are systematically established to provide reference for the construction of highway bridge precast factories.

Keywords: bridge precast factories; automated production lines; equipment selection; factory construction.

1 Introduction

Industrial construction means replacing the decentralized, low-level, and inefficient methods of traditional construction through modern manufacturing, transportation, installation and information management techniques. The industrial construction of concrete bridges can accelerate site construction. It greatly reduces the environmental impact and traffic disruption at the bridge site. Also, industrial construction easily ensures project quality and reduce the life-cycle costs of bridges. Its technical and economic advantages are increasingly recognized by the bridge industry in various countries[1-2]. Compared with traditional bridge cast-in-place construction, it has the following obvious advantages: (1)It is suitable for many types of bridges, which is less limited by span; (2)The proper application of prefabricated assembly technology can reduce costs compared to traditional construction methods; (3)It avoid impact on the environment and traffic; (4)The quality is guaranteed. The loading age and curing time are long, which can reduce the prestress loss of the girders; (5)Simple construction and short construction period. On the other hand, many studies[3-6] have proved that prefabricated bridge structures have certain seismic performance.

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Key technologies for design and construction of deep-buried capping cofferdam in the confined water layer area of the Yellow River Basin

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Abstract

The Anluo Yellow River Expressway Bridge is a (110+135+520+135+110) m double-tower double-cable plane composite beam cable-stayed bridge, The main pier cap adopts the separated octagonal cap, The outer outline size of a single bearing platform is 35.6m×32.1m, the thickness is 6.0m, and it is buried 12.2m underground. The cofferdam adopts PLC combined pile[1] structure, the outer contour size is 38.6m×35.1m, and three support systems are set up. About a series of problems for platform, such as: a long period of platform construction, high risk of sudden surge in foundation pits, high safety risk of cofferdom process conversion, high risk of temperature control in the construction of mass concret. Moreover, this deeply buried platform located in the Yellow River Basion pressurized water layer., through the calculation and design of Visual modflow software, a single cofferdam is set with 12 dewatering wells and 1 observation well for continuous dewatering to improve the anti-surge stability of the foundation pit; use MIDAS software to simulate the working conditions of each process of cofferdam construction to reduce the safety risk of process conversion, and it is calculated that the strength, stiffness and embedded stability of each component of the cofferdam can meet the design requirements.

Keywords: Composite beam cable-stayed bridge, pier cap, PLC combined pile, sudden surge in foundation pits.

1 Introduction

The main bridge of Anluo Yellow River Expressway Bridge is (110+135+520+135+110) m double-tower double-cable plane composite beam cable-stayed bridge follows: Figure 1, the semi-floating structure system is adopted, the main beam is a full bilateral steel box girder section, the cable tower adopts a steel shell concrete bottle tower, and 23 pairs of steel strand stay cables are arranged on each side.

The foundation of the main pier of the bridge adopts a separate cap, and 36 D2.7m~D2.2m bored cast-in-place piles are arranged under a single cap, arranged in a plum blossom shape, and the pile length is 95m. The design elevation of the top surface of the pile cap is +74.8m, and the size of the cap is 35.6m×32.1m×6m follows: Figure 2, the tower base with a height of 2.0m is set on the top surface of the bearing platform. The size of the upper plane of the tower base is 14m×14m,

and the size of the lower plane is 18m×18m. The main pier of the North Tower adopts the combined cofferdam of steel pipe piles and steel sheet piles for foundation pit support for the bearing platform range[3], the design adopts the 1985 National Elevation System Datum.

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Key technology for the construction of distributed pressure slurry extra-long pile foundation in Yellow River Wetland Reserve

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Abstract

In view of a series of pile foundation construction problems such as the high environmental protection requirements of the Yellow River Wetland Nature Reserve, the first application of distributed post-grouting technology in China, and the difficulty in implementing the traditional method of removing steel casings, this project creatively developed a self-circulating mud system; using distributed Post-grouting technology, the grouting tube and the acoustic measuring tube are combined into one, the pile side and pile end are grouted simultaneously, and the intelligent construction technology is used to monitor and control the grouting process in real time; by using the air compressor air cap technology Remove the steel guard. Finally, the construction of 72 pile foundations of the main bridge was realized, which provided a reference for the construction of pile foundations of the same type, especially the Yellow River Wetland Nature Reserve.

Keywords: pile foundation; pump suction reverse circulation; distributed grouting; gas cap

1 Introduction

The main bridge of the Yellow River Bridge with a semi-floating structural system is a double-tower double-cable plane composite beam cable-stayed bridge. The bridge span is arranged as (110+135+520+135+100) m follows: Figure 1. The main girder is the entire double-sided steel box girder section. The cable tower adopts steel shell concrete bottle tower, 23 pairs of steel strand stay cables are arranged on both sides, and separate bearing platform, group pile foundation. Auxiliary piers and transition piers all use single pile foundations. 36 D2.7m~D2.2m bored cast-in-place piles are arranged under a single bearing platform of the cable tower, arranged in a plum blossom shape, with a pile length of 95m, using temporary steel pipe construction, and the pile foundation is made of C35 underwater concrete follows: Figure 2.

The Sota foundation is located in the Yellow River Wetland Nature Reserve, with high environmental protection requirements, and the geology is dominated by silt and fine sand. The design maximum navigable water level is +88.14m, the minimum navigable water level is +79.78m (1985 National Elevation Datum), and the basic wind speed is 26.9m/s.

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Research on Key Technology of Large Tonnage Steel Beam Fast Sliding Positioning

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Abstract

A certain bridge adopts the green design of "one span across the river", and the installation of 21 pieces of steel box girder on the south span is limited by geographical conditions, tower limb width and construction period. Innovatively developed a dedicated skid scooter, the steel box girder successfully crosses the orbit change position with the help of the windlass，move laterally to the tower area，replace the longitudinal skid scooter，move to the design bridge. In the steel beam positioning link, firstly, set bearing pre-offsetting on pier top support to circumvent the influence of steel box girder welding, shrinkage creep deformation and closure temperature difference on the displacement of beam length. After the bridge is completed, the feasibility and reliability of the research method are verified by elevation measurement, static load test and implementation process.

Keywords: one span across the river; dedicated skid scooter; orbit change,pre-offsetting; Static load test.

1 Preface

With the gradual deepening of the concept of green roads, in order to minimize the impact of construction on the water environment and fishermen's lives, more cross-sea passages and bridges across rivers and valleys have adopted the design concept of "one span across the river" [1]. The green design allows the side span or secondary side span of bridge to be located on land or in the shoal area. For the installation of steel girders in this area, the first method is to lift the segment beam to the design bridge position at one time, subject to construction conditions.

However, in many cases, it is impossible to do this due to geographical environment, construction equipment and other factors. The commonly used method in China is to hoist the steel beam to a

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Seismic Behavior Analysis of a Novel Elastic-Plastic Structure Damping Bearing

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Abstract

A novel elastic-plastic sphere bearing with given fusing capacity is proposed in this paper, which can simultaneously control the pier damage and the relative displacement between girder and pier. To investigate the performance of the novel bearing developed in this paper, the compression-shear tests are carried out. It shows that the robustness of shear capacity of the fusing system is validated by the experimental test results，the expected goals of displacement and energy-dissipation of steel-ring damper elements are also achieved. To further illustrate the efficacy of proposed bearing in simultaneously controlling pier damage and displacement of girder, the demonstration case using a continuous girder bridge model is presented. It shows that the seismic behavior of bridges can be controlled by using the novel elastic-plastic sphere bearing developed in the paper.

Keywords: seismic and isolation device; elastic-plastic sphere bearing; shear pin; steel-ring damper; compression-shear test.

1 Introduction

In recent years, with the continuous development of the seismic design concept, the bridge structure design method has gradually changed from the ductile seismic design of piers to the seismic isolation design. The basic principle of seismic isolation technology is to extend the natural vibration period of the structure through the isolation device, thereby reducing the internal force response of the structure caused by the earthquake; to limit the excessive displacement due to the extension of the period through the energy dissipation device [1]. Therefore, the key of seismic isolation technology is whether a new type of seismic isolation device that can effectively control the dynamic response of the structure can be developed [2].

The post-earthquake investigation of the Wenchuan earthquake found that most of the bridge substructures using plate rubber bearings did not suffer serious damage. The plate rubber bearing has excellent shear deformation ability and stable sliding behavior, which can isolate the inertial force of the superstructure, but it will cause a large displacement of superstructure [3-5]. In order to control the relative displacement between superstructure and pier within a certain limit, elastic-plastic X-shaped block and plate rubber bearing are used together [6]. The X-shaped block has good energy dissipation characteristics and can control the relative displacement between superstructure and pier effectively. Ye [7] found that if triangular steel damper and plate rubber bearing are used together, the aseismic effect is good. This kind of seismic isolation design concept is gradually recognized and studied. Gao [8]

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Impacts of Supplemental Viscous Damping on Seismic Responses of Building Structures for Construction Extended Renovation Projects under Multilevel Decomposition Design Model Frame

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Abstract

The installation of supplemental viscous damping devices can effectively reduce the seismic responses of the engineering structure, so as to reduce the construction quantity of the renovation project. This paper addresses the impacts of supplemental viscous damping devices on the seismic responses of the construction extended renovation projects under the multilevel decomposition design model frame. Firstly, the multilevel decomposition design model of the seismic design of engineering structures is introduced. Secondly, the typical driving factors of the construction extended renovation projects are discussed. The impacts of supplemental damping on the seismic response of the structure are then investigated from the perspective of response spectrum. This paper takes a 250m ultra-tall structure as engineering case to analyse the multilevel decomposition design model, the driving factors of the construction extended renovation projects and the impacts of supplemental damping on the seismic responses of the structure. The results show that the supplemental viscous damping can effectively reduce the construction quantity of renovation projects.

Keywords: multi-level decomposition design; viscous damping; construction extended renovation project; seismic vibration mitigation design.

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Flexible Protection Technology of Bridge Pier against Ship Collision

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Abstract

Bridges across navigation channels are under the threat of accidental ship collisions. Many research works have been conducted to investigate the crashworthy device against ship-bridge pier collisions. However, the existing bridge pier protection facilities, mostly based on absorbing ship kinetic energy, are large structures with high strength, resulting in large collision forces that may cause ship damage. In this paper, flexible anti-collision technology is developed, which protects the bridge pier based on the ship's course guidance principle, hence taking away the huge kinetic energy of the ship in the process of collision. The pier flexible crashworthy device has a compact structure and can greatly reduce the impact force of ships, protecting both the bridge and the ship. The reliability and effectiveness of the technology have been verified through off-shore impact tests.

Keywords: ship-bridge collisions; flexible crashworthy device; ship guidance.

1. Introduction

With the development of land transportation, many bridges were built. However, bridges hinder the ship's navigation on the waterway. With the increase in the number, the tonnage and the speed of the ships, the accidents of ship collisions with bridges have become more frequent and severe. Those accidents may cause disastrous social and economic consequences such as bridge collapse, ship-sinking, casualties, environmental pollution, and interruption of the land and water transportation. Therefore, more attention should be paid to developing the techniques that avoid the increasingly severe accidents due to ship-bridge collisions [1-3]. Many people investigated vessel-bridge collision responses through impact tests [4, 5], analytical models [6] and numerical simulations [7-10]. The key issue in these investigations is how to correctly understand the dynamic process of ship-bridge collision. Only based on such knowledge can efficient crashworthy devices be designed [4].

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Moveable Facade Elements for Sustainable High-rise Buildings

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Abstract

This paper presents a sustainable semi-active distributed-Multiple Tuned Facade Damping (d-MTFD) system that utilizes the existing mass of the Double-Skin Facade's outer skin as damping mass to mitigate structural vibrations caused by wind excitation. Based on this concept, a prototype with one full-scale parallel moveable facade element has been developed, built, and validated. A stepper motor working together with its connected energy harvesting circuit is innovatively applied as an adjustable electrical damper and simultaneously as an energy harvester. Its feasibility has been proven through experiments using Hardware-in-the-Loop (HiL) simulations. An energy harvesting efficiency of 75% was achieved by using a two-stage power converter as the energy harvesting circuit. The self-sufficiency of the semi-active d-MTFD system was achieved.

Keywords: distributed-Multiple Tuned Facade Damping (d-MTFD) system; Double-Skin Facade (DSF); parallel moveable facade; electrical damper; grey-box system identification; Hardware-in-the-Loop (HiL) simulation; energy harvesting; semi-active control; wind-induced vibration; high-rise buildings; sustainability.

1 Introduction

Various types of damping systems have been developed to ensure the serviceability of high-rise buildings [1]. In addition to the widely used traditional single Tuned Mass Damper (TMD) system, different types of Multiple Tuned Mass Dampers (MTMD) systems have also been proposed and proven to be more efficient and robust than the single TMD. Based on the location of the multiple damping mass, the MTMD system can be categorized into series MTMD [2], parallel MTMD [3], and distributed MTMD systems [4].

Many high-rise buildings are installed with a Double-Skin Facade (DSF). The authors have intensively studied different approaches by using moveable DSF to reduce wind-induced structural vibrations of high-rise buildings [5-8]. The

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Research on Standardized Design of Assembled Pile-slab Road Structures

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Abstract

The assembled pile-slab road structure is a frame structure system composed of factory prefabricated plate girders and pipe piles, which has the advantages of fast construction, small footprint, and low environmental impact compared with the traditional earth roadbed. In order to develop a series of pile-slab road structures that can replace high-fill roadbeds, this paper studies the reasonable forms of pile-slab road structures suitable for replacing earth roadbeds in response to the needs of highway reconstruction and expansion and new construction. The reasonable form of pile-slab road structure travel lane plate is systematically analysed, and the reasonable upper and lower structure forms of pile-slab road structure are proposed. And for the need of assembly construction, the division method of the prefabricated sections of members is studied, and a series structure system of 6m~12m is established, which is suitable for application in road construction projects with tight land resources and has good comprehensive benefits. Finally, a standardized design method for pile-slab road structures is developed, which can provide guidance for the application of such assembled pile-slab road structures.

Keywords: Pile-slab road; structural form; standardization; design.

1 Introduction

Due to the shortage of land resources and the emphasis on environmental issues, the construction of highways is facing a huge challenge now. In order to deal with these problems, pile-slab subgrade structures have been proposed and applied highway construction, which solves the contradiction between highway traffic development and land resource protection with the structural system of road and bridge integration and realize sustainable highway construction. As a new type of prefabricated structure, the pile-slab structure has great application potential in the field of highway construction in the future with strong

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Design and Overall Mechanical Characteristics Analysis of Hybrid Composite Beam Single Tower Cable-Stayed Bridge

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Abstract

Composite beam bridges have been widely used in the main girders of cable-stayed bridges for their excellent performance. In order to study how to apply steel concrete composite girders and concrete π girders in single-tower cable-stayed bridges, the study explores the design technology of hybrid composite beam single-tower cable-stayed bridges based on Shouying Huaihe River Special Bridge of Hezhou Expressway. Through finite element analysis, a series of parametric analysis of the overall performance of the hybrid composite beam single-tower cable-stayed bridge is carried out to study the structural characteristics and analyze the rationality and economy of the structure. The result shows that the hybrid composite beam is a kind of single-tower cable-stayed bridge structure that can well adapt to the asymmetric span distribution with a large proportion of side and middle spans. The research results can provide support and guidance for the background engineering construction and help promote the application of the structural form.

Keywords: Hybrid composite beam cable-stayed bridge; steel concrete composite girder; design optimization; force analysis.

1 Introduction

A hybrid cable-stayed bridge refers to a cable-stayed bridge in which the main span of the bridge is a steel beam or a composite beam and the side span is a concrete beam. The main girder of cable-stayed bridge has a large span while the steel girder or composite girder is lighter in weight and has strong spanning capacity, which is very suitable for the main span design of cable-stayed bridge[1]. At the same time, the concrete beam has high self-weight and high rigidity. It is set on the side span, which can effectively balance the self-weight of the steel main beam or composite beam. For the hybrid cable-stayed bridge, the rational use of steel and concrete in the side and mid-span gives full play to their respective advantages. The ability to adapt to construction conditions has

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Next-Generation Modular Expansion Joints for Bridges – "Smart" And Easily Replaceable in Order to Minimise Life-Cycle Costs

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Abstract

This paper about bridge expansion joints of the modular type includes an introduction to the development of this type of expansion joint since its invention almost six decades ago. It also provides an insight into the current state-of-the-art technology in this field, including such innovations as the option of pre-equipping the joints with sensors for easy integration in a bridge's automated monitoring system – thereby making the joints "smart" – and the option of designing the joints to be easily replaceable when the need arises – thereby minimising the associated costs and disruption to traffic. Considering the huge contribution of maintenance and replacement works to the life-cycle costs of a bridge's expansion joints, the use of such options – combined with the design optimisations resulting from these decades of ongoing development work – enables the long-term costs associated with a bridge's expansion joints to be greatly reduced.

Keywords: bridge; expansion joints; modular; installation, replacement; monitoring; life-cycle costs.

1 Introduction

The best modular expansion joints available today for use in bridge construction and maintenance bear little resemblance to the original that was invented in 1965, due to an ongoing process of development ever since. In fact, decades of experience with thousands of specimens on bridges all over the world have prompted continuous improvements.

Such improvements are often aimed at maximising long-term performance and minimising life-cycle costs – very importantly, including those associated with replacement at the end of the expansion joint's service life – considering the increasing awareness of these issues among bridge engineers. The current state of the inventor's technology is described, with a focus on recent innovations such as the "smart" option of designing and pre-equipping the joints with sensors of all sorts, enabling them to be optimally integrated in a bridge's SHM system to optimise inspection and maintenance work. Another innovation that is likely to be increasingly valued in the coming years is the "quick exchange" option of designing the joints to be easily replaceable when they reach the end of their service life.

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The Modern PU-Based Flexible Plug Expansion Joint for Bridges – The Ideal Solution For City Expressways With Recent Innovations Making Installation Even Faster and More Reliable than Before

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Abstract

The modern polyurethane-based flexible plug expansion joint is vastly superior to the traditional asphaltic-type flexible plug joint, as has been shown by extensive laboratory testing and years of experience under traffic on many bridges. The advantages offered by the PU-based version include its great strength and elasticity (with the material allowing 650% elongation before failure), its resistance to both very low and very high temperatures, and the special advantages it offers when used to replace old small-movement joints in existing structures. These advantages relating to installation on existing, heavily trafficked structures have now been enhanced by recent prefabrication innovations that make installation even quicker and easier, thereby further reducing the impact on traffic. The expansion joint type and these recent innovations are described, with reference to their first applications on some of Shanghai's busiest city expressways.

Keywords: expansion joint; polyurethane; flexible plug; fast installation; city applications.

1 Introduction

When a bridge's expansion joints require to be replaced – as they inevitably will, considering the constant loading and stresses/movements to which they are subjected from vehicle wheels and superstructure movements – the selection of the expansion joint solution that will be used to replace the existing joints is worthy of careful consideration. Of course, such a project comes at a significant direct financial cost (typically at least several times higher than the cost of supply and installation of the bridge's original expansion joints), and the indirect costs relating to traffic disruption etc. can be even higher than the direct costs [1]. Such expansion joint replacement work can additionally have a negative impact on the bridge's structural integrity, where concrete, steel or waterproofing membrane also requires to be broken out and replaced.

Various expansion joint solutions have been developed to minimise the impacts on the bridge structure, and on traffic, by minimising the amount of the existing structure that needs to be removed and replaced [2]. Such solutions typically also reduce the direct financial costs of the project, and the environment impact, by reducing the materials,

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Design Method and Finite Element Analysis of Precast Longitudinal Split-Piece Cover Beam

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Abstract

In order to reduce the weight of prefabricated cover girders and solve the construction problem that it is difficult to realize one-time prefabricated assembly of large cantilever concrete cover girders, urban viaducts usually use large cantilever prestressed concrete cover girders. Taking a 2×30m simply-supported girder bridge as the superstructure, the paper proposes a precast longitudinal split type cover girder, and uses the large general finite element analysis software WISEPLUS to establish a finite element model to simulate and adjust the structural structure, prestressing distribution, and construction stage division of each cover girder (single 1,0m, 0,9m, 0,8m), and the cover girder under this design method in the construction stage and The design method is used to verify the feasibility and reasonableness of the design scheme, and to provide methods and references for similar designs.

Keywords: large cantilevered cap girder; prefabricated assembly; simply supported girder bridge; longitudinal splitting; WISEPLUS; finite element analysis.

1 Introduction

In recent years, Shanghai has taken the development of assembled buildings as a key task to promote the construction of ecological civilization, to promote the transformation and upgrading of the construction industry, and to build a green and livable city, and has been increasing its promotion efforts. Especially with the further promotion of the double carbon goal, the development of assembled buildings is imminent. As an essential building in the city, the assembly process of viaducts has also attracted much attention. Since urban viaducts usually use large cantilevered prestressed concrete cover girders, which usually have a self-weight of 200~400 t. In order to meet the requirements of assembly, it is necessary to reduce the weight of one-time lifting cover girders. In this paper, we propose precast longitudinal split type cover beam to solve the construction problem that large cantilever concrete cover beam is difficult to realize one-time precast assembly.

This paper intends to investigate the reinforcement of precast longitudinal split-piece cover beam, which has been studied more by many scholars in China so far. A research team from the School of Civil Engineering, Hunan University proposed a fully precast lightweight pre-stressed ultra-high performance concrete (UHPC) large cantilever thin-walled cap beam structure with about 40% reduction in self-weight.[1] Yuan Zihua, a member of China Railway 22nd Bureau Group 4th Engineering Co., analyzed the installation technology of prefabricated cover girders for urban expressway assembled viaducts.[2] A research team

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Research on Sectional Optimization Design of Fabricated Bent Cap of Urban Viaduct

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Abstract

With the rapid development of national transportation infrastructure, viaduct has been widely used in the construction of urban expressway. The prefabricated bridge scheme has significant advantages in such areas as traffic organization, construction period and environmental protection. Taking a project under construction in Jiangsu as an example, this paper compares and analyzes the impact of various bent cap segmental forms on the project construction, and provides for optimization design schemes, with the aim of providing reference for the design of Urban Viaduct of similar type in the future.

Keywords: fabricated bent cap; subsection; optimization design.

1 Development status of bridge assembly technology domestically and abroad

In recent years, with the strengthening of the green construction concept, prefabricated bridges have the characteristics of standardized design, industrial construction, short construction period, strong traffic protection ability and environment-friendly. They are widely used in the field of Urban Expressway Viaduct. The superstructure, lower bent cap, pier column, pile foundation and other components of the bridge are prefabricated in the factory according to the design size and reinforcement mode. After various components are transported to the site, they form an overall bridge structure after a series of processes such as installation and connection.

Scholars in China and abroad have carried out some research on the bridge fabricated technology, such as Won Deok Hee and others have studied the mechanical behaviour of the prefabricated pipe pier cap beam at the consolidation of the pier beam [1]; Zhao Zhuo and others analysed the seismic performance of fabricated piers connected with UHPC materials through ABAQUS numerical simulation [2]; Wang Quanqing studied the seismic performance of assembled bridges of mountain roads in high intensity areas [3]; Mr. Wang. R and others analysed the seismic performance of grouting sleeve connection between pier column segments [4]; Rehounek. Lubos and others optimized and analysed the spiral reinforcement configuration of fabricated pier[5]; Motaref and kavianipour studied the socket connection between Precast Pier and precast foundation, and filled the joint gap with high-strength cement slurry [6][7]; Xu Yan and others studied the minimum reasonable socket depth of socket precast assembled pier[8]; Sha Lixin and others verified the linear elasticity and nonlinearity of different segment schemes of fabricated inverted T-shaped bent cap by finite element numerical simulation [9]; Yan Xingfei and others carried out experimental research on the flexural performance of the

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Construction of Flexible Waterstops on Underwater Cofferdams for Pile Caps in Bridge Projects

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Abstract

The water-stopping efficiency of cofferdams for pile caps is an important indicator with direct influence to the quality and durability of the pile-pouring process. In recent years, a new technique featuring flexible capsules serving as waterstops has been introduced, but is still in experimental stage. This thesis, taking the water-stopping construction programme of underwater PC houses of the J. P. Magufuli Bridge project in Tanzania as background, analyzed the two existed types of flexible water-stopping construction methods, id est the integral and separate structures, and studied on measures for improving the flexible water-stopping construction techniques and optimizing the rubber capsule waterstops, in the hope of providing references and, possibly, inspirations for similar projects in the future.

Keywords: water-stopping; cofferdam; capsule.

1 Introduction

Since the dawn of the new millennium, China has seen a great leap in terms of urban transport infrastructure, and with the completion of multiple landmark projects like the Hongkong-Zhuhai-Macau Bridge, the country has achieved continuous improvement in cross-waterbody bridge construction techniques, including those for water-stopping between underwater cofferdams and pile casings[1]. Flexible capsule waterstop is one of the newest members of this kind; it takes effect by the bonding force generated by the swelling rubber capsules fixed on the bottom plate of the PC house against the casings within[2].

Despite being rarely seen in ongoing bridge projects, the technique deserves further research due to its advantages in being more environment-friendly and time-saving, and showing greater efficiency in water-stopping as well as higher versatility in sophisticated aquatic environments. The J. P. Magufuli Bridge project, in this case, provides the author with a precious opportunity to put the two existed ways of flexible water-stopping, i.e. the integral and separate structures, onto the anvil of practice, and makes detailed discussions about the technical improvement to the overall concept and the specific optimizing measures to the rubber capsule waterstops.

2 The Water-Stopping techiniques used on Cofferdams for Pile Caps in Bridge Projects

Cofferdams made from earth, rockfill, concrete boxes, steel sheet or pipe piles and reinforced concrete boxes are widely seen in bridge construction. Traditionally, there are 3 methods for water-stopping between underwater cofferdams and pile casings: introducing a tremie seal, which is a non-reinforced slab of concrete, (with a certain degree of

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Structural Design and Analysis of Orthotropic Steel-SSDC Composite Deck Used for the Widening of the Songpu Bridge

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Abstract

The old Songpu Bridge was a double-deck railway-highway combined steel truss bridge. In the widening and renovation project of Songpu Bridge, the upper deck, which carries highway traffic, was widened from 12 m to 24.5 m. To achieve an appropriate self-weight and better durability, a kind of orthotropic composite deck was used for the reconstructed upper deck; this deck consists of an 80 mm-thick low-shrinkage high-strength ductile concrete (SSDC) layer and orthotropic steel deck plates. Three types of SSDC materials with different composition and mechanical properties are adopted in regions with different tensile stress levels. The detailed design and key considerations of the composite deck are introduced in this paper. Finite element analysis of the composite deck is carried out, and the models and results are presented.

Keywords: the Songpu Bridge; Steel truss bridge; Widening of bridge; Orthotropic composite deck; Low-shrinkage high-strength ductile concrete.

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Modeling and Optimization for The Tensile Properties of 3D-Printed FRP using Artificial Neural Network and Artificial Bee Colony Algorithm

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Abstract

Fiber-reinforced polymer (FRP) has multiple applications as a primary material or reinforcing material for the structural elements. Controlling the quality of the 3D printed FRP is critical to guarantee a FRP material of high performance. In this research, machine learning (ML) model based on data collected from experimental studies was developed by artificial neural network (ANN) to control the quality of 3D printed FRP. ANN model predicts the ultimate tensile strength (UTS) of the FRP as function of 7 material and printing parameters. The UTS of the FRP was maximized via optimizing the printing and material parameters by using artificial bee colony (ABC) algorithm. ANN and ABC algorithms were coded by MATLAB. The results showed that the developed ANN model can predict with good accuracy the UTS of FRP. Moreover, it was found that the ABC optimization algorithm can design the input parameters such that a FRP with maximum UTS can be obtained.

Keywords: fiber-reinforced polymer composite; additive manufacturing; 3D printing; artificial neural network; optimization; artificial bee colony algorithm.

1 Introduction

Polymer-based composites, also called Fiber-Reinforced Polymer (FRP), are characterized by light weight and high performance in terms of mechanical and thermal properties. However, these properties are varies based on the type of polymer matrix and the reinforcing fibers of FRP. The polymer matrix of FRP can be either Thermoplastic, e.g., Poly-Lactic Acid (PLA), Nylon, or Thermosetting, e.g., Epoxy, Polyurethane; while the fibers reinforcing agent can be either Synthetic Fibers (SF), e.g., Carbon Fibers (CF), Glass Fibers (GF), Kevlar Fibers (KF), or Natural Fibers (NF), e.g., Jute, Flax, Wood, Bamboo (see Figure 1) [1]. The properties of the produced FRP not only based on the matrix and fibers types but also on fibers form whether it is continuous fibers, chopped fibers.

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Mobile 3D Printing Techniques for Construction Engineering: Outdoor Navigation and Printing Quality Control

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Abstract

In traditional three-dimensional (3D) printing, large-size 3D print machines, restricted print sizes of structural components and unstable printing quality limit its application in construction engineering. This paper proposes a mobile 3D printing technique for construction engineering. In this technique, a mobile 3D printing construction robot (M3DPC-Rob) is developed that takes advantage of a movable platform and flexible mechanical arm to cover the printing range of ordinary residential buildings. In order to locate the robot accurately in outdoor environments, an outdoor positioning and navigation method based on reflective columns is proposed. Furthermore, a quality control process is developed and modified to improve the quality of the printed line width. The results of a case study reveal that the outdoor navigation and printing quality control techniques of M3DPC-Rob show sufficient and steady accuracy that meet the requirements of construction engineering.

Keywords: 3D concrete printing; mobile construction robot; outdoor navigation technique; printing quality control technique; reflective-column-based absolute positioning method.

1 Introduction

The three-dimensional (3D) printing technique, as an emerging type of intelligent construction technology, has attracted much attention in recent years. Compared with traditional construction methods, the 3D printing technique requires less human labor, saves more building material and shows higher construction efficiency, which lead to lower construction costs [1]. Furthermore, the 3D printing technique can build architectures without formwork [2] and print structural components having complex shapes, which bring great convenience in construction engineering and inspire more innovations in both design and construction.

Nowadays, there are more and more studies focusing on research in, and application of, the 3D printing technique in construction engineering. Most of these studies emphasize the mechanical performance of suitable 3D printing material such as mortar, paste with small aggregate particles and concrete. The printability, fresh mechanical properties, hardened mechanical properties, durability [3] and fiber orientation effects [4] of those typical printing materials are researched and suggested design criteria are given. Most research shows that the materials used in 3D printing have

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Long-term Missing Wind Data Recovery for Bridge Health Monitoring Using Deep Learning

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Abstract

As the performance of the electronic equipment for bridge SHM system deteriorates, wind data often suffer from long-term data missing, which creates barriers for safety monitoring of the bridge structures. Therefore, we proposed a framework for long-term missing wind data recovery based on a deep neural network (DNN) utilizing a free access database (ECMWF). This framework consisted of one regression task (Task 1) and one temporal super-resolution task (Task 2). In Task 1, the hourly wind data provided by ECMWF were learned to the hourly ones of the SHM system. In Task 2, the low-resolution wind data were upsampled to high-resolution ones (10-min averages). The U-net architecture provided the basis for the DNNs in both tasks. The proposed framework's feasibility was verified through a case study of Sutong Bridge. The proposed methodology provides a new perspective for recovering long-term continuous missing SHM data.

Keywords: wind speed; missing data recovery; deep learning; convolutional neural network (CNN); structural health monitoring (SHM); free access database.

1 Introduction

Wind speed is an essential parameter in the bridges' structural health monitoring. The wind monitoring data (in combination with other monitoring data) can be used to obtain the wind field characteristics at the bridge site, evaluate the serviceability and safety of the bridge structure under wind action, and investigate the correlations between the wind action and other environmental actions on the bridge [1-3]. However, dysfunction of the sensors or data acquisition/transmission system and power failure of the structural health monitoring system (SHMS) usually lead to the missing wind monitoring data. Therefore, some researchers have attempted to recover the lost data to improve the usability of the wind monitoring data [4-6].

The wind data missing in the bridge SHMS falls into two types: discrete missing and continuous missing. Conventional interpolation techniques can be used to interpolate the first type of lost data. However, for the second type, the missing information duration may vary from several minutes to several

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Intelligent Upgrading and Application of Bridge Video Surveillance System Based on Computer Vision

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Abstract

The rapid development of computer vision provides a foundation for the intelligent upgrading of bridge video surveillance systems. In this paper, two intelligent upgrading methods were developed and deployed. The first method uses edge computing equipment as the core, to quickly identify and locate vehicles across the large-span bridge by YOLOv5, which was trained by synthesized vehicle dataset, and then a large-span bridge vehicle digital twin system was built and deployed in Baijusi Yangtze River Bridge, which is suitable for scenarios with high real-time requirements. The another one is based on cloud computing, relying on ShuffleNetV2 to build a waterlogging recognition model and early warning system, which is suitable for scenarios with low real-time requirements. The results show that the constructed intelligent system upgrades the traditional passive access system to an early warning system with active recognition, which improves the intelligence of the system and meets the needs of engineering applications.

Keywords: video surveillance; deep learning; intelligent upgrading; early warning.

1 Introduction

With the advance of civil engineering information construction, video surveillance has been widely used in bridge construction and maintenance phases. Video surveillance is conducive to real-time, remote to master the actual situation on site, and in case of special events, it can also be replayed for evidence. However, the existing monitoring system lack of automatic identification of the special tasks of bridge, the command center needs to view the monitoring screen in real time and determine the anomaly, which is time-consuming and easy to miss detection.

Intelligent upgrading of video surveillance refers to the use of the latest computer vision technology to actively identify useful information in the video stream and timely warning, the whole process does not require manual participation and there is also no need to reinstall any surveillance equipment, which can improve the utilization of the existing video resource.

To achieve the intelligence of video surveillance system, intelligent image processing technology has attracted a lot of attention from academia and

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Prediction of Concrete Column Reinforcement Corrosion Degree Under Initial Strain Based on Support Vector Regression

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Abstract

Faraday's law is usually used to predict the corrosion degree of reinforced concrete column members in the electric accelerate corrosion experiment. However, this law doesn't consider the influence of initial compressive strain on the corrosion degree. In this paper, using the experimental data of concrete column members under different initial compressive strain levels, the support vector regression (SVR) model is developed to forecast the reinforcement corrosion degree of column members. The predicted results are compared with the experimental results. The results show that when there is the initial strain in the column member, the reinforcement actual corrosion degree decreases, and the main reinforcement's actual corrosion degree is significantly less than that calculated by Faraday's law. The SVR model proposed can accurately and quantitatively reflect this phenomenon.

Keywords: reinforcement corrosion; column member; support vector regression; initial strain.

1 Introduction

The corrosion of steel reinforcement in concrete column members reduces the bearing capacity of column members and endangers the safety of bridge structures [1-3]. At present, there is much research on corroded column members. However, most are carried out under the condition of no continuous compressive strain, which is different from the column members in the actual bridge structure [4-9]. When the real column member is corroded, there is a continuous compressive strain in the column member. Some researchers have found that compressive strain can change reinforcement corrosion degree in column members [4,10-11]. The established Faraday's law cannot consider the change of strain on the corrosion degree and the different corrosion amounts between the main reinforcement and stirrup. This paper collects the existing test data of corroded column members under compressive strain [4,10-11]. It uses the SVR model to predict the corrosion amount of reinforcement and stirrup by training this model on the existing data. The model can consider the strain level and predict the actual corrosion amount nicely. A ten-fold cross-validation method is used to verify the model's generalization ability and prevent overfitting. Finally, the influence of strain level on the actual corrosion amount is analysed.

2 Predict the corrosion under strain

This paper uses the SVR model to predict the corrosion degree of corroded reinforcement in corroded columns under initial strain. The model inputs are strain, corrosion time, current amount, length of corroded main reinforcement and stirrup, the diameter of corroded main reinforcement and stirrup, eccentric distance, and the output is the

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Aerodynamic Parameter Identification and Flutter Performance Prediction of Closed Box Girder Based on Machine Learning

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Abstract

A bridge wind resistance database has been built based on the wind tunnel testing results of 20 long-span bridges. The artificial intelligence models for identifying aerostatic coefficients and flutter derivatives of close box girders are trained and developed via machine learning methods, including error back propagation neural network based on Levenberg-Marquardt algorithm and gradient boosting decision tree. The identification of the aerostatic coefficients can be achieved with high accuracy. For flutter derivatives, the model can also explore the underlying distribution of dataset. In this way, the present research work can make the identification of aerodynamic parameters separated from tedious wind tunnel test and complex numerical simulation to some extent. It can also provide a convenient and feasible option for expanding data sets of aerodynamic parameters. In addition, it can help determine the appropriate shape of the box girder cross-section in preliminary design stage of long-span bridge and provide the necessary reference for the aerodynamic shape optimization by modifying local geometric features of the cross-section to evaluate the influence of the aerodynamic shape on flutter performance.

Keywords: long-span bridge; closed box girder; machine learning; aerodynamic parameter; flutter performance.

1 Introduction

With the increasing span of bridges, bridges are characterized by light weight, high flexibility and low damping, making wind-resistance a key control factor in structural design. Aerodynamic parameters are important for describing the wind-resistance of bridges. They play a vital role in the analysis of static wind stability, flutter, galloping, vortex-induced vibration and buffeting. At present, the aerodynamic parameter identification methods of bridges are very mature, and all parameters can be obtained by wind tunnel test or numerical simulation. As the most effective and reliable means of wind-resistant design of bridges, wind tunnel test has the problem of high cost, and it can only be analyzed for a specific cross-section. The experimental results are not universal. With the advancement of computer technology, the numerical simulation developed rapidly, but its calculation accuracy still needs to be verified.

In recent years, machine learning methods have been widely used in the field of bridge and structural wind engineering, such as wind environment prediction, aerodynamic shape optimization, wind-induced effect simulation and aerodynamic parameter identification. Fu J.Y. made use of fuzzy neural network to predict the wind load on the long-span roof surface [1]. Xie Z.N. applied a 3-layer back propagation neural network to identify the wind-induced interference

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Validation and Updating of Regional Bridge Deterioration Model Incorporating Structural Health Monitoring

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Abstract

Civil infrastructure has aided economic development and social progress. Existing reinforced concrete beam bridges undoubtedly suffer the damages due to loads, structural defects, etc. To increase the accuracy of safety assessments, a reliable bridge deterioration model is required. This study presents a technique for validating and updating the regional bridge deterioration model by using monitoring data from a few bridges in the area. This method avoids data-level fusion and instead employs model-level fusion. In model validation, it makes full use of the depth of individual bridge monitoring data as well as the breadth of bridge group inspection data. The suggested method is validated in a case study including regional bridges in Northern China. When the number of monitored individual bridges grows, the validation and correction of the regional bridge deterioration model will be more effective.

Keywords: deterioration model; regional bridges; inspection data; structural health monitoring; model updating; condition assessment.

1 Introduction

In recent decades, huge expansions in civil infrastructure have supported economic growth and social advancement. China, the United States, Europe, and other areas have large in-service bridge holdings, and a great number of bridges are classed as damaged, posing a possible safety risk to the serviceability of local transportation networks [1]. Simultaneously, the vast amount of regional bridge inspection and monitoring data generated over time contains some structural performance-related information [2]. As a result, it is essential to generate a credible bridge deterioration model.

In general, the regional bridge deterioration model is generated from years of visual inspection reports. Although the regional bridge database consisting of bridge structural inspection data has been pre-processed with data cleaning and reconstruction techniques [3], It still consist of some errors that may misguide the deterioration model generation. Structural health monitoring is a more reliable and objective way to acquire in-service data that reflect the condition on measured structures, but the huge costs of structural health monitoring systems prevent their installations on every bridge.

Previous studies have proposed some methods to take advantages of inspection and structural health

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A New Clustering Method for Damage Assessment of Fiber Reinforced Concrete Using Piezoelectric Transducers and a Wireless Impedance-Admittance Monitoring System

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Abstract

Nowadays there is an extended need for real-time applications of Structural Health Monitoring in existing concrete structures. This paper deals with the application of a new, low-cost and wireless SHM system that utilises small-sized piezoelectric transducers for continuous damage assessment of Fibre Reinforced Concrete specimen. A PZT-based Wireless impedance-Admittance Monitoring System used for detection of damage degree due to concrete cracking. The Electro-Mechanical Impedance signatures of an array of externally bonded PZT sensors in FRC specimen subjected to four-point bending in several damage states. Quantitative damage evaluation is achieved using the frequency signal measurements of the PZT transducers and comparisons of several commonly statistical indexes. Further, a new damage index based on k-means clustering methods that provides more reliable results on damage identification is also proposed and evaluated herein.

Keywords: structural health monitoring; Electro-Mechanical Impedance; lead zirconate titanate (PZT); fibre reinforced concrete; damage detection.

1. Introduction

Climate change affects the ability of Reinforced Concrete (RC) structures to expand their lifespan. Sustainable development invigorates crucial importance to the design, construction, rehabilitation, and refurbishment of concrete structures. Fiber Reinforced Concrete (FRC) constitutes a solution, which has shown superior mechanical properties, and mainly, greater durability [1-3]. Especially for the latter, the ability of the structures to withstand structural degradation due to environmental agents is improved with the application of synthetic fibers in comparison to the steel ones, thanks to the greater corrosion resistance properties. Therefore, FRC materials have expanded their applications in the construction industry [4-7].

Structural Health Monitoring (SHM) has strong potential to expand the lifespan of RC structures by regular evaluation of their structural integrity. In real-life applications, SHM's aim is to prevent sudden collapse and even heavy structural damage through a prompt damage detection. For the aforementioned reasons, SHM systems must be capable of operating on a real-time basis to prevent extensive damage. In Electro-Mechanical Admittance (EMA) and its inverse Electro-Mechanical Impedance (EMI) method, the use of Piezoelectric ceramics and particularly lead zirconate titanate (PZT) patches is advantageous because of their active-sensing capability, small size, and inexpensive cost [8-10].

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Numerical and Experimental Study on the Temperature Distribution of an RC Maglev Viaduct Based on Meteorological Monitoring

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Abstract

Thermal energy exchange induces non-uniform temperature distribution on the concrete bridge structures, leading to variation of static and dynamic properties of structural systems. The finite element method can facilitate thermal simulation and predict the structural temperature distribution based on heat flow theories. Previous studies mainly focused on the daytime with sunny weather, and the effects of solar shadow distribution were not fully considered or even ignored. In this paper, a systematic all-weather thermal simulation method was proposed to investigate the temperature distributions of concrete maglev bridges. The solar shadow distribution on the bridge surface could be accurately simulated to determine the solar radiation-imposed range. A meteorological station and some thermocouples were installed on a real concrete maglev bridge to obtain the real-time structural temperatures and environmental conditions. Results show that the simulated structural temperature matches the measured results under various weather conditions. Moreover, the simulation method acquired a higher accuracy under overcast or rainy weather due to weaker solar radiation effects. The proposed methodology for temperature field simulation is oriented by all-weather prediction of structural temperature, which is reliable for concrete bridge structures with the help of accurate measurement of real-time solar radiation.

Keywords: RC bridge structure; structural temperature field; all-weather temperature simulation; filed test; validation.

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A New Method for Calculating Bridge Influence Surface

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Abstract

Bridge influence surface (BIS), which reflects the relationship between the bridge response and the unit load moving on the bridge, has been commonly used in bridge weigh-in-motion, bridge damage detection, etc. Generally, the BIS can be obtained by interpolating bridge influence lines (BILs) at different lateral positions. In field tests, the BILs are usually extracted from the bridge response induced by a moving calibration vehicle with known axle loads. However, when taking the axle loads of the calibration vehicle into calculation, the impacts of the transverse distance between coaxial wheels and the unbalance of the coaxial wheel loads are ignored. Hence, errors may be brought to the calculated BIL and then propagated to the BIS. To remove these impacts, a new BIS calculation method, which takes the load of each wheel rather than each axle into calculation, is proposed in this research. Numerical simulation shows that the BIS can be successfully estimated by this method.

Keywords: bridge influence surface; bridge influence line; wheel load; axle load.

1 Introduction

A bridge influence line (BIL) is the bridge response curve under a unit concentrated load crossing a bridge along the longitudinal direction [1]. A bridge influence surface (BIS) is the lateral extension of the BIL, which is the contour of bridge response under a unit concentrated load traveling throughout the entire bridge deck [2]. The BIL and BIS have been widely applied in bridge engineering such as damage detection [3-5], safety evaluation [6-8], model correction [9-10], and bridge weigh-in-motion [11-12].

Obtaining the BIS via the finite element (FE) analysis is economical and convenient, but getting a reliable FE model is usually difficult. Therefore, field tests are usually adopted for BIS identification. There are generally two types of field test methods: the static loading method [13] and the dynamic loading method [14]. In the static loading method, the bridge deck firstly needs to be meshed into grids. Then a concentrated load is set to act at each grid point in turn, and the BIS can be obtained from the recorded bridge response after being divided by the size of the concentrated load. This method is simple and direct, but not efficient [15] due to the point-by-point loading. Thus, the dynamic

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Semi-active Control of Cable Vibration Using MR Damper under Wind Loads

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Abstract

One of the most effective countermeasures for mitigating cable vibration is to install mechanical dampers near the anchorage of the cable. The parameters of passive dampers are usually determined based on the optimal damper force obtained from the universal design curve for linear dampers, which is chosen based on a predetermined principle vibration mode. Passive dampers will be most effective if cable undergoes single-mode vibration where the vibration mode is the same as the principle mode used in the design. However, in the actual engineering practice, multi-mode vibrations are often observed for cables. Therefore, it is desirable to have dampers that can suppress different modes of cable vibrations simultaneously. In this paper, MR dampers are proposed for controlling multi-mode cable vibrations, because of its ability to change parameters and its adaptability of active control without inquiring large power resources. Although the highly nonlinear feature of the MR material leads to a relatively complex representation of its mathematical model, effective control strategies can still be derived for suppressing multi-mode cable vibrations based on nonlinear modeling, as proposed in this paper. Firstly, the nonlinear Bouc-wen model is employed to accurately portray the characteristics of the MR damper. Then, the input voltage (current) of MR damper corresponding to the desired optimal damper force is calculated from the nonlinear Bouc-wen model of the damper using a piecewise linear interpolation scheme. Numerical simulations are carried out to validate the effectiveness of the proposed control algorithm for mitigating multi-mode cable vibrations induced by wind load excitations.

Keywords: semi-active control; MR dampers; multi-mode cable vibration; wind load; optimal damper force.

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Detection of Concrete Structural Surface Cracks Based on VQ-VAE-2

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Abstract

The deep learning models can detect surface cracks of concrete structures efficiently, but training sets which include a great number of crack pictures generally are relied on when training the deep learning models. This paper presents a detection method based on VQ-VAE-2, an unsupervised learning model, which requires no cracks when trained. Firstly, a VQ-VAE-2 model is trained on a training set which only contain pictures of normal concrete structural surfaces. The VQ-VAE-2 model is expected to produce low reconstruction error for pictures of normal concrete structural surfaces and high reconstruction error for ones of concrete structural surface cracks. Then the reconstruction error of test set is computed by the VQ-VAE-2 as the judgment criteria. Lastly, the model is evaluated by precision, recall, F1 and accuracy. The result shows the method based on VQ-VAE-2 can achieve the crack detection without crack samples.

Keywords: computer vision; crack detection; unsupervised learning; vector quantized variational autoencoder (VQ- VAE).

1 Introduction

Concrete cracking is one of the main diseases of concrete structures. Crack detection is of great significance for bridge health monitoring. However, the traditional detection method for concrete surface cracks depends on manual inspection, which is inefficient and inaccurate. Therefore, a variety of methods based on computer vision technology have been proposed and tested in some concrete structures. Aside from typical computer vision algorithms, various classical deep learning models of computer vision technologies, such as AlexNet, GoogLeNet, ResNet, and YOLO [1-3], have been used to replace traditional crack detection. Those modes detect cracks belong to the precision-based model. Although precision-based models are quite good at detecting apparent cracks of concrete, they won't operate if there aren't enough crack samples available.

Considering the lack of concrete crack samples, unsupervised anomaly detection methods should be presented and applied. Some unsupervised techniques detect cracks by building a detailed profile of normal concrete pictures, like k-nearest neighbor method [4] and GMM [5]. Different from those methods, other unsupervised techniques detect cracks relying on the higher reconstruction error when crack samples are reconstructed by a model trained only on normal concrete data. Autoencoder (AE), such as MemAE and VAE, is recognized as a powerful tool to achieve reconstruction so it has been adopted to detect anomaly in various fields [6]. Surface cracks are abnormal compared with normal concrete surface data and can also be detected by AEs. Therefore,

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Detection Algorithm of Structural Surface Cracks Based on Class Activation Map

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Abstract

The computer vision algorithm based on deep learning has achieved excellent performance in structural surface damage detection, but the accurate detection algorithm has high requirements for the quantity and quality of data sets. This paper presents a method based on class activation map (CAM), which can detect the crack position and distribution only by image-level data labeling. Firstly, a classification model Vgg16-Crack is trained based on the transfer learning method, and the accuracy and generalization ability of the model are tested by the confusion matrix. Then, based on the CAM algorithm, this paper improves and optimizes the current Grad-CAM++ algorithm, and takes the CAM generated by Vgg16-Crack as the result of crack detection. Finally, the method proposed in this paper is tested in the field. The test result shows that the method proposed in this paper can realize the accurate detection of structural surface cracks.

Keywords: crack detection; computer vision; transfer learning; Convolutional Neural Networks (CNN); Class Activation Map(CAM)

1 Introduction

The identification and detection of structural surface damages, especially cracks, can provide reliable data support for the operation and maintenance of the structure. The traditional crack detection adopts manual detection, and the detection results are often subjective. Furthermore, the traditional detection method is often lack of universal standard, which leads to low accuracy. With the development of computer vision technology, the crack detection algorithm based on computer vision has the advantages of automation, high efficiency and no contact [1] to better solve the problems existing in the manual detection method [2]. Especially with the rapid development of deep learning technology in recent years, Convolutional Neural Network (CNN) model greatly improves the accuracy and efficiency of detection. At present, the detection algorithm based on CNN model has been used to detect the surface damages of buildings [3], bridges [4] and tunnels [5].

The functions of CNN models are mainly distributed into three types: image classification [6], object detection [7] and semantic segmentation [8]. The image classification model can judge the category of the input image, the object detection model can roughly judge the position of objects in the image, and the semantic segmentation model can detect the objects in the image pixel by pixel. In terms of accuracy, the semantic segmentation model is the most accurate, but it needs pixel-level labeled data as the training set, which requires a lot of manual work and has become an important factor restricting the application of CNN models in

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Application of NLP Technology in the Information Extraction of Bridge Management and Maintenance Documents

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Abstract

Bridge management and maintenance document is the accumulation of authoritative technical data to record the history of bridge operation, current technical status and management and maintenance process, which contains substantial information to support bridge maintenance decision. With more and more extensive application of bridge health monitoring in civil engineering industry, bridge management and maintenance documents become more common and quantitative. Therefore, a large number of these reports need to be manually read and analyzed to obtain effective information, which will waste a lot of effort. In order to improve this situation, this paper develops a frequency state analyzer using LSTM neural network to classify these documents automatically, and improve the efficiency of bridge management and maintenance work.

Keywords: natural language processing; bridge management and maintenance documents; text categorization; LSTM

1 Introduction

Bridge structure management and maintenance is a necessary link to ensure the safe and normal operation of existing bridges. Its management and maintenance information (such as bridge overview, operating environment characteristics, structural safety assessment, special load action assessment, conclusions, suggestions, etc.) is mostly recorded in the document in the form of natural language. The content of the document has the characteristics of comprehensiveness, specialization, and standardization: the content framework is similar, a large number of professional words are used, and the whole content as well as the potential safety hazards are summarized and pointed out in the final chapter. However, with the substantial increase in the number of bridges and management and maintenance documents, the traditional manual reading and analysis method is difficult to meet the engineering needs. Therefore, it is proposed to use natural language processing technology, an emerging technology in the field of computer science, to analyze a large number of management and maintenance documents and

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Structural Health Diagnosis Under Limited Supervision

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Abstract

Structural health diagnosis has been investigated following a data-driven machine learning paradigm. However, the model accuracy and generalization capability highly rely on the quality and diversity of datasets. This study established a framework for structural health diagnosis under limited supervision. Firstly, an image augmentation algorithm of random elastic deformation, a novel neural network with self-attention and subnet modules, and a task-aware few-shot meta learning method were proposed for vision-based damage recognition. Secondly, deep learning networks were established to model intra- and inter-class temporal and probabilistic correlations of different quasi-static responses for condition assessment. Finally, a two-stage convergence criterion merging with the subset simulation and Kriging surrogate model was designed for reliability evaluation. Real-world applications on large-scale infrastructure demonstrated the effectiveness.

Keywords: intelligent infrastructure; structural health diagnosis; machine learning; computer vision; small data

1 Introduction

During the long-term service period of civil infrastructure, damage accumulation and resistance deterioration will inevitably occur due to coupled effects of material erosion and cyclic fatigue loads, especially for large-scale bridges and tunnels. Following the paradigm of damage prognosis established by Farrar and Lieven (2007) [1], structural damage recognition, condition assessment, and reliability evaluation were the most significant issues towards health diagnosis. For past decades, one of the most commonly used ways was manual inspection, which had the shortcomings of high dependence on subjective judgment and engineering experience, severe unreliability, and low efficiency [2].

Since the 1990s, structural health monitoring techniques have been widely adopted in large-scale infrastructure. Conventional non-destructive testing and vibration-based methods have been investigated for damage detection and condition assessment. The measured signals were directly compared with peak values or statistical indices with thresholds regulated by the design code. However, the following challenges remained to be addressed: these techniques required the dense deployment of sensors on bridges and faced the ill-posedness of the reverse problem; the modal parameters were insensitive to minor damage in a

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Computer-Vision-Based Real-Time Rock Fragment Recognition During Tunnel Excavation

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Abstract

Timely recognition of rock fragments can help predict the deformation of the tunnel during tunnel boring machine (TBM) tunneling. Traditional manual inspection highly relies on subjective judgments of operators and conducting sieving tests is not real-time. Rock fragments in the real-world are often observed against a dark background, distributed with high size diversity, complicatedly distributed, and blocked by each other. This study proposes a computer vision-based method for on-site rock fragments recognition. The proposed method consists of an image pre-processing module, an instance segmentation model, and a post-processing module. The results show that the pixel-level rock fragment recognition takes 0.15s for processing a 512×512 patch on average and 88% of rock fragments can be recognized. The predicted size distributions of the major and minor axis lengths of the rock fragments fit well with the ground-truth ones statistically.

Keywords: tunnel boring machine tunnelling; rock fragment recognition; computer vision; instance segmentation.

1 Introduction

During TBM tunneling, operators often need to adjust the excavation parameters and ensure construction safety according to the mechanical properties of the rock mass. One way is involving operators making decisions after manual inspection of rock fragments by the naked eyes. Another way is conducting a sieving test to obtain the particle size distribution, which is not real-time and energy-consuming. Although structural health monitoring systems have been widely implemented in large-scale tunnels to assess structural conditions [1-3], they cannot function during the excavation process. With the booming development of computer vision techniques, a potential solution is using cameras to capture on-site rock fragment images and accomplishing real-time vision-based recognition to provide additional support for determining rock properties and excavation parameters. Huang et al. systematically highlighted the recent significant progress in computer vision techniques in tunnel construction [4]. A few related studies on the identification of particulate size from images have been conducted. For example, Amankwah et al. segmented rock images using a Voronoi diagram, and rock edge detection was achieved using the watershed transform [5]. Bai et al. employed the watershed algorithm, k-nearest-neighbors algorithm, and

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Sensitivity-based Structural Damage Identification via Response Reconstruction

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Abstract

The limitation of sensor number and results that the monitored data is difficult to reflect the true state of the structures, which limits the reliability of bridge damage identification and deterioration assessment. There are many full-field response reconstruction methods developed to obtain the complete responses. However, the quality of the reconstructed data is comprehensively affected by finite element model errors, noise interference and strong coupling environmental effects, resulting in the low accuracy of dynamic-based damage indicators. Thus, this paper explores a damage identification method based on static response reconstruction and solve the damage factor using the relationship between the sensitivity matrix and the structural deformation. Taking simply-supported and cantilevered beam as examples, numerical calculations confirm that the method can effectively locate the damage of the structural system.

Keywords: structural health monitoring; damage identification; sensitivity analysis; response reconstruction.

1 Introduction

Damage inevitably occurs in structures during their service life due to a variety of factors such as environmental erosion, operational loads, fatigue, and accidental collisions, and the theory related to damage detection methods (DDM) has attracted extensive attention early on. The current work mainly includes DDM based on vibration data[1] (e.g., inherent frequency[2], vibration type, frequency response function[3], modal flexibility matrix, dynamic response, etc.) and DDM based on

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Beneficial Effect of Combining Similar Low-Cost Accelerometer to improve the overall Accuracy and Noise Density

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Abstract

Structural Health Monitoring applications are receiving more and more attention nowadays. The epidemic problem with these evaluations is their high cost. For applying them to structures/ infrastructures with a low budget of SHM evaluations, low-cost sensors must be taken into account. However, low-cost accelerometers have higher noise density ratios which affect their accuracy and resolution. Using filters or post-processing methods alters the acquired information of the accelerometers. This article aims to enhance the accuracy and resolution of low-cost sensors by improving and controlling the spectral noise level through active noise improvement. This improvement is studied in this paper and supportive laboratory experiments have been illustrated.

Keywords: low-cost sensors; accelerometers; data acquisition; structural health monitoring; arduino.

1 Introduction

Structural Health Monitoring systems are composed of sensors that measure the structural response (such as accelerations, rotations, strains or deflections) over time. This information can be used to estimate changes in the structural performance of infrastructures [1][2]. The time variation of some environmental factors (such as temperature or humidity) that could produce crack opening, rotations, settlements, corrosion and other pathologies is so slow that they can be considered as quasi-static or static [3][4]. On the other hand, some events (such as the wave response due to earthquake ground motion, traffic-induced vibrations or ambient activities) surely need to be accounted for the dynamic nature of the structural response they induce. To observe and control them, dynamic SHM Systems are required [5][6]. The modal parameters needed for SHM application are mostly acquired by accelerometers [7].

MEMS sensors are silicon-based micromachined devices that traditionally incorporate an

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Experimental Verification of a Novel Accelerometer Intended for Structural Health Monitoring of Bridges

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Abstract

Bridges can be considered one of the most critical infrastructures of any country. Subsequently, their health state assessment is of great importance. However, durable monitoring of bridges can be highly costly and time-consuming. In addition, the current Structural Health Monitoring applications are only applicable to individual structures with a high budget for their health assessment. For a long-term economic evaluation of bridges, low-cost sensors are currently being developed for SHM applications. However, their resolution and accuracy are not yet suitable for structural system identifications. For that, a novel accelerometer based on Arduino technology is introduced in this work. Experiments show that this accelerometer has a better resolution. Illustrated test results of this paper on a frequency range of 0.5 to 8 Hz validate the performance of the proposed accelerometer.

Keywords: low-cost sensors; arduino due; accuracy and sensibility; structural health monitoring; mpu9250.

1 Introduction

Civil structures and infrastructures could be considered as the main foundation of present modern society and, hence, their soundness is of utmost importance. However, the reports of ASCE infrastructure grades shows that in the United States: (1) 9.1% of all the bridges are not structurally efficient, (2) 188 million trips are taken every day over these deficient bridges, (3) The average age of bridges is 43 years old [1]. Monitoring and evaluating the health state of these structures are required for the maintenance applications, for minimizing the reparation costs and, eventually, for guaranteeing infrastructure safety [2][3]. Structural Health Monitoring (SHM) applications provide information on the state of structures, their functioning and their structural response. As pointed out by many scholars (see, e.g. [4]), SHM can be used to calibrate structural models of real structures (digital twins) that mimic

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Long-Term Damping Characteristics of a Cable-Stayed Bridge

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Abstract

Damping ratio is a crucial factor in assessing the vibrational serviceability of flexible large-scale structures such as cable-supported bridges. While the natural frequencies of structures have been estimated from operational modal analysis (OMA) with relatively minimal scattering, damping ratios have shown a high degree of scattering due to analytical uncertainty and in environmental and operational variations (EOV). To examine the damping ratio in context of EOVs, an automated damping estimation framework is applied with minimal user intervention to 2,5 years of long-term data acquired from a sparse continuous monitoring system. Daily and long-term fluctuations of damping ratios are examined. Environmental and operational factors such as temperature, wind environment and level of excitation are examined in context with damping ratios. The probability distribution of the damping ratio is also suggested based on statistical methods.

Keywords: damping; cable-supported bridges; system identification; operational modal analysis; long-term monitoring; environmental and operational variations

1 Introduction

In wind-resistant design and dynamic analysis, damping ratio is one of the most important parameters in assessing safety and serviceability for lightweight structures. Phenomena such as vortex-induced vibrations and vehicle-bridge interaction are some of the examples in which damping ratio are used to estimate the dynamic response of a structure. In particular, vortex-induced vibration has been a recurring problem for cable-supported long-span bridges around the world. Miniscule differences in modal damping ratios can make the difference between satisfactory serviceability and harmful vibrations. Thus, it is imperative that damping ratios of such sensitive structures be understood well. While past research on predictive damping models have relied on damping models derived from limited real-world data, recent advances in the field (cite

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A Multi-Label Classification Method for Anomaly Detection of Bridge Structural Health Monitoring Data

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Abstract

In past years, massive data has been accumulated by many bridge structural health monitoring systems, and various methods have been proposed to detect data anomalies to ensure the reliability of subsequent data analysis. However, these methods are incapable of determining if there still exist usable data segments in a data sequence providing a specified anomaly type has been identified. To address the problem, a deep learning-based multi-label classification method is proposed in this paper. A multi-label anomaly dataset is first constructed using monitored acceleration data of a cable-stayed bridge. Then, a multilabel anomaly classification model based on a convolutional neural network is developed and trained with the constructed dataset. The developed method exhibits desirable performance in simultaneously detecting the existence of both usable data and the other data anomalies.

Keywords: bridge; structural health monitoring; acceleration; data anomaly; deep learning; multilabel classification.

1 Introduction

Structural health monitoring (SHM) has been widely accepted as a promising means to ensure structural safety by analyzing accumulated monitoring data. However, the problem of data quality should be first examined to ensure the reliability of subsequent data analysis[1]. The problem of data quality is mainly induced by sensor faults, which could result in different types of data anomalies in measured data. Manually inspection and picking are feasible to avoid these data anomalies given limited data to be analyzed, however, the method becomes extremely inefficient in processing massive data. Therefore,

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A novel portable vision-based bridge weigh in motion method

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Abstract

Accurate vehicle load information is critical for bridge maintenance. On the one hand, traditional weigh-in-motion (WIM) and bridge weigh-in-motion (BWIM) have certain limitations due to their high cost and complicated installation. On the other hand, targetless contactless bridge weigh-in-motion(CBWIM) is easy to install, but due to the lack of marker points and low image quality, resulting in poor recognition accuracy, it cannot be widely promoted. In this paper, we propose a novel portable vision-based bridge weigh-in-motion method(PBWIM). First, a high-precision image encoding system and illumination-invariant infrared target device were developed, which were installed at the bottom of the beam. Then, the target tracking algorithm based on improved geometric matching automatically identifies the target point image and calculates the actual displacement to obtain the deflection time-history curve. Finally, the accurate vehicle weight is calculated by solving the Tikhonov regularized error equation. After field tests, the results show that the method proposed in this paper has a greater efficiency than the CBWIM algorithm, and can basically achieve the recognition accuracy of the traditional BWIM, and the cost is low, which has a wide range of application and promotion significance.

Keywords: bridge weigh-in-motion; object detection; vehicle load monitoring; computer vision; displacement monitoring.

1 Introduction

The accurate identification of vehicle loads plays an important role in the maintenance and operation of bridges. Traditional WIM methods require sensors to be installed under the road surface, which requires disruption to traffic and is prone to damage. The traditional BWIM method obtains information such as the wheelbase and speed of the vehicle on the bridge deck through the FAD sensor, and then combines the WS sensor to calculate the weight information of the vehicle during driving, but this method requires the installation of many sensors and special data processing equipment , higher cost. In recent years, with the development of computer vision, vision-based monitoring methods have received extensive attention from scholars.

At present, a considerable number of bridges are equipped with video monitoring systems. At the same time, with the development of deep learning technology, the detection and tracking of vehicles

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Unit influence surface identification of long-span bridge based on spatial-temporal vehicle load monitoring

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Abstract

On-side bridge unit influence surface (UIS) calibration traditionally relied on the vehicle load test, which is expensive, time-consuming and traffic-interruptive, especially for long-span bridges. This paper proposes a novel method for bridge UIS identification based on the vehicle load monitoring. By employing a multi-vision system and computer vision algorithms, the distribution of the vehicles on the bridge deck is obtained. Then the data fusion between the vision system and weigh-in-motion (WIM) system is implemented to acquire the spatial-temporal vehicle loads on the deck. In the meanwhile, the deflection of the main-span is also obtained by the SHM system of the bridge. Thus, by means of the iterative computation and surface fitting, the UIS of the deflection is identified. The proposed method is arranged and applied to a practical long-span suspension bridge. Results have shown the feasibility of the method.

Keywords: long-span bridge; unit influence surface; vehicle load monitoring; computer vision; data fusion.

1 Introduction

The unit influence surface (UIS) is a mathematical model to to characterize input (loading) - output (response) interactions of a structure by analysing measurement data. Generally, the UIS of a practical bridge is identified via an experiment with testing vehicles, which requires various standard vehicles and long-term traffic closure. Specifically, for long-span bridges, the requirements are cumbersome and unaffordable for frequent structure experiments.

During the recent years, the computer vision aggregated with deep learning methods have been applied to civil engineering for complex modelling[1]. Typical cases such as damage recognition[2][3], vehicle monitoring[4], bridge reconstruction[5] and scene understanding[6]. These applications have verified the robustness and supplementary of the vision sensors.

In particular, the vision system is able to obtain the spatial-temporal distribution of the vehicles on the bridge deck. By means of the multiple cameras and weighing sensors, the complete vehicle load monitoring is which is one of the main dynamic loads of long-span bridges. On the other hand, the response of the bridge is obtained via the pre-embedded structural health monitoring (SHM)

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Research on Identification of Time-Varying Cable Force

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Abstract

Cables have been widely used in the construction of cable-supported bridge due to their light weight and high strength mechanical properties. As the key component of cable supported bridge, real-time monitoring of the time-varying cable force of cable is very important for the construction, operation and maintenance of long-span bridges. Based on the time-frequency analysis method of multisynchrosqueezing transform, a new identification method of time-varying cable force is proposed. First, the theory of time-varying modal parameter identification based on time-frequency analysis method is studied. On this basis, the relationship between the time-varying cable force and the instantaneous natural frequency is obtained. Finally, the accuracy of the proposed method under different conditions is studied. The results show that the proposed time-varying cable force identification method has good accuracy and robustness.

Keywords: cables and hangers of bridge; time-varying cable force; time-frequency analysis; multisynchrosqueezing transform.

1 Introduction

In recent years, cable-supported bridge, as the main choice of long-span bridge, has developed rapidly [1]. As the key component of cable-supported bridge, the internal force state of the bridge structure is affected by the cable force directly. Real time monitoring of the dynamic cable force in the process of tensioning, use and replacement is of great significance for the construction, operation and maintenance of long-span bridges.

The frequency method based on vibration has the advantages of simple, convenient, fast and low cost. It has become the most popular cable force test method at present. In principle, higher natural frequency identification accuracy requires a longer cable vibration response data block, which means that the identified cable force is at the midpoint of the data block, and there is still a delay of half a data block compared with the current time [2]. Therefore, the traditional identification method of cable force based on vibration can only identify the average cable force in a period of time, and can't obtain the time-varying cable force.

The identification of time-varying cable force is essentially an inverse problem of structural dynamics, that is, the modal parameters or physical parameters of the structure are identified

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Research on the Damping Ratio Variation of Vehicle Bridge Interaction System Based on the Complex Mode Method

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Abstract

Vehicle-bridge interaction (VBI) is a classical problem in bridge structural health monitoring (SHM), and there are many studies on this problem. However, most of the studies have focused on the frequency of VBI systems and neglected the damping. In this paper, the effects of vehicle parameters on the damping ratio of VBI systems are investigated. First, the equations of motion (EOM) of the VBI system are given. Then the damping ratios of the VBI system are solved by the complex mode method, and the results are verified by numerical simulation. Finally, the effects of vehicle parameters on the damping ratio of the bridge are analyzed. The results show that the speed, position, mass, frequency, and damping ratio of the vehicle will affect the damping ratio of the VBI system. When the vehicle frequency is close to the resonance condition, the change of damping ratio of the bridge is not negligible.

Keywords: Vehicle-Bridge Interaction; Damping Ratio; Complex Mode Method; Vehicle parameters.

1 Introduction

The frequencies and damping ratios of bridges are important indicators in the bridge structural health monitoring (SHM), as the dynamic characteristics of bridges contains information on structural damage. Traffic loads also have an impact on the dynamic characteristics of bridges[1], therefore it is important to explore this issue in order to assess the condition of bridges.

Many studies have shown that the natural frequencies, damping ratios and vibration modes of bridges will change due to the vehicle-bridge interaction (VBI) effect. Yang[2] studied the variation of vehicle and bridge frequencies when a vehicle acts on a simply supported beam and gave a closed form solution considering only the first order vibration mode without damping. The results show that the effect of the VBI effect on the inherent frequency of the bridge cannot be ignored, when the vehicle mass is large or the frequency is close to the resonance condition. Yang[3] proposed an indirect method based on S-transformation to identify the bridge frequency when a vehicle passes over a bridge. From the identification results it can be seen that the bridge natural frequency varies with the vehicle position and vehicle mass. Cantero[4] conducted an experiment to measure bridge frequencies and modes for vehicles in different positions and used a simplified numerical model to analyse the results. The results show that the bridge frequency varies with the vehicle position. Stoura[5] and Yau[6] studied the additional damping effect of bridges caused by the VBI effect. They also gave separate simplified formulas for additional damping applicable to railroad bridges. From the above studies it can be found that the position, speed, mass and dynamic characteristics of the vehicle have an effect on the frequency and damping ratio of the bridge. However, there are few studies that discuss the

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Response Reconstruction Based on a Multi-End Convolutional Neural Network

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Abstract

Structural health monitoring (SHM) techniques evaluate the state of the structures and detect damages based on the analyses of the monitored responses. As the measurement of all target responses can be difficult due to various limitations, reconstructing the target responses using measured data is necessary. To reconstruct the response data in the field of structural health monitoring, this paper proposes a multi-end deep convolutional network with an encoder-decoder structure and skip connections. The responses are computed by the finite element model and then divided into the training set. The proposed network model is trained to map the relationships among the various responses of involved positions. Varied measured data can be fused to reconstruct different desired responses at multi-position, leveraging a single network. Two numerical simulations are conducted to demonstrate the proposed method's applicability.

Keywords: response reconstruction; multi-end convolutional neural network; data conversion; data fusion; structural health monitoring.

1 Introduction

In structural health monitoring (SHM), measured response data is one significant basis for structural condition evaluation and other in-depth analyses. However, obtaining all the desired responses directly can be hard or even impossible due to the economic and technical restrictions.

Various indirect approaches have been proposed aiming to convert available responses to the target ones. These methods can be roughly categorized into two types: model-driven and data-driven.

Early-developed model-driven approaches include inverse-FEM[1-3] and dynamic expansion(or reduction)[4,5] methods. Besides, the hybrid monitoring theory has been proposed[6,7]. By forming and solving an underdetermined equation, it can estimate the equivalent load and then apply it to the FEM to compute the desired responses.

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Bridge Performance Prediction Approach Based on Improved Particle Filter and Structural Health Monitoring Data

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Abstract

To reasonably and dynamically predict the performance of the in-service bridges, this paper proposes an adaptive-variance Bayesian-dynamic-linear-model Improved Particle Filter (IPF) prediction approach to reliability for bridge structures with sensor measurements. First of all, the adaptive-variance dynamic linear model, which provides state equation, monitored equation and initial state information for the PF, is built with the measurements of bridge sensors. The corresponding theoretical and numerical recursive processes are carried on with the Bayes method. Then the built adaptive-variance Bayesian-dynamic linear model is applied to provide the dynamic importance distribution functions for PF, which can solve the sample degradation problem of the traditional particle filter. Proceed to the next step, using the IPF prediction approach and FOSM method, structural reliability at critical points is dynamically predicted based on the sensor data. Finally, an actual bridge is provided to illustrate the feasibility and application of the proposed model and method.

Keywords: sensor measurements; performance; adaptive-variance dynamic linear model; the importance distribution function; structural reliability.

1 Introduction

Structural Health Monitoring (SHM) is a valuable technology to ensure the safety of civil infrastructures and achieve their sustainable management [1]. For the in-service bridges, structural safety is essential. The sensor data provided by SHM systems is a critical parameter in structural safety analysis and can be used to evaluate and predict structural dynamic safety reliability.

SHM has become the escalating urgent need for modern bridge engineering in recent years and has grown into a hot topic in investments and research worldwide. With the innovation of sensing data acquisition, SHM systems are comprehensively deployed and used to obtain the extreme stress data of the long-span bridge bridges in different sampling frequencies. Making reasonable use of sensor data for predicting the dynamic reliability of the existing bridge has been still in the initial research stage. Still, it has become one of the leading scientific problems in the BHM field.

Nowadays, Structural Health Monitoring (SHM) research mainly focuses on sensors-based data acquisition and sensor data application. The research about data acquisition mainly concentrates on data compression, data recovery, data acquisition technology, system assembly technique, and so forth [2-6]; currently, these researches have been mature in the hardware and

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Uncertainty Minimization Technique for Joint Input-State Estimation Using Dummy Measurements

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Abstract

Joint input-state estimation algorithm is a Kalman filtering based technique that can be used for the identification of forces applied to a structure together with the unmeasured response quantities of interest. However, when applying this technique, displacement or strain measurements have to be used in order to guarantee the stability conditions. This paper presents a joint input-state estimation algorithm that uses dummy displacement or strain measurements to yield stable results. The quantification of the estimation uncertainty originating from the errors of using dummy measurements is elaborated in this paper. As joint input-state estimation is an on-line algorithm, this paper also provides an updating method to minimize the estimation uncertainty during the real-time estimation. This uncertainty minimization technique that uses dummy measurements in joint input-state estimation is verified using numerical simulations.

Keywords: kalman filtering; joint input-state estimation; uncertainty quantification; uncertainty minimization; on-line estimation.

1 Introduction

The problems of estimating the dynamic forces applied to a structure and the true states of the system are very important in structural dynamics. Several Kalman filtering based techniques have been proposed in the literature to jointly estimate the input forces and the corresponding states [1, 2, 3, 4]. The classical Kalman filter assumes the input forces either known or broadband, which may easily lead to bias errors in the results. While estimating the unknown forces and states together can yield unbiased estimates. However, if only acceleration measurements are used for jointly estimating the forces and states, the results will be unstable, where a drift can be seen in the estimated result [2, 3]. In order to guarantee the stability condition, displacement or strain measurements have to be used together with acceleration measurements in the estimation [5].

Displacement measurements can be measured with GPS or visual positioning systems, but unfortunately the accuracy of the measurements is usually too poor to give any practically useful results. High-quality strain measurements can be obtained with standard Fiber-optic Bragg Grating (FBG) strain sensors. However, the placement of strain-gauges is an arduous process and the interrogator instruments for FBG sensors are still very expensive. Without directly measuring the actual displacement or strain response, Naets [6] proposed to use dummy measurements to satisfy the stability condition.

In this contribution the method using dummy displacement or strain measurements for stable force identification is further investigated by

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Pixel-level Road Crack Detection and Segmentation Based on Deep Learning

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Abstract

This paper proposed an integrated framework for detecting and segmenting road cracks in complex backgrounds. Based on the latest real-time object detection algorithm, YOLOv5l6, a modified U-Net embedded Bottleneck and Attention mechanism modules was developed to segment crack pixels from the detected crack regions. Validation of the proposed approach was conducted based on a total of 150 images, which were taken from different backgrounds, angles, and distances. Based on the computation, the results derived from the YOLOv5l6-based crack detection had a mean average precision of 92%, and the mean intersection of the union of the modified U-Net was 87%, which is at least 11% higher than the original U-Net model. The results showed the integrated approach could be a potential basis for an automated road-condition evaluation scheme for road operation and maintenance.

Keywords: road engineering; object detection; crack segmentation; deep learning.

1 Introduction

Cracks, as a common defect during the road serving process, have posed an adverse influence on driving comfort and transportation safety [1]. Road management and maintenance departments generally collect images and confirm diseases by the traditional manual method, which involves high cost, high risks, and high subjectivity. With gradually increasing demand and diverse detection scenarios, there is an urgent need for an economical, efficient, and accurate method of road crack detection to assess road performance [2-4].

Convolutional neural networks (CNNs), a deep learning algorithm simulating the top-level arithmetic logic of the human brain, possess unique superiority compared with conventional methods in the machine vision field [5,6]. Road crack detection tasks based on CNN are divided into three categories, including image classification, object detection, and pixel segmentation [7], and the latter two were studied in this work.

Object detection means identifying crack objects in an image and locating their position with bounding boxes. Cha et al. [8] used the faster region proposal convolutional neural network (Faster R-CNN) for automatic crack detection and showed it well-performing with an average accuracy of 94.7%. Du et al. [9] proposed a road surface detection and classification method based on the You Only Look Once (YOLO) algorithm, which can rapidly identify and classify road surface defects. However, due to the irregularity of crack distribution path, shape, and density, the object detection algorithm simply

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Safety Risk Analysis of Super-Large Span Suspension Bridge Supporting Rotary Structure Composite Ground Wall Anchorage Foundation

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Abstract

According to the geological characteristics of the deep soft overburden and high pressurized water where the anchor of the 2300 meters suspension bridge is located, the safety risk analysis of the diaphragm wall anchorage foundation with rectangular-ambulatory-plane was carried out, and the risk sources were sorted out. The risk levels of each risk source were evaluated by expert questionnaire, and the risk levels of anchorage were analyzed by Kent index method. The countermeasures of all risk sources were formulated, and the main risk factors were studied. On this basis, the design scheme of anchorage foundation was optimized, the key control measures of risk factors in the construction process were put forward, and the corresponding emergency plans for main construction risks were formulated, which provided a guarantee for the smooth implementation of anchorage foundation scheme.

Keywords: anchorage; risk assessment; suspension bridge; diaphragm wall; deep excavation; composite foundation.

1 Project Overview

1.1 Geological Conditions

The main span 2300m span of the Zhangjinggao Yangtze River Bridge Southern passage bridge is a two-span suspension bridge with continuous steel box girder elastic support semi-floating system. The strata where the anchorage is located are mainly quaternary alluvial-diluvial silty sand, partially intermixed with silty clay and silty clay. The upper strata are loose and slightly dense, the middle strata are slightly dense-medium dense, and the lower strata are dense. The geological characteristics are as follows: (1)There is no good holding layer within the range of 60m depth; (2) There is no good waterproof layer within 100m

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Research on Fatigue Vehicle Models of Yangtze River Highway Bridge

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Abstract

In order to propose an equivalent fatigue vehicle suitable for the actual traffic flow, the vehicle load characteristics and fatigue vehicle load models were investigated based on WIM database in a Yangtze River highway bridge. The research results show that the bridge has the characteristics of large traffic volume, high proportion of heavy vehicles and severe overloading. All the vehicles can be divided into 6 types based on the wheelbase, and the fatigue vehicles with an equivalent vehicle weight greater than 10 t accounted for 85.9%, of which 6-axle vehicles dominated the fatigue damage. Compared with the Eurocode's four-axle standard fatigue vehicle, the single axle weight derived from the actual traffic flow in this paper is 1.30 times that of the standard fatigue load model, which can provide guidance for fatigue design and maintenance of the same type bridges in the area.

Keywords: fatigue loading spectrum; traffic flow; fatigue vehicle model; steel bridge deck; standard fatigue vehicle.

1 Introduction

With the rapid development of China's social economy, people's communication and traffic have become more frequent, and the road traffic flow has increased accordingly. However, the continuous growth of traffic volume has brought great challenges to the operation and maintenance of the bridge, especially the increase of heavy trucks and the existence of overloading vehicles, which results in the fatigue problem of the orthotropic steel bridge decks.

Reasonable and accurate vehicle loads are the key to the safety assessment of bridge structures during the operation. Therefore, it is of great significance to clarify the fatigue vehicle load spectrum for the anti-fatigue design and fatigue life evaluation of steel bridge decks. Numerous studies on fatigued vehicles have been carried out in many countries, and relevant results have been brought into specifications or codes. The fatigue load of the AASHTO is a 3-axle standard fatigue car with a total weight of 325kN [1], and the load form used in the anti-fatigue design is simple. In contrast, the BS5400 and the Eurocode both give more detailed frequency spectrum of the fatigue load vehicle model [2-3]. Ye [4] investigated the distribution of wheelbase, axle weight and gross vehicle weight and proposed a six-axle fatigue-loaded vehicle model based on WIM system. Maljaars[5] suggested to replace the standard fatigue load model III in the Eurocode with a more accurate five-axis fatigue vehicle through the analysis of Dutch measurement data.

Apparently, vehicle load distribution varies in different areas, European and American standard fatigue vehicle does not reflect the current traffic conditions in China. In addition, the sample size of vehicle is not enough to reflect the operating vehicles and early established fatigue vehicle can not reflect the development and variation of

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Quantitative Analysis of the Importance and Correlation of Urban Bridges and Roads in the Study of Road Network Vulnerability

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Abstract

The city development is closely related to the performance of the transportation network system. Bridges and roads are important parts of the transportation system, and are also inseparable components of the transportation network. However, the effect of the correlation between bridges and roads on the network system has not been studies thoroughly in the literature. Therefore, it is necessary to analyze the vulnerability of the road network when both bridges and roads are involved. In this paper, the urban road network is modeled into the form of network connection and node, based on the analysis of the related research results of road network vulnerability in the literature. Taking the urban roads at all levels as the connection and the transportation hubs (including bridges) as the nodes, the paper puts forward the corresponding measurement indexes and calculation methods, and establishes the importance and correlation analysis model of roads and bridges in the urban road network.

Keywords: urban road network; transportation system; vulnerability analysis; importance and correlation between bridge and road.

1 Introduction

Road traffic network vulnerability usually refers to the sensitivity of road network capacity reduction caused by emergencies, which is manifested as the cascading failure of related road sections caused by the loss of capacity of some road sections, resulting in large-scale traffic network congestion [1]. With the enrichment of modern means of transportation and modes of transportation, the vulnerability analysis of road network has become an important work of urban road planning.

Scholars have done a lot of research on road network vulnerability. Berdica [2] defines vulnerability by considering the probability and consequence of events that affect the road transportation system, that is, vulnerability in the road transportation system is the susceptibility of events, which can greatly reduce the maintainability of the road network. Jenelius [3] pointed out that the purpose of road network vulnerability analysis is to assess the possibility of emergencies and their economic and social

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The Durability and SHM System of Hong Kong-Zhuhai-Macao Bridge

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Abstract
The Hong Kong–Zhuhai–Macao Bridge (HZMB) located at the Pearl River Estuary on the south coast of China, links Hong Kong in the east with Zhuhai-Macao in the west with a total length of 55 km; It is the longest sea-crossing made of artificial island, immersed tunnel and steel bridge in the world, and was opened to traffic in October 2018. The environment where HZMB located is almost the most severe subtropical marine corrosive environments in China, the durability, maintenance and operation are undoubtedly amongst the major work of this project. In the view of the prominence of this bridge, it is a huge challenge for the engineers to achieve this. This paper describes the durability and integrated structure health monitoring system of HZMB.

Keywords: Hong Kong-Zhuhai-Macao Bridge; durability; integrated SHM; monitoring results.

1 Introduction
The 55-km-long Hong Kong-Zhuhai-Macao Bridge is the longest sea-crossing bridge in the world, which consists of a six-lane highway connecting Hong Kong with Zhuhai and Macao at the mouth of the Pearl River Estuary in China, as shown in Figure 1.

The HZMB main bridge made of bridge, immersed tunnel and artificial island, has a length of 29.6 km, The tunnel is approximately 6.7km in length, with 2 artificial islands approx. 625m long and the immersed tunnel approx. 5.7km long. The immersed tunnel comprises of 3-cell, 180m long precast concrete segments. The bridge has a length of 22.9 km, including three navigation channel cable-stayed bridges, approx. 15-km-long steel box girder marine viaducts with 110-m spans and 5-km-long concrete-steel composite box girder viaducts with 85-m spans. which is the largest scale of sea-crossing steel bridge in the world, over 2-million m^3 concrete and 425 000 tons steel structures. A design service life of 120 years was first used in China Mainland. The project was completed in February 2018 and was opened to traffic in October 2018.

The HZMB is situated in the southern subtropical marine monsoon region of China, subjected to

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Seismic Performance Evaluation of an Existing Vertical Irregularity Reinforced Concrete Building using Nonlinear Time-history Analysis

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Abstract

On 5th May 2014, the Mw 6,1 Mae Lao earthquake occurred at a depth of approximately 6 km in the northern Thai province of Chiang Rai, which caused extensive damage to the community, and spread to Bangkok, an epicentral distance of 670 km, where tall buildings swayed. This paper evaluates the seismic performance of an existing 26-storey reinforced concrete (RC) building with vertical irregularity located in Bangkok, Thailand. The understanding gained from this evaluation can be used to propose effective control measures for similar existing high-rise RC buildings. As the building was constructed in 1990, the structure no longer meets the new Thai regulation. As a result, the building may have sustained significant damage, and an assessment had to be conducted according to the Thai Ministerial Regulation B.E. 2564 (2021). A seismic safety evaluation was applied by using the nonlinear time-history analysis (NLTHA) which was performed by the software ETABS 18.1.1.

Keywords: seismic performance evaluation; nonlinear time-history analysis; high-rise building.

1 Introduction

On 5th May 2014, the Mw 6,1 Mae Lao earthquake (EQ) [1] occurred at a depth of approximately 6 km in the northern Thailand (TH) province of Chiang Rai (Figure 1a), which caused extensive damage to the community, and spread to Bangkok (BKK) where tall buildings (BLDG) swayed. BKK is built on deep and soft alluvial soil, which can amplify incoming ground motion even from events occurring hundreds of kilometers away. Figure (Fig.) 1b shows how ground motion experienced at locations on deep alluvial basins can be further amplified above and beyond what would be expected using the near-surface soil stiffness parameter only. An example EQ was observed in 1985, the Mw 8,1 Michoacan EQ in Mexico City [2], a city which has geological conditions particularly well aligned to yield destruction from distant subduction EQs, and serves as a warning for BKK. Due to its surficial geologic setting, and the ability of regional sources to cause a major EQ, BKK is susceptible [3,4]. Fig. 2 shows major historical EQs in Thailand (1920-2020). The Thai Meteorological Department (TMD) seismic station is located in the BKK basin (Fig. 3) [5,6]. Fig. 4 shows acceleration time history, Fourier spectra and horizontal-to-vertical (HV) ratio of Fourier spectrum of the EQ.

2 Aim of the Study

This paper evaluates the seismic performance [7] of an existing 26-storey RC BLDG with vertical irregularity using NLTHA. The BLDG is located in BKK and was constructed in 1990. The structure no longer meets new regulations. As a result, the BLDG may have sustained significant damage, and an assessment had to be conducted according to the Thai Ministerial Regulation B.E. 2564 (2021).

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Seismic Performance Assessment of Multi-Span Continuous Railway Bridges Across a Symmetrical V-Shaped Canyon Considering the Near-Source Topographic Effect

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Abstract

Topographic features have remarkable influences on the characteristics of ground motions, which may cause the amplification of input seismic waves. The objective of this study is to numerically explore the near-source topographic effects on the seismic behaviors of an existing railway bridge crossing a symmetrical V-shaped canyon. Numerical results demonstrated that the topographic effects can noticeably amplify the seismic responses of the bridge. Compared to the bridge without crossing a canyon, the peak displacement of the girder and pier in the case of the canyon-crossing bridge increases by 15.2% and 2.9%-14.5%, respectively. The piers at the illuminated side of the canyon experience larger seismic responses compared to the piers at the shaded side of the canyon due to the unequal motion amplitudes at each support.

Keywords: railway bridges; V-shaped canyon; topographic amplification; seismic response.

1 Introduction

To improve socio-economic development, the transportation network has been extended to the mountainous areas in western China[1]. Many bridge structures have been or are being constructed across various canyons in high seismic zones. One case in point is the Sichuan-Tibet railway in China, which is being constructed in a high seismic risk region and across numerous deep canyons or valleys along the railway line [2]. Past earthquakes have demonstrated that the canyon slopes may cause the amplification of the ground motions [3-6] and as a result, the bridge structures may experience serious seismic damage. For example, the Miaoziping bridge crossing the Zipingpu canyon and the Baihua bridge crossing the Minjiang river sustained serious damages under the Wenchuan earthquake [7]. These damage examples have raised public concerns on the seismic safety of the canyon-crossing bridges near an active fault.

It has been widely recognized that the scattering of seismic waves in the presence of a V-shaped canyon may cause significant modification on earthquake ground motions. Many researches have been conducted to investigate such topographic effects through domain methods [8-

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Fire Risk Evaluation of Cable Bridges due to Vehicle Fires

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Abstract

Cable bridges use multiple cables as main members, and there is a risk of bridge failure in the event of cable loss. To manage the bridge safety from such event, a risk analysis method is necessary. In this study, fire risk analysis was performed on Seohae Bridge, a steel composite cable-stayed bridge, and on Yi Sun-sin Bridge, the longest suspension bridge in Korea. A fire risk analysis method is proposed to determine the final annual frequency of bridge failure. This method calculates the annual frequency of vehicle fires based on statistical data and appropriate assumptions, and determines the conditional probability of exceeding the limit state of the main structural member through fire analysis and bridge structural review. For the statistical data on the annual fire frequency, domestic statistical data were investigated and actual data were analysed and applied, and various probabilities such as oil leakage and ignition probability in the event of an accident were assumed.

Keywords: fire risk evaluation; cable loss; fire risk analysis; annual frequency of bridge failure; conditional probability; annual fire frequency.

1 Introduction

Recently, the construction of sea-crossing and long-span cable-supported bridges, such as cable-stayed and suspension bridges, has increased to overcome topographical constraints. In the cable-supported bridges, a number of cables are used as a main structural member to provide vertical restraint to the stiffening deck against the superstructure loads, and thus the loss of the cables may lead to a collapse of the bridge. A risk management of the cable system is subsequently necessary in the event of a disaster. Similarly, a risk management of the other main structural members, which are the tower and the stiffening deck, is also necessary in the event of a collapse of the cable system. For the cable-stayed bridges, there was a cable rupture due to lightning in the Rion Antirion Bridge (Greece) in 2005 and the Seohae Bridge in 2015. In 2007, there was a cable

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Measure the Application of Pre-Stressed CFRP Laminates Using Deep Learning for Computer Vision

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Abstract

Strengthening of reinforced concrete (RC) structures with pre-stressed Carbon Fiber Reinforced Polymer (CFRP) laminates is a well-known application. The development of vision-based approaches for monitoring the strain imposed during the pre-stress application, with the required precision and accuracy, represents an important contribution for the state of the art. A new system, named Strain-Vision, was design and developed tacking into account three main modules: (i) development of a customized high precision strain monitoring CFRP laminates (hpsm-CFRP); (ii) definition of a set-up for image acquisition during pre-stress application; (iii) design of computer vision architecture based on deep learning to measure the strain. The pre-processing of data, to be analysed with an architecture previously training, is herein discussed, aiming to improve the quality and performance of the system without the need for large datasets, usually required in deep learning applications.

Keywords: CFRP laminates; strengthening RC; strain monitoring; deep leering; computer vision.

1 Introduction

The application of pre-stressed Carbon Fiber Reinforced Polymer (CFRP) laminates for strengthening of reinforced concrete (RC) structures is a widespread solution. In the case of slabs and beams, the pre-stress is applied with a hydraulic jacks and the laminates are externally glued (Figure 1). The pre-stress level is measured from the pressure applied or from the displacements measure by rulers and markers. The direct measurement of the strain applied with traditional instrumentation, such as strain gauges and transducers, are time-consuming and laborious, and is just used in special cases. Therefore, development of new methods to monitoring the pre-stress application on the CFRP laminates represents an important contribution in these cases. Thus, an innovative vision system, based on deep learning for computer vision, for monitoring the strain with high level of precision and accuracy during the application of pre-stress was developed and implemented. The system is developed in three main modules: (i) development of customized high precision strain monitoring CFRP laminates, designated hpsm-CFRP; (iii) definition of data acquisition set-up, based on digital cameras to acquire images during pre-stress application; (iii) design of a deep learning architecture for computer vision to measure the

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Inspection Information Preprocessing for Regional Bridge Condition Assessment

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Abstract

Condition assessment of bridges on a regional level can provide an accurate assessment of bridges lack of inspection data and reliable prediction of structural condition for regional bridges. The core work of regional bridge condition assessment (RBCA) is the establishment of regional deterioration models, which requires a large amount of historical health data of bridges provided by inspection reports throughout service history. An inspection information pre-processing framework is proposed in this study, including data extraction, integration, and storage. The proposed framework can greatly reduce the amount of time and work invested in the information gathering process, providing richer data support for (RBCA). The framework is applied to 2 sets of inspection reports of 2 different highway bridge networks in Shandong.

Keywords: regional bridge condition assessment (RBCA); structural condition assessment (SCA); inspection data; regional bridges.

1 Introduction

Massive construction of civil infrastructure has been launched in China since the 1980s. Up to 2021, more than 913 thousand bridges are in service, with a total mileage of 662,855 kilometres in China[1]. Suffering from environmental erosion, overloading, and natural and human hazards, it is inevitable that bridges are constantly deteriorating [2]. Due to the constant deterioration, regular maintenance is required to ensure the safety and utility of bridges. However, bridge maintenance has always been a trade-off between cost and effectiveness. A short maintenance cycle can lead to a satisfying maintenance outcome and a huge budget. An imprecise maintenance strategy may significantly reduce the cost of time and effort and leave safety hazards undiscovered. Therefore, it is essential to assess structural condition accurately, preventing waste of limited maintenance resources.

Structural condition assessment (SCA) always is the focus of the civil engineering community. New theories and technologies kept been emerging in the past few decades. Current SCA theories can be divided into two categories: theories based on probabilistic reliability models and theories based on historical health data[3]. For theories based on probabilistic reliability models (PRM), the key to

Crack Control Technology in Construction of V-Shaped Piers of the Main Bridge of China-Maldives Friendship Bridge

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Abstract

The piers no.19~21 of the main bridge of China-Maldives Friendship Bridge are V-shaped piers, which are constructed by the method of "cast-in-place slant legs with cable-stayed connection and hanging section + cast-in-place block no.0 with inner supports". Based on the analysis of the whole construction stage of the bridge by the finite element method, the factors of concrete cracking during the construction of V-shaped piers are grasped. In view of the risk of structural cracks, the scheme of setting prestressed steel beam in the slant legs and accurately controlling the removal time of the cable hanging bracket is adopted to effectively prevent the concrete cracking during the construction of V-shaped piers.

Keywords: continuous rigid frame bridge; v-shaped piers; crack control; construction technology; prestress; stress control.

1 Project overview

The main bridge of China-Maldives Friendship Bridge is a six-span rigid frame bridge with concrete and steel box composite girders and V-shaped piers. With a total length of 760m, asymmetric spans of (100 + 2×180 + 140 + 100 + 60)m are adopted. The triangular area of piers no.19~21 is a concrete V-shaped pier structure.

Pier no.20: the angle between the middle axis of slant legs and the center line of the pier is 64°; the bottom of block no.0 on triangular pier top is a cambered surface with a radius of 50m and the circular chamfer with a radius of 3.1m is applied for transition between V legs. Overall 1910.5m³C55 marine concrete with a total weight of 5063t is used in the V-shaped pier in the triangular area.

Pier no.19 and no.21: the radius of bottom of block 0 of box girder on triangular pier top is 50m and the circular chamfer with a radius of 1.5m is applied for transition between V legs. Angles between the middle axis of slant legs and the center line of the pier are 70° and 66° respectively. Overall 1764.1m³ C55 marine concrete with a total weight of 4675t is used in V-shaped piers in the triangular area.

V legs are single box double chamber concrete sections with top width of 9.9m, bottom width of 8.8m and cross section of 3.4~4.6m. The structure of block no.0 box girder is the single box double chamber with top width of 21m and bottom width of 12.1m. The beam height varies gradually and the minimum beam height is 2.7m. The closure of V legs and block no.0 forms the main girder structure.

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Study on the Influence of Bridge Expansion Joints on Vehicle-Track-Bridge System

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Abstract

Bridge expansion joints (BEJs) are equipped at the girder end of long-span railway bridges to ensure the reliable transition of the track. The track structure of BEJs is more complex than that of bridge, so the BEJs should have suitable dynamic stiffness to ensure the safety and stability of vehicle. Taking a high-speed railway bridge equipped with densely arranged BEJs as an example, a vehicle-track-bridge coupled model was established to analyse the influence of vertical stiffness of BEJs on the dynamic response of whole system. Base on the established model, the study shows that the deformation of the BEJs will cause the short-wave irregularity of the rail and high-frequency impact on the vehicle. The unreasonable stiffness of BEJs will greatly increase the derail risk of the vehicle, so the influence of the stiffness of BEJs on the dynamic response of vehicle should be considered adequately in the design of the BEJs. According to the research results, it is recommended to use a larger stiffness of cushion plate. The results have been applied to the design of the BEJs on the studied railway lines, which are in good service condition at present.

Keywords: BEJs; railway bridge; vehicle-track-bridge coupling model; dynamic response.

1 Introduction

With the rapid development of railway industry and the increasing of bridge span, BEJs have become a vital device for long-span railway bridges. It not only needs to match the deformation of the girder end, but also needs to have good strength and stiffness to bear the dynamic load brought by the vehicle. Since the track structure of BEJs is more complex than that of the bridge, BEJs are regarded as the weak parts of the railway and has attracted extensive interest of researchers.

The performance of BEJs, including the deformation and joint force, in service condition have been studied [1-4], and plenty work has been done on the failure mechanism of BEJs [5, 6]. Although BEJs have been widely studied, the impact of BEJs on vehicle is not clear enough. According to the detection results of the railway department, the dynamic response of vehicle on BEJs is significantly greater than that on other areas. The dynamic stiffness of BEJs is the main factor affecting the dynamic response of vehicle. Therefore, this study built the vehicle-track-bridge coupled model to investigate the influence of the vertical stiffness of BEJs on the dynamic response of vehicle.

Taking a high-speed railway line in China as a case to study. In order to reduce the seismic response of the structure, hyperboloid bearings are used as

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Numerical Examination in Bridge Responses due to Fracture of Truss Member in a Steel Truss Bridge under Vehicle Loadings

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Abstract

This study investigated the bridge responses and modal parameters of a steel truss bridge based on FE analysis considering vehicle loadings and aimed to propose an adjustable damage scenario for a loading test on the target bridge. The idea of this study is that the modal parameters and stress distribution identified under assumed damage scenario can provide useful information to decide artificial truss member cut-off patterns and to ensure the bridge safety in the vehicle loading tests. A three-dimensional FE model is constructed using commercial FE analysis software suite for calculating modal parameters (natural frequencies and mode shapes) and maximum internal member force of the bridges. The eigenvalue analysis and static loading analysis were conducted with intact bridge and damaged bridge whose member fracture is simulated by removing one vertical, diagonal member, or two vertical members, in order to find the most severe condition for cutting locations where largest axial force occurs. Results show that variation in modal frequency and mode shape due to different damage scenario are conspicuous. Effect of cut-off pattern changes of damage scenarios are observable by comparing the analysis results between intact and damaged bridge. Finally, two vertical steel members are determined to be cut off in the field loading test.

Keywords: steel truss bridge model; member fracture; FE analysis; cut-off truss member.

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Research on the Layout of Temporary Piers of Large-span and Super-Width Steel Box Girder during Incremental Launching Construction

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Abstract

It is difficult to understand the mechanical performance of large-span and super-width steel box girder during the incremental launching construction, and it varies with the number of temporary piers. Combined with the engineering example of Qilu Yellow River Bridge in Jinan, this paper conducts research on the layout of temporary piers. Firstly, stress envelope of main girder and maximum support reaction forces under different layout schemes are analyzed with the frame model. Then, the local plate-shell model is used to obtain stress distribution of main plates and local stability of main girder segment under the most unfavorable loading conditions. The results show that local mechanical performance of steel box girder plays a crucial role in ensuring its safety during the incremental launching construction. Besides, rational spacing between temporary piers is 70m for Qilu Yellow River Bridge.

Keywords: bridge engineering; incremental launching construction; steel box girder; layout of temporary piers; finite element analysis.

1 Introduction

The incremental launching construction method has no influence on the traffic under the bridge and does not require large lifting equipment, so it is widely used in bridge engineering. Nowadays, there has been a relatively complete method of force analysis for concrete beam bridges during the pushing process[1~4].

With the improvement of steel production and computer simulation technology, the incremental launching method is no longer limited to concrete bridges, but widely used in the construction of long-span steel bridges, such as Millau Bridge in France [5], Chiapas Bridge[6] in Mexico and Jiubao Bridge[7] in Hangzhou. In recent years, many scholars have carried research on the incremental launching construction of steel bridges. Gao Dong[8] has analyzed the influence of parameters such as

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Research on two Parameters Control of Walking-Type Incremental Launching Box Girder

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Abstract

In order to ensure the safe implementation of walking-type incremental launching steel box girder. Taking a simply supported wide steel box girder bridge as an example, this paper analyzes the local stress of the wide steel box girder with four supporting points of walking pusher, and quantitatively determines the three single parameter related control thresholds of lateral deflection, longitudinal pusher asynchrony and vertical lifting asynchrony that are concerned in the construction. Based on the single parameter control research, the two parameters dynamic control threshold range is proposed. The calculation results show that two parameters analysis provides a more reliable means for walking-type incremental launching construction and is a necessary supplement to the conventional single parameter control.

Keywords: walking-type incremental launching construction; wide steel box girder; local stress; multi-parameter control.

1 Introduction

In recent years, the walking jacking construction method has developed rapidly in China [1]. This method has the characteristics of less interference under the bridge, safety and economy, and is widely used in the construction of bridges spanning railways, highways, and rivers [2-4]. In the process of pushing the steel box girder on foot, the beam body needs to bear the huge support and reaction force caused by its own weight. Under the action of this force, the web and the bottom plate of the beam body are prone to buckling instability. For safe implementation, construction control must be carried out on multiple parameters in the construction process [5-6].

At present, the risk control of walking jacking is to assess the risk of the main girder through a single early warning value of the monitoring data. The risk control of steel box girder by parameters lacks the relationship between the mechanical deformation characteristics of steel box girder, ignores a large number of mechanical relationships between monitoring data, and has relatively weak ability to analyze the local force of steel box girder, so it often occurs that the monitoring data fully meet the Specification or design requirements, but pushes the fact that a risk accident has occurred. For example, the vertical jacking of the same pier meets the 4 mm control threshold specified in "Technical Specifications for Construction of Highway Bridges and Culverts"(JTG/T 3650-2020) [7], and the lateral offset also meets the design requirements, but when the lateral offset and vertical jacking do not When the synchronous combination is applied to the steel box girder, the local stress of the steel box girder may have exceeded the limit, which leads to the case of local buckling of the steel box girder.

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Stress-strain Model Adapted to Bolted Connection in Ultimate Behaviour Considering Energy Absorption

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Abstract

Bolted connection is one of the well-used techniques to connect structural members of steel bridges. Not only load capacity but also energy absorption are important characteristics of the structure to resist seismic action. In a finite element analysis, a true stress-true strain material model is needed to obtain an accurate evaluation in case the structure is exposed to excessive forces and deformed largely, although the true stress-true strain model is almost the same as to nominal stress-strain model in the small strain part. This study proposes a simple true stress-true strain model. And, the validity of the model was confirmed by the compare the finite element analysis and steel material tensile test or tensile experiment of bolted connection. Some true stress-true strain models were investigated and discussed from the viewpoint of load capacity and energy absorption.

Keywords: true stress-true strain model; steel plate; bolted connection; ultimate behaviour; energy absorption.

1 Introduction

Bolted connection is one of the major on-site connection techniques for steel structures in Japan. The design method of highway bridges was recently changed from the allowable stress design method [1] to the limit state design method [2]. Previously, a bolted connection is verified the slip resistance and the yield resistance before the slip. Additionally, the bolted connection was verified the yield resistance of plates in post-slip behaviour and the ultimate resistance of bolt shank shear. Thus, it is important not only to yield behaviour but also ultimate behaviour.

By the way, a true stress-true strain material model is needed in finite element analysis to obtain the accurate behaviour of steel structures including large plastic deformation. We can obtain a stress-strain relationship by the material tensile test of the steel plate. The stress-strain relationship obtained is a nominal one. However, the true stress-true strain is needed for the evaluation by finite element analysis. The difference between nominal and true stress-strain relationship before reach to tensile strength is small and is increased after the tensile strength because the partial deformation of the test specimen called necking occurred after tensile strength. The authors had proposed a simple true stress-true strain model [3, 4]. That was a tri-linear model and determined by the data in the inspection certificate of the steel plate and other values which was complemented by the relational expressions between material properties.

For seismic resistance, the important structural characteristics are not only the load capacity but also energy absorption. The validity of the proposed stress-strain model was checked from

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Computer Vision-based Finite Element Model Updating Method Using Measured Static Data: An Experimental Study

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Abstract

Accurate FE models play an important role in structure health monitoring (SHM). In the traditional static finite element model updating (FEMU) process, loading tests interrupting the traffic are required for obtaining static data, which is inconvenient. This paper proposes a novel static FEMU method based on computer vision technology and WIM system, avoiding the mentioned defects. Firstly, the static response simulation under traffic load is carried out with the computer vision determining the load location and the BIW system deciding the load value. Secondly, signal processing technology extracts the measured static data from the monitoring data. Thirdly, the PSO method is utilized to perform the FEMU. An experiment is designed on a bridge model with an SHM system, and results verify the convenience and accuracy of the proposed method

Keywords: FEMU; computer vision; PSODE; parallel calculation.

1 Introduction

Detailed and accurate finite element (FE) models are vital for structural health condition assessment and damage detection [1]. The initial FE model established based on the documents inevitably differs from the existing structure due to parameter errors, signal processing errors, etc. [2]. Finite element model updating (FEMU) aims to decrease the variation by adjusting the structural parameters such as material elastic modulus and density [3].

According to the data type used in the FEMU process, the FEMU methods are divided into dynamic FEMU, static FEMU, and FEMU using dynamic and static data. In the existing studies of static FEMU methods, the static data are always procured from field tests, which interrupt the traffic and limit the loading scenarios. Up to now, several studies (Xiao et al. [4] and Wang et al. [5]) have carried out static FEMUs using the static data, including static influence lines, static displacements, and stresses. It's worth mentioning that the static data are all generated in the field test, interrupting the traffic and needing lots of preparations. To simpler the process, we can regard each vehicle passing over a bridge during the operational phase as a load test and transform designing vehicle loads in the field tests into

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Algorithm of the Risk of Ship-Bridge Collision Considering Ship's Dimension

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Abstract

The issue of ship collision with bridge is very important topic in the academic research, however, the studies only regard the ship as a particle at present, ignoring the size of the ship, which cause the accuracy of the active early warning system cannot meet the requirements of practice. In this paper, proposes the algorithm of the risk of ship-bridge collision considering the ship's dimension, including the L_{OA} and B_{MAX}. First, utilizing the mercator projection method to make convertion of coordinate system. Secondly, analysing the relationship of geometric position based on the ships, bridge piers and channel to constructe the algorithm of the risk ship collision with bridge. Thirdly, the active early warning strategy is proposed depending on the value from the descripted algorithm. Finally, the reliability of the algorithm is validated by case study. It can improve the accuracy of the risk of ship-bridge collision significantly, and conducive to the application of the warning system.

Keywords: ship collision with bridge; ship's dimensions; position coordinates; risk degree; channel centreline.

1 Introduction

With the development of economy and water transportation, the accidents of ship-bridge collision is increasing[1], which makes the navigational environment be complicated sharply, and the potential risk of ship collision with bridge is concerned widely by the industry. In order to deal with the adverse effects of uncertain factors such as human factor in the accidents, an active early warning system for ship-bridge collision avoidance was born at the right moment. The key to the function of the system dependding on the core index of the risk of ship collision with bridge which touching off the facilities and equipment for warning.The algorithm of the risk of ship-bridge collision and the strategy of early warning are the core key of the system.It is the critical key that the system can be applied to practice really.

Over the years, domestic and foreign scholars have studied the algorithm of ship collision risk from different aspects. Through literature research, the author found that: (1) The traditional methods for anti-collision for bridge only focused on itself, it just depend on its' strong structure to against ship collision in order to minimize the loss. For example, Keke Peng[2] adopted AASHTO method to calculate the ship-bridge collision probability from the perspective of bridge; Tao Fu[3] studied ship collision with bridge based on structural reliability theory; (2) Most of the research adopted subjective qualitative analysis method at present, and only a few scholars studied it from an objective perspective. For example, Yihua Liu[4] designed an algorithm to describe the risk of ship-bridge

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Reliability Evaluation of Bridge Fatigue Life through Refined Statistical Analysis of Stochastic Traffic Flow Monitoring Data

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Abstract

To evaluate the reliability of the fatigue performance of key bridge components under stochastic vehicle loads, a prediction and evaluation method for the fatigue life of bridges based on elaborate statistical analysis of traffic flow and strain influence line identification is established in this paper. Firstly, The two-step clustering (TSC) method is applied to distinguish the different traffic states with the clustering numbers to be determined objectively. The elaborate stochastic traffic flow is simulated by random sampling of vehicle feature probabilistic models for each traffic state. Secondly, the actual bridge strain influence line inverted based on the fatigue detail measured strain data is used to be loaded by the stochastic traffic flow, and the stress time history under the stochastic traffic flow is calculated. The Monte Carlo method is applied to predict fatigue life. Finally, a real bridge is taken as an example to verify the effectiveness of the proposed method.

Keywords: vehicle load monitoring; stochastic vehicle flow; cluster analysis; influence line identification; fatigue reliability.

1 Introduction

In the process of long-term service, the bridge structure is repeatedly loaded by vehicle loads of variable amplitudes, which leads to the continuous accumulation of fatigue damage. The high cycle fatigue problem of bridge components, such as steel bridge decks, is very prominent and seriously affects bridge safety in its design service life [1]. Therefore, it is necessary to evaluate the fatigue performance and predict the fatigue life of a bridge during the operation period by considering the influence of vehicle loads. The vehicle-induced bridge fatigue damage is related to the stress amplitude and stress cycles. The traffic flow per unit time affects the number of stress cycles, and the axle weight and distance affect the stress amplitude. Therefore, it is critical to obtain the vehicle load information for the evaluation of vehicle-induced fatigue.

SHMS can monitor data, such as vehicle load and structural strain under the actual operating conditions of the bridge. Monitoring data-based fatigue evaluation of bridges has attracted considerable attention. Research in this area can be divided into two categories as follows.

The first group of studies mainly focused on fatigue damage evaluation based on structural strain monitoring data [2-3]. The field strain measurement-based fatigue evaluation has the following two shortcomings: i. The field-measured strain is produced by multiple actions, including vehicles, wind and temperature; ii. There are limited strain measuring points for the SHMS,

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On the Benefit of Including Modal Strains in FE Model Updating for Damage Assessment

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Abstract

FE model updating has mostly been performed relying upon natural frequencies and mode shapes. These modal parameters only provide global information about the structure, which leads to important uncertainties. The recent development of fiber optic strain sensors has made it possible to include modal strains in FE model updating. In this paper, it is investigated how including modal strains in FE model updating allows complementing the global information on natural frequencies and mode shapes by the local information in modal strains. Including modal strains can be of major benefit for identification of local damage. With the additional information obtained using modal strains, local uncertainties in FE model updating can be effectively reduced. The benefit of including modal strains in FE model updating is illustrated using modal data from numerical simulations on a reinforced concrete (RC) beam.

Keywords: modal strains; FE model updating; uncertainty quantification; bayesian inversion; complementary information.

1 Introduction

It has since long been recognized that modal curvatures or strains are more sensitive to local damage, therefore, including modal strains in FE model updating can overcome the limitations in FE model updating resulting from the use of natural frequencies and modal displacements only. The recent development of fiber optic strain sensors has made it possible to use directly measured modal strains for FE model updating. Recently developed signal processing algorithms allow standard fiber-optic Bragg gratings (FBG) capturing the very low strain levels (sub-microstrain) occurring under ambient excitation in operational conditions. The use of modal strains in FE model updating has already been explored by several authors [1,2]. The benefit of including strains in terms of the additional information they provide, is yet to be explored, however.

In this paper, modal strains are included in FE model updating for damage assessment. A Bayesian framework is adopted to investigate how the additional information provided by modal strains helps to detect

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Automated Crack Detection Method Based on Deep Learning and 3D Reconstruction for Concrete Bridges

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Abstract

Automated image-based bridge crack detection, as a promising technique, can be used to overcome the limitations of human visual inspection. However, results from current image-based methods are generally localized and lack 3D geometric information, which makes it difficult for structural assessment. To solve this issue, a crack detection method that combines deep learning and 3D reconstruction is proposed in this paper. Firstly, a 2D feature-based approach is developed to extract keyframes from the video adaptively. Secondly, a segmentation network is implemented to conduct pixel-level crack segmentation. Finally, image-based 3D reconstruction and crack mapping are used to create the 3D structure model with crack semantics. A field experiment is also carried out on an in-service concrete bridge for validation and discussion of the proposed method. The 3D model created by the proposed method can significantly improve the crack inspection of concrete bridges.

Keywords: bridge crack inspection; crack detection; deep learning; 3D reconstruction.

1 Introduction

As one of the most important transport infrastructures, bridges are vital to the proper functioning of modern society. To ensure the safety of bridges, regular visual inspections are required, of which surface cracks are one of the indispensable inspected items. Currently, the inspection of surface cracks in bridges is mainly conducted manually, which consumes human resources and has the limitations of being time-consuming and dangerous [1].

To improve the crack inspection process, computer vision-based methods for automated bridge crack detection have been widely studied in the last two decades. Traditional image-based crack detection is mainly based on image processing techniques (IPT) [2,3], but these methods are difficult to distinguish the crack-like interference (e.g., Shadow) in complex scenes. Recently, deep learning is regarded as a promising technique and has been widely used in crack detection [4-6]. Deep learning-based methods greatly improve the identification capability by learning crack features from the dataset and show great potential for

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A Novel Method for Generating Apparent Panoramic Image of Real Texture of Concrete Bridge Based on Multi-View Registration

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Abstract

With the improvement of the informatization and digitization of bridge structures, the importance of technologies such as Building Information Modeling(BIM) and computer vision is constantly increasing. This type of technology all relies on a scan of the structure's appearance. However, based on the principle of optical imaging, there is a contradiction between imaging field of view(FOV) and pixel resolution. Therefore, the existing apparent detection or scanning technology either uses lower pixel resolution to obtain the structured apparent image at the panoramic scale, or a series of scattered high-resolution images in a local area, which has caused two aspect of defects in the detection of apparent damage. On the one hand, low-resolution image data has an adverse effect on the accuracy of deep learning or machine vision models. On the other hand, due to the single surface texture of concrete materials, the number of feature points is scarce in image processing, which reduces the stability of the image stitching algorithm based on feature points. These problems make the apparent images collected in the current inspection work cannot be well applied to the long-term evolution analysis of apparent damage. In order to achieve high-resolution imaging within the panoramic range of the structure, we propose a panoramic image stitching method. Firstly, the traditional single-view imaging is extended to multi-view imaging, and the result images are used for panoramic stitching. Because the feature information in a single image is greatly increased, the stability of the image stitching algorithm based on feature point matching has also been greatly improved. Secondly, through experiments, we determine the number of cameras with the highest efficiency for this novel panoramic image stitching method. Lastly, based on real bridge image data, we evaluate and compare several image stitching algorithms in terms of accuracy, efficiency, and robustness. The experimental results show that this panoramic image stitching method can be well adapted to the apparent scanning task of large-scale components in concrete bridges, and is meaningful for the standardization and automatic acquisition of structural appearance images.

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An Experimental Investigation of the Indirect Bridge Frequency Identification

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Abstract

Indirect identification of bridge frequencies, which refers to identifying bridge frequencies from the dynamic responses of a vehicle moving or stopping on the bridge, has the potential to fast inspect bridges in large quantities. Although there have been extensive studies on this topic, most of them are built on theoretic analysis or numerical simulation, which could differ from the situations in real practice. As a complement, this study carries out an experimental investigation of the indirect approach for bridge frequency identification. In the experiments, a normal passenger car instrumented with accelerometers moves and stops on a real bridge for indirect sensing, and a stationary accelerometer is directly deployed on the bridge as a control. Experimental results provide some new insights into the indirect bridge frequency identification from the practical aspect.

Keywords: indirect bridge frequency identification; vehicle-scanning method; drive-by sensing; power spectral density; signal-to-noise ratio; field test.

1 Introduction

Bridges are key traffic infrastructures that require regular inspections to ensure their operational and structural safety. Among the tasks of bridge inspections, one essential job is to identify the dynamic properties such as the natural frequencies of bridge structures [1]. Currently, one of the prevailing and familiar ways to identify the dynamic properties of in-service bridge structures is the fixed sensing framework. Tough the fixed sensing framework is pretty mature, it manifests some inherent demerits during the engineering practice. First and foremost, this framework is time- and labour-consuming because it needs to deploy a sensor network and a transmission system as a prerequisite [2]. Therefore, this framework is unable to satisfy the vast inspection demand for short- and medium-span bridges that are in large quantities.

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A Fully Automated and Noncontact Method for Force Identification of Cables Based on Microwave Radar

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Abstract

This study proposes a full-automated and non-contact cable force identification method based on microwave radar. Several algorithms have been presented for data processing. The time domain data records by microwave radar is firstly transformed into frequency domain by Fast Fourier Transform. Then, the eigen-frequencies are simultaneously identified with the proposed fast sieve method. Subsequently, a novel algorithm using hash map and weighted voting is applied to estimate orders of eigen-frequencies. Finally, the average ratio between eigen-frequencies and their orders is estimated by weighted least square method, and then the cable force is calculated by using cable frequency formulas. The method has been validated by field tests.

Keywords: cable force, frequency spectrum, microwave radar, sieve method, weighted hash voting, least square method, tension string theory.

1 Introduction

Cable is one of the most significant load-bearing components of cable-stayed bridges. Therefore, cable force estimation is of vital importance in bridge inspection and health monitoring for structural assessment.

Vibration method is widely used in cable force identification, where cable force is calculated by identified cable eigen-frequencies. The most commonly used sensors for this purpose are accelerometers and displacement meters, etc. Nevertheless, the installation of these sensors is time-consuming and labour-intensive, particularly considering hundreds of cables of one bridge.

In recent years, lots of optical detection technologies have been developed and applied in cable vibration measurement. Chu et al. [1] introduced optical method into cable vibration identification by utilizing a novel processing method of image threshold matching. Du et al. [2] proposed that single point and multi-point images can be taken by camera, and compared their theoretical results with the results of

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Numerical Study on Influence of Input Wave's Frequency on Dynamic Pre-Hole Isolation Pile-Soil Interaction in IABs

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Abstract

The expansion joints and bearings can be eliminated in integral abutment bridges (IABs) to fundamentally resolve their durability problems. The pile beneath the abutment is considered as the most vulnerable component of IABs under earthquake. The seismic response of the pile in IABs could be reduced by using the pile with pre-hole filled by damping material (called pre-hole isolation pile). In this paper, a finite element model of shaking table tests on the pre-hole isolation pile-soil system under sine wave load was established by using ABAQUS/Explicit. The influence of the input wave's frequency and the dimension of pre-hole on the dynamic pre-hole isolation pile-soil interaction was analyzed. It can be concluded that with an increase in the dimension of pre-hole, the fundamental frequency of pile-soil system decreased. When the input wave's frequency is less than 8 Hz, the pre-hole isolation pile is more flexible than the normal pile. When the input wave's frequency is 4 Hz, the pre-hole isolation pile with larger pre-hole diameter or depth shows the best seismic performance. However, when the input wave's frequency is 8 Hz, the best seismic performance of pre-hole isolation pile with smaller pre-hole diameter or depth is obtained.

Keywords: integral abutment bridge; pre-hole isolation pile; dynamic soil-pile interaction; finite element model; input wave's frequency; dimension of pre-hole; fundamental frequency of the pile-soil system.

1 Introduction

In order to resolve the durability problems of expansion joints and bearings, improve the driving comfort and reduce the maintenance cost, the concept of integral abutment bridges (IABs) can be adopted. The seismic performance of IABs could be excellent because of high redundancy and integrity [1-2]. The bending moment of the superstructure in IABs can be transferred to the substructure because the superstructure is rigidly connected to

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Corrosion Suppression Effect of Bridge Cables Using Environmental Isolation Paint

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Abstract

This study examined the corrosion suppression effect of bridge cables using environmental isolation paint. The strand rope which is also used for the main cables and hanger ropes of short/middle-span bridges is used for the specimens and compared the presence or absence of the paint on the surface. The accelerated corrosion test was conducted by the salt spray test method to examine corrosion suppression effect. As a result, the rust was confirmed on the appearance of the unpainted specimens, but no rust was confirmed on the painted specimens. Furthermore, the corrosion state from surface to inside was confirmed by EPMA analysis on the cross-section. The distribution of oxygen and chloride were large, and the occurrence of corrosion was confirmed in the unpainted specimens. On the other hand, no corrosion was confirmed on the rope surface in the painted specimens.

Keywords: suspension bridge cables; cable corrosion; anticorrosion; isolation paint; EPMA analysis.

1 Introduction

Main cables, hanger ropes, and stays used for suspension/cable-stayed bridges have been suffer from corrosion and breakage, which has become a serious problem [1)-6)]. Generally, cables are provided with anti-corrosion treatment such as dehumidification system, but this system is economically limited to installation on long-span bridges [3)]. Inexpensive, effective maintenance and repair measures are still required for short/middle-span bridges. This study examined the corrosion suppression effect of bridge cables using an environmental isolation paint.

The environmental isolation paint used in this study is an epoxy resin-based rust inhibitor. Submicron-sized ultrafine particles penetrate into the gaps of the rust structure and have the property of almost blocking the steel substrate from the atmospheric environment. It is expected

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Experimental Study on Activation Performance of Fe-Based Shape Memory Alloy for Strengthening Steel Bridge

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Abstract

To reveal the effect on heat transfer and the distribution of temperature in Fe-SMA during its activation, a series of tests was performed on Fe-SMA strips in this paper. The mechanical properties of Fe-SMA were preferentially studied by uniaxial tensile test, and the activation performance of Fe-SMA strips was investigated by independently designed set-up, in which the temperature can be monitored by eight K-type thermocouples. The test results reveal that the heat-transfer effect of activation in Fe-SMA strips was dramatical with different spacing and transfer time. Furthermore, a theoretical predication equation was proposed to obtain the peak temperature at any point of the structural member, which serves for deciding the adhesive type and the bonding length of adhesive bonding joint for Fe-SMA reinforcement. This paper offers basic material properties and activation performance of Fe-SMA, which can be employed for further numerical study and theoretical study on the smart reinforcement of steel bridges via Fe-SMA.

Keywords: Fe-SMA; steel bridge; strengthening; activation; mechanical property; recovery stress; temperature distribution.

1 Introduction

With the in influence of chloride ion-induced corrosion[1] and the increase in repeated traffic loads[2], numerous steel bridges are threatened by racking, aging and insufficient load-bearing capacity. Degraded structures need to be strengthened or repaired to prolong the service life and reduce maintenance costs[3].

Shape memory alloy (SMA) has been applied to bridge strengthening for its shape memory effect which is controlled by transformation of two basic phases, austenite and martensite[4-6]. The so-called shape memory effect refers to the stress-induced deformation of SMA can completely or partially restored under heating[7-8]. If the recovery strain is limited, a considerable recovery stress is generated, which can be applied for structural reinforcement as a prestress.

The nickel-titanium based SMA(NiTi-SMA) and iron based SMA(Fe-SMA) are the commonly used alloys for bridge engineering. NiTi-SMA is often used as dumping or connection for stable shape memory effect and superelasticity[9-10]. Recently, it has been applied in local reinforcement of steel structures as hybrid composite patches with CFRP sheet[11-12]. However, the high cost and low elastic modulus have obstructed its application[13].

Alternatively, Fe-SMA, featuring low-cost, wide transformation hysteresis, and excellent mechanical performance, have been widely studied[14]. Fe-SMA was firstly successfully applied by Soroushian et al.[15] to strengthen a concrete T-beam bridge. Dong et al.[16-17] developed a new

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Fatigue Performance Evaluation of FRP Reinforced Steel Tubular K-Joint

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Abstract

Welded steel tubular joints have been widely used in bridge engineering, but fatigue cracks are common in the joints under cyclic loads due to structural discontinuity and manufacturing defects. The formation and development of cracks have a great influence on the bearing capacity of joints, and even lead to the lack of safety of joints, thus the normal use of joints is affected. In this paper, for the cracked tubular K-joints under fatigue load, the change of stress intensity factor (SIF) before and after reinforced with carbon fibre-reinforced polymer (CFRP) is discussed by numerical simulation. The influence of the number of carbon fibre-reinforced polymer layers on the SIF of the reinforced joints is also discussed. The numerical simulation results show that the SIF can be effectively reduced by using CFRP to strengthen joint, and the fatigue performance of the joints can be greatly improved.

Keywords: circular hollow section gap K-joint; FRP reinforcement; finite element analysis; stress intensity factor (SIF).

1 Introduction

Fatigue is an inevitable issue in steel bridges, resulting in cracking even sudden failure after a certain number of cycles [1-2], and Oehme's [3] study shows that fatigue occupies the third place among the causes of failure of fatigue-prone steel structures. For bridge engineering, fatigue cracks are usually located at locations where the geometry suddenly starts to change, such as at the weld of a welded joint. Owing to the discontinuity of the welded joint structure and some unavoidable process defects in the welding process, the stress concentration caused by the local increase in stress here will lead to cracks [4]. Therefore, as fatigue damage is brittle damage and the formation and development of cracks have a large impact on the joint load capacity, can even lead to a lack of joints safety and thus affect the normal use of the joints. The fatigue life of the structure and the fatigue of the crack-prone area is very relevant, especially for the construction of a long time, the use of increased load and the aging state of the bridge structure. The problem of fatigue at the joints leading to a reduction in the reliability of the structure needs to be solved in an economical and efficient way.

As a promising material for structural reinforcement and repair, FRP is attractive in the implementations like bridge deck and other engineering scenario [5-7]. In the application of FRP, the design of the layering angle is very important. The author [8] investigated the stress concentration of pultruded GFRP perforated plate

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Regional Bridge Data Extraction and Integration Based on Historical Detection Reports

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Abstract

This study firstly analyses the information source of individual bridge condition evaluation, then expand the analysis from individual bridge to regional bridge-group evaluation, and formulate integration rules for regional inspection, monitoring, traffic volume, and drawings. The integrated data from multi-source information are stored and expressed in the logical form of "route-bridge-component". After data cleaning, a road network database is established, the integrated data is mined for features, and then a comprehensive network level evaluation of regional bridge groups is carried out. The proposed information integration and data mining method and application model can effectively reveal the common characteristics and degradation laws of bridge groups in the road network and can be used for regional bridge network-level assessment.

Keywords: regional bridges; network-level evaluation; information integration; short and medium span bridges.

1 Introduction

Regular inspection of bridges is a sufficient basis for bridge technical evaluation, and it is also a relatively direct and complete record of bridge status. The monitoring of critical bridges supplements regional bridge status information. The existing bridge evaluation system is essentially a "one bridge, one file" single evaluation method, and the data obtained from a single bridge can only be used to evaluate and improve the bridge. On the one hand, the potential laws and value of the data are greatly wasted; on the other hand, the

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Establishment of Regional Bridge Degradation Model for Shandong Province

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Abstract

In this paper, a neural network-based regional bridge condition degradation model establishment method is proposed for the problem of regional bridge network level assessment and management and maintenance strategy optimization. First, a subset of features for bridge condition prediction is extracted from the road network database, and a suitable secondary transcoding technique is selected to accommodate the training of artificial neural networks; then, a cost-sensitive training error is introduced to obtain the optimal bridge degradation model through model selection. To verify the feasibility of the method, a case study of a small road network in the main highway section of Shandong Province was selected to obtain the degradation model of the bridge group in the region, which provides a basis for the future maintenance strategy of the regional road network.

Keywords: bridge engineering; network-level assessment; neural network; regional bridges; degradation model.

1 Introduction

Transportation infrastructure is the economic lifeline of the national society, while bridges are the hub of the transportation road network. In the road network, small and medium span bridges occupy the main position. As of 2017, there are more than 800,000 highway bridges in China, of which, nearly 90% are small and medium span bridges [1]. Behind this huge base, a large number of old bridges tend to have significant structural damage and degradation, and safety hazards are increasing day by day, which makes it urgent to evaluate the performance, predict the degradation, and

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Reinforcement Design for Abutment-Beam Joint of an Integral Abutment Bridge Based on “Tensile Stress Region” Theory

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Abstract

An integral abutment bridge (IAB) is a type of bridge in which bearings and expansion joints are eliminated at the abutment. Its superstructure is usually connected to its substructure by casting the abutment-beam joint in-situ, which is responsible for transferring loads and reaction forces. Like the knee joint of the frame, the joint is in stress disturbed region and the reinforcement is more complicated. In this paper, based on the principle of equal stiffness, the whole structure is simplified to a “single girder + single pile” structure equivalently. Then combined with the “tensile stress region” theory, by calculating the element stresses of an engineering example under four load combinations, a simpler design method is proposed for the reinforcement of the joint of an IAB.

Keywords: integral abutment bridge (IAB); abutment-beam joint; “single girder + single pile” model; tensile stress region; reinforcement.

1 Introduction

An IAB is a kind of bridge which eliminates the bearings and expansion joints at the abutment, that is, its superstructure and substructure are poured together. As a result, its substructure restrains the rotation and translation of the superstructure at the beam end, while the bending moment and axial force are transmitted from the superstructure to the substructure. However, the IAB also avoids the diseases of the weak parts such as expansion joints and bearings, improves the durability of the whole structure and reduces the maintenance cost. Hence, IABs have been widely used in small and medium span bridges.

Under various loads, the force of an IAB not only depends on the stiffness of the structure itself, but also on the structure-soil interaction. Therefore, two equally dominant issues in the structural analysis of an IAB are: how to simulate the structure itself and how to simulate the structure-soil interaction.

Regarding the calculation of the internal force and displacement of the pile under lateral load, the early method adopted was to treat the pile as a beam on the Winkler elastic foundation, i.e., the soil around pile is simulated as a series of discrete Winkler springs. While a pile within a unit length produces a unit deflection, the lateral reaction force provided by the spring is defined as the subgrade reaction coefficient k. When k is a

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Mechanical Analysis of Central Buckle Region of Long Span Suspension Bridge

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Abstract

A central buckle is generally set in the middle of long-span suspension bridge to improve the structure mechanical performance. With a large number and sophisticated composition of steel plates, the mechanical behaviour of central buckle region is obscure. In this paper, a shell-beam hybrid finite element model of a 428m main span self-anchored suspension bridge was established, and the mechanical characteristics of central buckle region were analysed. The result shows that the normal stress of steel plates in central buckle region is mainly dependent on by dead loads, the effect caused by live loads only accounts for approximately 15% of that caused by dead loads; axial force of central buckle is mainly transmitted to the diaphragms and webs of the girder.

Keywords: bridge engineering; long-span suspension bridge; finite element model; central buckle; force transmission.

1 Introduction

Suspenders in classical suspension bridges are generally vertical arranged. However, the structure cannot provide effective longitudinal constraint between cables and girders, and the relative displacement between cables and beams may cause large bending stresses in suspenders, which will probably lead to the fatigue failure of short suspenders [1]. After the Tacoma bridge accident in 1940, bridge engineering experts has spent great effort on improving the dynamic performance of suspension bridges. Studies have shown that, setting central buckle connections in the middle of large span is an effective way to limit the relative longitudinal movement between cables and girders and improve the stiffness of suspension bridge. And since central buckles were used in new Tacoma bridge in 1950, three configurations of central buckles have been invented: 1, rigid central buckle; 2, flexible central buckle, 3, cable-beam connection [2]. In the United States and European countries, rigid central buckles are more popular in construction of suspension bridges, and in contrast, flexible central buckles are used more in Japan. In China, Sidu River Bridge, Runyang Yangtze River Bridge, Aizhai Bridge, the second Dongting Lake Bridge, and Baling River Bridge were all designed with a central buckle, among which the central buckle of Runyang Yangtze River Bridge was used for the first time in China [3]. Recently, the central connection between cables and beams in the main span has been widely used in suspension bridges, becoming a development trend of suspension bridge structure.

Up to now, related research of central buckle is ongoing. Hu Tengfei et al. studied the influence of the central buckle on the modal characteristics of Aizhai Bridge by using finite element analysis and dynamic testing methods [4]. Wang Hao et al. studied the influence of the central buckle on the

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Influence of different debonding gap types on mechanical performance of axially loaded CFST stub columns

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Abstract

The mechanical performance of concrete-filled steel tubular (CFST) members could be affected by the debonding gaps between steel tubes and core concrete. In this paper, the finite element models (FEMs) of axially loaded CFST stub columns with different debonding gap types, i.e., circumferential debonding gap (CDG) or spherical-cap debonding gap (SDG), were implemented by ABAQUS. The accuracy of FEMs was verified by test results. The influence of different debonding gap types on the mechanical performance of axially loaded CFST stub columns with the same debonding cross-sectional area was compared by using FEMs. The results showed that compared with SDG, the influence of CDG on the ultimate load-bearing capacity (N_u) was larger and on the failure mode was smaller. With an increase in CDG arc-length ratio (R_{CDG}), the reduction coefficient of N_u (K_D) firstly increased and then decreased. With an increase in SDG ratio (χ_{SDG}), the K_D decreased. With an increase in R_{CDG} or χ_{SDG}, the N_u decreased. All the debonding specimens showed inward buckling in steel tubes within the debonding range, while the outward lateral deflection towards the no-debonding range was also observed. With an increase in R_{CDG}, the inward buckling of steel tubes was more severely to contact with the core concrete at the middle-height of columns, then an outward buckling was found. With an increase in χ_{SDG}, the inward buckling of steel tubes become more significant, but the failure modes remained unchanged.

Keywords: Axially loaded CFST stub column; Circumferential debonding gap; Spherical-cap debonding gap; debonding area; Ultimate load-bearing capacity; failure mode.

1 Introduction

Concrete-filled steel tubular (CFST) structures have the advantages of high ultimate load-bearing capacity, good plasticity, and ductility [1-4]. In fact, the compressive strength and ductility of core concrete can be increased by the lateral confinement provided by the steel tube, and the local buckling of steel tube delayed and restrained by the filled concrete [5,6]. In engineering applications, debonding gaps can be found between steel tubes and core concrete, which can be divided into the circumferential debonding gap (CDG) and spherical-cap debonding gap (SDG), as shown in Figures 1(a) and (b), respectively. The CDG is mainly caused by several unavoidable reasons, such as concrete shrinkage [2,7,8], temperature difference [9], and confining force

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Preliminary Analyses for the Study of the Effects of an Explosive Action on a Long-Span Suspension Bridge

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Abstract

Terrorist attacks have nowadays become an important issue for the structural design of constructions such as bridges. Indeed, during the last decades, the increase in the number of terrorist attacks has resulted in the loss of many human lives and socio-economic impact on our society. The aims of this research consist in a series of preliminary analyses in view of a study of the effects of an explosion on a long-span suspension bridge. As a suspension bridge was considered the project of the bridge over the Strait of Messina, having as main span of 3300 meters. The structure was modeled using ABAQUS/Explicit software using beams-type 3D finite element modeling. The objectives of the research are double. The first one is the study of the pressures generated by an explosive charge to model the phenomenon during numerical simulations while, the second objective, is to test different discretizations to have a reliable numerical response.

Keywords: long-span suspension bridges; blast loading; mesh-size problem; fast dynamic; numerical simulations.

1 Introduction

Suspension bridges are the longest-span structures of any type. Typically, this type of structure consists of two piers, two main cables passing through the top of the towers and anchored to large foundations at the ends of the structure, as well as the deck, which is suspended along its entire length from the main cables by multiple suspension hangers. Throughout history, technical and scientific advances have made it possible to build ever larger suspension bridges. The first of them was the "Jacob's Creek Bridge" built in 1801 in Pennsylvania in the United States with a span not exceeding 21 meters. Since then, the engineers of the last two centuries have been constantly improving the original concept, materials, and calculation methods. Today, the records of span easily exceed the one and a half kilometers and the maximum span ever built reaches almost two kilometers with the famous Akashi Kaikyõ Bridge of Japan that crosses the Seto Inland Sea linking the cities of Kobe and Awaji.

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Failures of Steel Silos for Grain Storage - Fortuity or Underestimated Risk

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Abstract

The paper describes and investigates several cases of failures of silos made from corrugated thin steel sheets which were delivered and assembled in Bulgaria by foreign companies

Two main patterns of failures which occurred in different times of the year and at different locations in Bulgaria have been analyzed. The first failure pattern is related to collapses of conical roofs made from profiled trapezoidal steel sheetings while the second pattern involves fracture of cylindrical corrugated silo walls. On-site visual investigation of the failed silos and numerical analyses simulating the loading and stress state at the pre-failure situations have been performed.

Based on the lessons drawn from the investigated silo failures recommendations for improved structural design of the corrugated steel silos are proposed with the aim to avoid similar failure situations in the future.

Keywords: steel silo; grain storage; shell structures; failure analysis.

1 Introduction

The cylindrical steel silos are commonly used worldwide as an optimal structural solution for grain storage (wheal, maize, sunflower seeds, etc.). This structural form allows thin-walled sheets and higher steel grades to be used in combination with fast and easy assembling on site using standardized components. Steel silos are very adaptive to modern technology for grain storage and offer relatively low-cost operation and maintenance due to the reliable corrosion protection (zinc coatings). A general classification of the steel silos for grain storage is proposed on Fig. 1.

In attempt to produce highly competitive and lightweight structures for the silo market, often steel sheets and profiles with very low thickness are used without previous testing or performance evaluation. The basic fact that the thin-walled steel members do not have essential over-strength and good ductility is often overlooked. In addition, the slender silo walls are very sensitive to initial imperfections and more vulnerable to local (patch) loading.

The most of the steel grain silos are assembled on site using bolted connections. Bolted connections significantly accelerate the installation of the facilities but produce significant reduction of the steel sheeting cross-section areas. Often oversized bolt holes are used in favour of erection operations but this type of bolted connections have lower resistance and exhibit larger slip deformations under loading.

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Fatigue Tests on Compact-tension Specimens Repaired by CFRP

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Abstract

Six fatigue tests were conducted to investigate the fatigue behaviour of CFRP-repaired compact-tension specimens (CT specimens), considering the effects of CFRP material type, patch configuration and patch layer numbers. Beach marking technique and digital image correlation (DIC) technology were employed to depict the crack propagation and the strain distribution on the specimens. The differences in fatigue life and fatigue crack growth rates (FCGR) results reveal that CFRP patches can prolong the fatigue life, even tripling the cycle number in a test. There is a salient advantage in double-side repairing compared to its one-side counterpart. However, the CFRP sheet layer number doesn't guarantee the strengthening efficacy. The specimen repaired by CFRP plate had a mixed failure mode of adhesive layer failure and CFRP debonding. The failure mode of CFRP-sheet repaired specimens was a mix of CFRP debonding, delamination and adhesive layer failure.

Keywords: compact-tension specimen; steel plate; CFRP; digital image correlation (DIC); fatigue life; fatigue crack propagation rate (FCGR).

1 Introduction

Metallic infrastructures subjected to cyclic loads including wind load and traffic load are susceptible to fatigue crack initiation and propagation. Crack propagation may cause brittle failure. Repairing fatigue-damaged steel components with CFRP material has shown many advantages including longer fatigue life extension[1,2], reduction of residual deflection and transformation of failure modes. Fatigue performance improvement has become one of the most important aspects of CFRP strengthening of metallic structures[3].

Previous research on the CFRP reparation of mode-I cracks was based on various kinds of steel plate specimens including centre-cracked steel plates[4,5], edge-cracked steel plates[4,6], I-beams and rectangular hollow-section beams[7]. In the experiments, the specimens are predominantly under tension except for steel beams. CFRP collaborates with the steel substrate, simply bearing tension. CT specimen is classic in tests related to fracture mechanics such as fatigue crack growth rate (FCGR) and fracture toughness determination. A relatively low load could realise a high stress intensity factor (SIF) on the CT specimen[8]. Also, the specimen is under bending during the test. Some researchers have conducted experimental research on CT specimens to study the effects of various CFRP fatigue strengthening strategies[1,2,9–12]. Factors including initial damage level, CFRP patch configuration, CFRP material quantity and even steel types of different ages[9–12] were under investigation. However, the experiments on double-side repaired CT specimens

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Analytical Study on Slip Strength of Long Bolted Joint Combing with Bearing Type Bolts

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Abstract

In recent years, high-strength bolt friction joints have been becoming larger and longer owing to the increase in load and need for the rationalization of steel members. However, as the length of the joint increases, the force that the bolted joint can resist decreases because the distribution of the bolts inside the joint becomes uneven. The present study proposes a method that improves the slip strength of a long friction bolted joint by combining it with the bearing type joint. Finite element (FE) analysis was conducted to clarify the load share and slip strength of the hybrid joint. From FE analysis result, we found that the slip load/design slip strength ratio of the long friction bolted joint is 0.83, while the ratio of the hybrid joint B2 with bearing type bolts installed at each end of the joint is 0.94 and 0.98 in the B4 case. Therefore, it could be concluded that the hybrid joint with bearing type bolts installed at both ends of the long friction bolted joint can effectively improve its slip strength.

Keywords: long bolted joint; friction type bolt; bearing type bolt; high-strength bolt; slip strength.

1 Introduction

High-strength bolts are widely used when constructing steel bridges to fasten steel members together through a frictional joint to resist force[1]. In recent years, owing to the increase in load and need for the rationalization of steel members, high-strength bolt (HSB) frictional joints have become larger and longer[2,3] , as shown in Figure 1.

The structural design of long or large high-strength bolt frictional joints has several problems. There are concerns that larger HSB frictional joints can reduce cross-section area due to drilling. Therefore, a reasonable compact joint structure must be developed to allow the use of fewer bolts to transmit more load, which could also improve the service limit capacity of the joints.

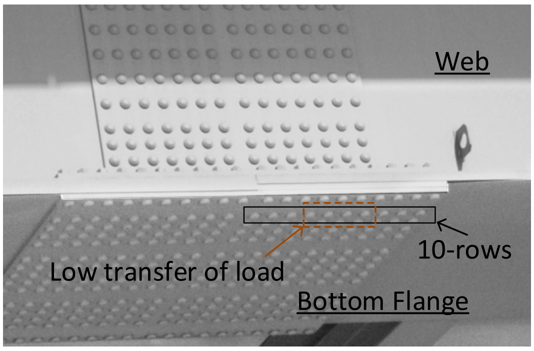

Figure 1 Long bolted joints at bottom flange

On the other hand, as the length of the joint increases, the actual force that can be withstood

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Experimental Study on Simply Supported Bridges of Steel-Concrete Composite Structure Strengthened with Externally Pre-Stressed CFRP Plates

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Abstract

This paper mainly studies the mechanical properties of steel-concrete composite beams reinforced with trapezoidal prestressed un-bonded retrofit (TPUR) system. The prestressing of CFRP plate through the jacking of columns can not only apply the prestressing force to the main beam, but also provide upward lifting force to the bottom of the main beam to reduce the deflection of the original structure. Moreover, the surface treatment of steel beams is not required in the TPUR system, which can improve the speed and efficiency of reinforcement construction. The effects of the amount of CFRP, the prestress level, the height of the pillars and other parameters on the stiffness and bearing capacity of the composite beam are studied through static tests on the scaled model.

Keywords: tension string reinforcement; CFRP plate; steel-concrete composite beam; active reinforcement method; flexural bearing capacity.

1 Introduction

1.1 Development background and existing problems of steel-concrete composite girder bridges

The steel-concrete composite structure can give full play to the characteristics of concrete and steel, and is a sustainable form of bridge structure[1]. Due to the advantages of small height, short construction period and high degree of industrialization[2], steel-concrete composite beams have been widely used in highway and urban bridge construction. There are some problems in the use of steel-concrete composite girder bridges built in the early days. On the one hand, with the increase of service life, various structural damages and quality problems occur in composite beams, which affect their bearing capacity; on the other hand, if there are defects in the early design, the increase of traffic loads will lead to insufficient overall bearing capacity[3].

1.2 Application of CFRP material in bridge repair

When CFRP is used for bridge structure reinforcement, there are mainly two reinforcement methods: passive reinforcement method and active reinforcement method. The disadvantage of passive reinforcement method is that it cannot reduce the deformation and cannot close the cracks of the original structure[4]. The active reinforcement method is represented by the application of prestress to CFRP materials, which generates prestress in the bridge structure and redistributes the internal force of the original structure, which can effectively overcome the defects of the passive reinforcement method[5].

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Fatigue Performance of Cracked Bridge Diaphragm Repaired by SMA/CFRP Composite Patch

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Abstract

Under long-term service conditions, fatigue cracks are easily generated at the arc-shape cutouts in diaphragm of the orthotropic steel bridge decks when subjected to vehicle-induced vibration and cyclical wheel loads. For repairing cracks in diaphragm, this paper proposes the carbon fiber reinforced polymer (CFRP) sheets patched crack-stop hole method and shape memory alloys (SMA)/CFRP composite patched crack-stop hole method which introduces prestress by activating SMA. Moreover, in the numerical study the diaphragm model and reinforcement schemes are introduced, and the corresponding finite element model is established. The failure modes and fatigue lives of diaphragm specimens under different repair methods were obtained and compared by fatigue loading tests. It can be found that the bonding of CFRP sheets and SMA/CFRP composite patches can effectively postone the initiation of fatigue cracks and inhibit the propagation of cracks, which are ideal repair methods for strengthening the fatigue cracks of diaphragms in orthotropic steel bridge decks.

Keywords: bridge engineering; crack of diaphragm; structural reinforcement; finite element simulation; fatigue test.

1 Introduction

Orthotropic steel decks are widely used in various structural forms and bridges due to its advantages of light weight, high strength and high load-bearing capacity[1-3]. However, there are many welding parts in orthotropic steel decks and its connection is complex. With the increase of service life and overloaded vehicles, the fatigue cracking problem of steel bridge decks is becoming increasingly prominent[4-6]. Fatigue crack at the arc-shape cutouts of diaphragm account for about 60% of all fatigue cracks, which is one of the main fatigue repair objects of orthotropic steel bridge decks[7-8].

CFRP is pasted on the fatigue crack through structural adhesive, increasing the stiffness of the cracked area, reducing its stress under fatigue load, and postponing the development of fatigue cracks. Zheng and Yue et al. carried out the middle-cycle and high-cycle fatigue tests on the unreinforced and CFRP-reinforced steel beams, and found that the fatigue life of the steel beams strengthened with CFRP increased by 2,98-6,74 times[9]. Ghafoori et al. strengthened cracked steel beams with CFRP plates and prestressed CFRP plates, and the fatigue life of steel beams strengthened with prestressed CFRP plates increased by more than 5 times comparing with steel beams strengthened with CFRP plates[10]. Hosseini and Ghafoori et al. found that the fatigue life of the steel plate can be

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Lifting and Rehabilitation of 5 Highway Overpasses in Brazil

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Abstract

This paper presents the structural solution for the lifting and rehabilitation of 5 overpasses crossing a Federal Highway, located in the south part of Brazil. All structures were built in the 1960s, a period in which the design practice required a minimum height of 5,0 m to allow the flow of vehicles under the deck. Due to the recent expansion of taller vehicles and increment of traffic in the region, the highway administrator, in order to meet the space requirements of 5,5 m, financed both project and construction works. The main requirement was to carry out the entire construction without causing the interruption of traffic under the overpasses. The proposed solution included: preliminary static load tests, construction of corbels to support hydraulic jacks, localized strengthening of structural components, replacement of the originally designed fixed bearings by new elastomeric bearings and the heightening of the piers using steel plates as reinforcement.

Keywords: overpass; lifting; rehabilitation; strengthening; load test.

1 Introduction

The Brazilian Federal Highway BR-290, where the 5 overpasses are located, connects major states of Brazil and other South American countries to the Ports of Rio Grande and Porto Alegre. It has been experiencing recently an increasing in the traffic of larger and taller vehicles (see Figure 1), responsible mainly for the transportation of agricultural production, such as soy and wheat grains for exportation. From 2020 to 2021, export volumes in the region surpassed 47 million tons, which represents an increase of 19,37% in one year. China market alone was responsible for the consumption of 56,32% of the goods exported in the same period, according to the Regional Communication Advisory.

Within this context, our office was hired by the currently highway administrator to develop the structural project for the lifting of all overpasses and, therefore, achieve the safety requirement of 5,5 m established by the federal regulations. Due to economic importance of the highway under the structures, the entire construction process had to be carried without causing the interruption of traffic.

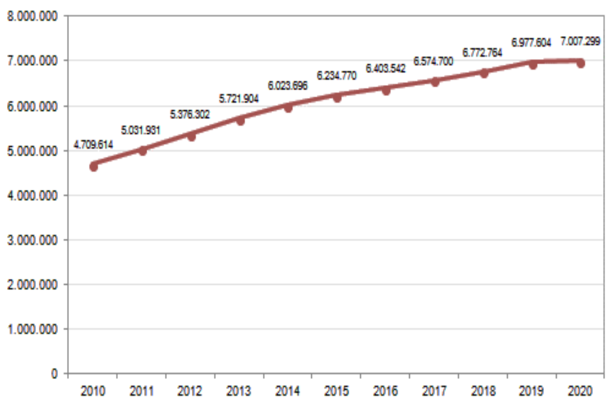

Figure 1. Evolution of motorized vehicles fleet in Rio Grande do Sul from 2010 to 2020 (DETRAN-RS)

Failure Mechanism Analysis of Circular Cfrp Components Under Unequal Impact Load

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Abstract

This paper investigates the responses of circular CFRP-RC components when subjected to an asymmetrical impact force. The impact performance of CFRP-RC components was investigated using drop-hammer impact test equipment. The failure mechanism and dynamic response properties of the CFRP-RC components were considered critical to obtaining. Three specimens were used in the experiments. The specimen's crack propagation pattern, failure mechanism, impact force, and deflection time history curves are all obtained. The test results indicate that shear fractures occur between the impact point and the adjacent support. The failure mode of reinforced concrete components transforms from bending to shear related to the unequal span impact load. A finite element modeling method was proposed and demonstrated efficiently. The control variables were used to analyze the failure mode and mechanism. Once the impact velocity or the number of CFRP layers decreases, the component fails in shear rather than bending. During an impact load, the internal force distribution of components differs significantly from that of a static load. The mechanical properties and failure mechanisms of CFRP-RC components are investigated using test and FE analysis. The failure modes of the components and the distribution and development of bending moments, shear forces, reinforcing strain, and energy consumption are all investigated.

Keywords: static load; bending failure; FE analysis; failure mode; shear crack; energy dissipation; impact velocity; unequal span; bearing capacity.

1 Introduction

Whether it is the past "iron engineering foundation"-railways, highways, airports, ports, water conservancy facilities, and other construction projects, or by 2022, "new infrastructure" including high-speed intercity railways and intercity rail transit, infrastructure construction plays an important basic role in the process of the world's economic development. The emergence of infrastructure has provided great convenience for human activities and improved people's living and working environment. However, at the same time, the destruction and failure of infrastructure under natural or man-made disasters seriously threaten human life and property safety and stability. When an accident occurs, the impact is impressive with its destructive power, and once it occurs, it will cause huge economic losses and casualties, which arouses people's attention. In recent years, many shock accidents have caused RC structural members relatively bad social impacts. In recent years, many shock accidents have caused relatively destructive social impacts. Reinforced concrete (RC) structure is one of the most commonly used structural forms. These RC structures may face various impact problems during their life cycle, such as impact

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Design and Dehumidification Effect of Dry Air Dehumidification System Inside the Main Cable

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Abstract

To improve the durability of the main cable of the suspension bridge, a new dehumidification system for delivering dry air from the interior of the main cable is proposed. The dehumidification system delivers dry air through the dry air supply conduct embedded inside the main cable, which can improve the dry air delivery efficiency. Based on the 1560m long-span suspension bridge of Longtan Yangtze River Bridge, the overall design of the new dehumidification system of the main cable is carried out. The components of the new dehumidification system are designed, the key technologies for the design of the new dehumidification system are clarified, and the corresponding solutions are proposed. To verify the dehumidification effect of the new dehumidification system, the main cable dehumidification test was carried out to test the relative humidity change pattern inside the main cable during the dry air delivering process. The test results show that the new dehumidification system has a good dehumidification effect and can be used to protect the main cable of the long-span suspension bridge against corrosion.

Keywords: main cable of suspension bridge; high-strength steel wire corrosion; dehumidification system design; dehumidification effect.

1 Introduction

The main cable is the load-bearing component of the long-span suspension bridge, which is almost irreplaceable in the operation stage. So, it is called the "lifeline" of the suspension bridge [1]. The main material of the main cable is high-strength steel wire, which is easily corroded in a high humidity environment, affecting the bearing capacity and durability of the main cable. The main cable opening inspection in recent years found that the corrosion of the high-strength steel wire is quite serious [2-3]. How to slow down the corrosion rate of the steel wire and improve the durability of the main cable deserves further study [4-6].

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Proposal Based on the Social Assessment Methodology for a Scenario in which the Road Network Faces a Bridge Collapse. Case Study: Seminario Bridge, Chile

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Abstract

In Chile several natural hazards (earthquakes, landslides, etc.) create high road structure vulnerability resulting in road disruption. One of these conditions can be exemplified by the collapse of a road bridge resulting in high human and economic cost.

The current Bridge Management System must provide comprehensive inspection, diagnosis and intervention (strengthening or repair) protocols, always with a limited budget. For that reason, the budget allocated to O&M is usually reduced and has to be technically justified.

A tool to provide adequate decision-making is to know the direct and indirect costs associated with the collapse of the bridge and how this collapse impacts on the funding allocated to management activities.

This paper is a proposal based on the social assessment methodology to quantify the direct and indirect costs of a bridge collapse on a route that is critical for the Chilean road network, following the current social assessment methodology and applying it to a specific bridge. An analysis and comparison of the funding of inspection and monitoring is carried out. This analysis considers visual inspection, UAV, NDT and instrumentation of the bridge.

Keywords: bridge; collapse; assessment; road network.

1 Introduction

Chile is a country undergoing everyday natural disasters, among which not only include the large earthquakes (for which Chile is internationally classified/recognized as a highly seismic country), but also the numerous volcanoes, landslides, wildfires, floods, droughts, etc. This is due to our country's geography and geology and, therefore, cannot be predicted accurately, let alone be avoided. Its location makes it one of the countries with the highest volcanic and seismic activity in the world, being the OECD member with the greatest exposure to natural disasters, given 54% of its population and 12.9% of its area is exposed.

According to the Inter-American Development Bank (IDB), over the last twenty years, Chile has disbursed a yearly average of roughly 200 million dollars to cover these issues, which makes it the country with the highest annual expense on this type of emergencies in the region.

It should be noted that, at a national level, in recent years the Ministry of Public Works has been boosting the strategy of contributing to the

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Analysis of Influencing Factors of Track Static Geometric Deviation of Super-Long-Span HSR Bridge

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Abstract

Aiming at deformation characteristics of super-span bridge and track in high-speed railway at the acceptance stage, the key factors to track static geometrics are identified, namely the route profile, surrounding temperature, construction deviation and ballast density deviation. According to the study results, the principles of track profile setting is proposed, and the integrated criteria of midpoint chords based on 60 m, 30 m and 10 m is recommended to determine the track target geometric profile. The optimized track adjustment scheme should meet two conditions, first condition is that the irregularity midpoint chord values should not exceed 6 mm/60 m, 3 mm/30 m and 1 mm/10 m, and second condition is that the adjustment range of ballast thickness should be within (-20 mm~+100 mm).

Keywords: high speed railway; long-span bridge; deviation of track static geometrics; temperature-induced deformation; engineering deviation.

1 Introduction

In recent years multiple combined highway and railway bridges have been proposed and built in China, each with over 1 km main span and design speed of 250 km/h. For example, with a 1,092 m main span, the Husutong Yangtze River Bridge and the Wufengshan Yangtze River Bridge have already been put into operation, while the Changtai Yangtze River Bridge (with a main span of 1,176 m) and the Ma'anshan Yangtze River Bridge (with 2*1,120 m main spans) with the structures of cable-stayed bridge and steel truss girder have already been in construction. The preliminary designs of the Xihoumen Yangtze River Bridge (1,488 m in main span, separated steel box girder as stiffening girder) and the Jiangyin Yangtze River Bridge (1,780 m in main span, steel truss girder as stiffening girder) have been approved, and the cooperation system of cable-stayed structure and suspension structure is adopted in both designs.

With more significant deflective deformation and a rise in structural stress, the increase of bridge span also intensifies the track irregularity on bridge. Unlike common span bridges, long-span railway bridge stands out for its engineering scale, systematic complexity and large displacement. Upon static/dynamic acceptance stage and operation period, the structural deformation and

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Bridge Management Systems – A Crucial Link to BIM

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Abstract

Fatal bridge collapses and accidents, climate change effects and critical maintenance condition of many bridges recently increased the interest among bridge owners worldwide to transition from preventive to more proactive bridge maintenance and support by digitalization. Analyzing maintenance information systematically contributes to successful maintenance management. Inspections and maintenance require organized, automated, open, and transparent digital processes. Worldwide Bridge Management Systems evolve, associated with the technological evolution, but are in urgent need for a digital upgrade, especially considering BIM technology. Existing BIM models must be enriched by assets obtained from inspection and maintenance processes. An Open BIM platform should be the goal and to this end IABSE Task Group 5.6 "BIM for Existing Structures" has defined its aim as helping to stimulate debate on this topic and give recommendations on how to address the issues raised.

Keywords: Bridge Management System (BMS); Building Information Modelling (BIM); open source, open BIM; cloud-platforms; visualization.

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Design of a bridge digital twin system for Intelligent operation and maintenance based on machine vision

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Abstract

Under the background of the transformation and upgrading of bridge maintenance management, aiming at the problems of weak processing capacity, low management efficiency and intelligent degree of the bridge operation and maintenance process, this paper proposes a digital twin system solution of bridge intelligent operation and maintenance based on machine vision. Then framework of the bridge digital twin system for Intelligent operation and maintenance is proposed, followed by the realization methods based on machine vision. Finally, a case application of the concrete simply supported girder bridge is given.

Keywords: bridge; operation and maintenance; system; machine vision; digital twin

1 Introduction

By the end of 2021, China has built 961,100 highway bridges with a total mileage of 73,800 km. Typically, the successful construction of representative bridges such as Sutong Yangtze River Bridge, Nansha Bridge, Lupu Bridge, and Hong Kong-Zhuhai-Macao Bridge indicates that China has reached the international leading level in bridge design theory, construction technology and bridge construction equipment. At the same time, with the increase of service life of bridges and the deterioration of service environment, maintaining the structural durability and safety of in-service bridges, and ensuring and extending the service life of bridges has become one of the main problems faced by bridge engineers[1]. Monitoring and testing the performance of bridges in service, and making scientific evaluation and maintenance decisions, has become a research hotspot in the world[2]. The traditional operation and maintenance system has problems such as poor real-time monitoring or detection, difficult condition evaluation, high management cost. Therefore, it is necessary to study a management system with a new service model. Digital twin provides a fresh idea to this challenge, which describes the whole life cycle trajectory of

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Resilience Quantification Based on Monitoring & Prediction Data Using Artificial Intelligence (AI)

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Abstract

Lately, there is an increasing demand for resilient infrastructure assets. To support the documentation of resilience, Structural Health Monitoring (SHM) data is a necessity, as well as traffic loads. Those diagnosis and function data can be the basis for the prognosis of future prediction for the performance of the assets. Towards this direction, this paper develops a new methodology that uses real monitoring data and Artificial Intelligence (AI) algorithms to quantify the resilience based on future traffic load predictions of functionality. It includes the case study of the “Hollandse Brug” bridge in the Netherlands considering strains and traffic load predictions and other external. Resilience is derived as a function of both functional and structural parameters throughout the lifecycle. The quantification is supported by sustainability indices and key performance indicators representing the traffic flow, the structural integrity and the sustainability level of the asset.

Keywords: resilience; bridges; artificial intelligence; machine learning; structural health monitoring; traffic.

1 Introduction

Critical Transport Infrastructures (CTIs) such as highway Reinforced Concrete bridges (RC) have a crucial socio-economic impact [1],[2]. The ageing RC bridges are deteriorated by diverse stressors, e.g. increased traffic load, corrosion and multiple hazards, e.g. extreme temperatures, seismic events, floods [1],[2]. Therefore, maintenance and retrofitting measures are necessary to ensure the asset’s safety [3]. Though, according to the European Union (EU) Road Federation, the maintenance of damaged CTIs due to natural hazards is significantly expensive and reaches approximately €20 billion per year [4], accompanied with bridges’ disruption and further economic losses [2],[4].

The adaptation of the decaying highway RC bridges to the ever-changing environment and increased traffic demands are incorporated into the concept of the forthcoming EU Adaptation Strategies [5]. In particular, the main goal of the new strategies is to guarantee the resilience of CTIs, especially to climate change [5],[6].

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Direct Shear: A Mechanism that is Often Ignored and Rarely Studied

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Abstract

The defect of excessive lone time deflection of prestressed concrete bridges has been researching for decades. Many researches focused on reducing the long time dead-load deflection of the completed bridge. Another research method is trial calculation, which includes adjusting prestress loss, structural stiffness, or modifying the creep model to fit the deflection changes of the real bridge. Nevertheless, there is still a lack of recognized solution. In this paper, with the continuous research on the excessive long time deflection of PC girder bridges in the Department of Bridge Engineering at Tongji University, another kind of shear caused excessive defection is proposed, which is also a mechanism that is often ignored and rarely studied: direct shear. The transverse analysis method of the box section and its influence on longitudinal direct shear are presented in detail. Finally, some research and design suggestions are put forward.

Keywords: direct shear; concrete bridge; excessive deflection; stress indicator of box section; transverse analysis of box section.

1 Introduction

The defect of excessive lone time deflection of long-span prestressed concrete bridges has been researching for decades[1]-[8], but there is still a lack of recognized solution. Researches included three major ideas: The first was to focus on reducing the elastic deflection by adjusting the design state or design parameters to optimize the long time dead-load deflection of the completed bridge. However, the dead-load deflection can be adjusted by controlling the construction process and by cambering the deflection of the completed bridge, which is not the defect of continuous excessive deflection to be studied. The second was trial calculation, which includes adjusting prestress loss, structural stiffness, or modifying concrete creep model to fit the deflection changes of the real bridge. However, the trial calculation method often only takes into account the deflection changes, but does not take into account the structural force state such as structural cracking. The trial calculation method could not achieve “both fit”, that is, while trying to fit the deflection, it also needs to pay attention to the structural stress and cracking. The both, i.e., the deflection and the stress distribution, need to be mutually verified. Third, inclined cracks of the web due to shear develop and the shear reinforcement in the web yields, which leads to the decrease of the shear stiffness of the web and leads to the increase of deflection. The author noticed this mechanism during the research on the auxiliary channel bridge of the Sutong Bridge, and began to study the shear reinforcement theory of concrete structures, which continues to this day. In this paper, with the continuous research on the excessive long time deflection of prestressed concrete girder bridges in the Department of Bridge Engineering at Tongji University, another

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Mechanical performance of skewed deck-extension bridge

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Abstract

The deck-extension bridges is the most widely used jointless bridges in China due to the simple structure and convenient construction. The mechanical performance of skewed bridges is more complex than that of right bridges. To understand the difference between the skewed deck-extension bridge (SDEB) and the skewed jointed bridge (SJB), a SDEB built in China was chosen as a case study. The girders and approach slabs longitudinal displacements were monitored. A finite element model (FEM) was implemented by using the MIDAS-Civil software, of which the accuracy was verified by monitoring results. The mechanical performance of the SDEB and SJB under different load cases was compared. The influence of different skew angles on the mechanical performance of the SDEB was studied. The results indicated that the mid-span bending moment of the SDEB was slightly smaller by 5% than that of the SJB. Compared with the SJB, the mid-span torque of the girder in the side span and axial force at the girder end in the SDEB were significantly larger, which should be paid special attentions to during the design. The in-plane rotation of the girder in the SDEB was limited by the approach slab; therefore, the lateral displacement of the SDEB was significantly smaller than that of the SJB, especially for the skew angle of 30°. Bearing unseating and deck cracks may be improved in SDEB.

Keywords: jointless bridge; deck-extension bridge; skewed bridge; mechanical performance; finite element model.

1 Introduction

To meet the requirements of road alignment, bridge location and terrain, skewed bridges are often used. With the development of highways and urban expressways in China, the number of skewed bridges can reach up to 40~50% of total bridges in one route [1]. The deck joints in the skewed bridges were easily damaged, which affected the bridge durability and traffic safety [2-3]. Deck-extension bridge is one type of jointless bridge. The expansion joints between the girders and abutments are retained, however, the deck joints are eliminated. Therefore, the longitudinal expansion and contraction deformation of girders can be transferred to the connections between the approach slabs and pavements [4-7]. The skewed deck-extension bridge (SDEB) can not only resolve the vulnerability problems of deck joints but also

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Technical Research on OVM250 PSC System with High Fatigue Strength and Full Life Cycle Durability

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Abstract

With the development of modern long-span cable-stayed bridges, due to the Parallel strand cable (PSC) being assembled on-site strand by strand, which has the advantages such as no need for large-scale equipment for cable-making, delivery, hoisting, traction, tensioning, and the corrosion protection of the cable is excellent, it is more and more favored by designers.

As the load-bearing components, the stay cables are known as the life cable of the cable-stayed bridge. Its reliability and durability are the key factors that determine the safety and the service life of the cable-stayed bridge. In accordance with the requirements specified in international recommendations, in-depth research has been carried out on cable fatigue, anti-corrosion, vibration control to optimize OVM250 PSC system. All research results have been successfully applied to cable stayed bridge projects.

Keywords: high fatigue strength; corrosion protection; UV resistance; vibration control.

1 Introduction

Continuous development and breakthroughs of anti-corrosion technology of the stay cable system have provided favorable conditions for the development of modern long-span and super-long-span cable-stayed bridges. And the increasing demand for cable-stayed bridge construction has promoted the development of stay cable technology and ushered in a new technological innovation in the stay cable system. In order to ensure the safety and durability of long-span cable-stayed bridges, higher requirements are put forward to the reliability, durability, construction convenience, cable force monitoring and even fire & explosion protection of the stay cables. In recent years, the PSC technology is favored and has been applied in more and more super-long-span cable-stayed bridges all over the world (e.g. Russky Bridge in Russia with main span 1104m) for its multi-layer redundant anti-corrosion, strand-by-strand installation and stressing method, the lightweight erection equipment, and the convenience of maintenance and individual strand replacement.

In 1993, a survey on bridge stay cable systems was carried out, for the question “what are the three most important aspects/requirements for a stay cable[1]”, durability and fatigue received a relatively close percentage rating 28.3% and 26.6%, respectively, they are much higher than other aspects.

In international recommendations of Setra CIP[2], fib bulletin 30[3] and PTI[4], fatigue and subsequent static tests are specified. In these three(3) recommendations for stay cable system, the

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Effects of Corrosion on the Capacity of the Nib of Reinforced Concrete Dapped-End Beams

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Abstract

Many studies have been conducted in the past decades to determine the impact of corrosion on public infrastructures such as bridges, due to the deterioration that has been witnessed since their construction, sometimes very early in their working life. This degradation has caused collapses, not only leading to economic losses but also provoking human casualties. The layout of certain structural elements complicates the inspection and maintenance processes, by creating tight spaces or blocking the access to certain surfaces. This is the case for dapped-end (half-joint) beams, whose height at the extremities has been shortened to create a support, called a nib, reducing the floor height and allowing the placement of an expansion joint. However, water can seep into this joint and stagnate on the lower nib if the drainage system and waterproofing are not adequate. During winter, when de-icing salts are spread on roads, this water becomes charged with chloride ions, which are the leading cause of corrosion in reinforced concrete structures. The purpose of this research is to numerically evaluate this reduction, using a non-linear finite-element analysis that is able to represent an evolving crack pattern taking into account both mechanical degradation due to loading and degradation caused by environmental factors.

Keywords: corrosion; dapped-end beams; durability; nonlinear numerical analysis; finite element modeling.

1 Introduction

A dapped-end beam (DEB), or half-joint beam, is a type of beam frequently used in precast construction, whose section has been reduced at the extremities to create a support, see Figure 1. While this geometry allows for a reduced floor height, easier assembly and a greater lateral stability compared to beams supported at their bottom face [1], it creates a locally disturbed region which relies heavily on its reinforcement to transfer the stress into the full depth of the beam.
The major difference between the stress flow inside the nib of a dapped-end beam and a typical corbel is that while the inclined compression force is transmitted to the column in the case of the corbel, for a DEB this force must be resisted by a tensile force in the vertical reinforcement close to the full-depth face of the beam, as illustrated on Figure 2.
To satisfy equilibrium, this tensile force must be equal to the vertical shear force V acting on the nib. A group of stirrups should be placed close to that interface to resist this component, and be correctly anchored to the longitudinal reinforcement. Two typical reinforcement layouts are presented on Figure 3.
The experiments of Mattock and Chan [1] on DEBs revealed that the nib can be designed as a corbel

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Analysis on Segmental Deck Replacement Plan for Large-Span Network Arch Bridge

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Abstract

As a long-span network suspender arch bridge, the main girder of Qilu Yellow River Bridge was designed as steel-concrete composite structure, and the concrete deck was designed as replaceable components due to the possible severe local damage caused by the direct vehicle load. In this paper, different segmental replacement plans were put forward according to the structural characteristics, and an integral mixed finite element (FE) model was established based on the 420m main span in order to study the mechanical performance of this bridge in the process of deck replacement. The effect of variable replacement lengths and positions on the structural response, in both longitudinal and transverse directions was figured out. The analysis results show that all the deck replacement plans discussed in this paper are feasible, and different demolition methods affect the stress change amplitude of the structure in different way, of which the lateral change of replacement methods has a more obvious impact on the structure.

Keywords: large-span network arch bridge; steel-concrete composite beam; segmental deck replacement; FE.

1 Introduction

For the steel-concrete composite structure, cracks are inevitable to occur on the concrete deck caused by directly vehicle load, especially for the negative bending moment area[1-3]. In contrast, the damage degree of steel beam which is not directly subjected to external force is lighter. So it is necessary to adopt appropriate repair strategies to prolong the service life of deck to be consistent with the life of steel beam. Compared with overhaul, replacement repair strategy has greater advantages in carbon emissions, energy consumption and cost at all stages of the bridge deck life cycle[4]. Therefore, it is a wise choice to design the concrete bridge deck as a replaceable structure in the composite beam considering the life-cycle economy of the bridge and the benefit of environmental protection[5].

Segmental replacement and whole-span replacement are two main forms of deck replacement according to the specific damage location and degree of concrete, of which segmental replacement is a more appropriate

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Study on Risk of Ship Collision in Bridge Life-cycle Based on Synergetic Theory

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Abstract

The study on the risk of ship-bridge collision has always been a significant subject in academic research. However, the study of ship-bridge collision risk is rarely mentioned from the perspective of the bridge life-cycle. This paper proposes the concept of "bridge-ship common safety" based on the synergetic theory and constructs a high-level cooperative platform to solve the problem of bridge-ship collision. It was given in this article by analyzing the interaction relationship among subsystems of environment, ship, and bridge. In this paper, it proposed the analysis method of the ship-bridge collision risk based on synergetic theory with order parameters, including ship-bridge collision probability and collapse probability of bridge. Finally, the Lanjiang Xiangnv Bridge project as the case study is demonstrated. The risk of bridges is evaluated by utilizing order parameters and synergetic degrees. The result shows that the model can reflect the risk of ship-bridge collision properly, which achieves great scientific significance and academic value for enriching the theory in bridge-ship collision avoidance and implementing the concept of " bridge-ship common safety ".

Keywords: ship-bridge collision; synergetic theory; bridge life-cycle; order parameters; rask.

1 Introduction

1.1 Research Background

The Ministry of Transport's newly issued "Outline of Inland Waterway Shipping Development" which guides that we will basically build a modern and powerful inland waterway shipping system by 2035. According to incomplete statistics, by 2020, there will be about 2,600 bridges across the "two horizontal and one vertical, two networks and eighteen lines" of inland waterways in China, including the Qiongzhou Strait Project, the Yangtze River Estuary Crossing Project and the Pearl River Estuary Lingdingyang Project. Chinese President Xi Jinping pointed out that a modern and powerful country must possess a strong shipping industry. Although bridges have brought rapid development dividends to coastal transport and the economy, they have produced to some extent restricted water transport and brought certain safety risks to navigable ships and bridges themselves. The occurrence of ship collision has limited the development of China's shipping industry

In order to investigate and manage the safety hazards of ship-bridges collisions comprehensively, the General Office of the Ministry of Transport and the Comprehensive Department of the State Railway Bureau issued the "Three-year Action Plan for the Implementation of the Management of Hidden Hazards of Ship Collisions on Bridges" to focus on the risk of ship collisions on bridges. This action has alleviated the current safety hazards partly, but it has cost a lot of financial resources. As

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Flutter Fragility Analysis of Long-Span Bridges Based on 3D Typhoon Model Using Geographically Weighted Regression

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Abstract

The long-span bridges in coastal region of China exposed to the challenge of typhoon-induced flutter instability with the continuous increase the span length and flexibility of bridges. A Monte-Carlo-technique-based framework to analyse the flutter fragility long-span bridges subjected to typhoon winds is developed. A 3D typhoon boundary layer wind field model and a geographically-weighted-regression (GWR) -based stochastic track model are proposed to generate a large quantity of synthetic tracks around the bridge site before achieving the typhoon wind hazard curves at the height of the bridge deck. The flutter critical wind speed of the bridge is derived accounting for the structural modal and damping randomness as well as experiment-induced errors of aeroelastic flutter derivatives. The typhoon-induced flutter failure probabilities of the bridge are then predicted and compared with code-suggested target reliability indices.

Keywords: typhoon; long-span bridge; flutter; fragility; geographically weighted regression; uncertainty; extreme wind speed; probability of failure; reliability index.

1 Introduction

The aerodynamic flutter instability issue of long-span bridges has received intensive attention since the collapse of the 853.4 m-main-span Old Tacoma suspension bridge in 1940. As a divergent motion that would lead to catastrophic failure of the bridge, flutter is the top priority issue during the wind-resistant design process. Recently, the advanced high-strength materials, progressive technologies of construction and continuous improvements of design theory have allowed the main spans of bridges to be longer than 2 km or even reach 5 km to cross wide canyons, rivers and straits [1-2]. The risks of wind-induced aeroelastic instability for such extremely slender and flexible structures should be carefully evaluated,

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Damage Study of Dhamdum Bridge Concrete Pier by Flowing Rock Impact

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Abstract

Near Samtse Dzongkhag in Bhutan, the country terrain is flat and hence the river 'Dhamdum chu' is very wide and remains dry during most of the time of the year. But during monsoon, rain water with melted ice from mountain, it becomes mighty. The bridge proposed over Dhamdum chu connecting the community residence to Samtse Industrial Park is a multiple span concrete bridge supported by solid concrete piers placed on open foundation. A very large span bridge was possible but not considered practical from the view point of economy and social aspect.

This paper represents the output of non-linear analysis carried out during design of the bridge to ensure safety of the bridge Piers against damage by impact from flowing rock if any. Rock impact simulation of the bridge pier is done using Finite Element Code[1]. Continuous Surface Cap Model (CSCM) of concrete model is used to identify the possible damage of Pier concrete. Plastic kinematic model of steel is used to represent the reinforcing steel. Two-way automatic surface to surface contact algorithm is employed between the rock and the static Pier.

Keywords: impact simulation; concrete damage; CSCM model of concrete; cracking; failure criteria; LS DYNA.

1. Introduction

The river at the bridge location becomes dry during winter but during monsoon it flows between the banks full but with shallow depth. The water sometime carries large tree logs and boulder from the mountain area. The purpose of this study to check the potential harms that the 'flowing boulder' may cause to the structural integrity of the Piers.

No data available about the size of the boulder that may carry by the water. Following assumptions are made for the boulder and its probable strike velocity in discussion with the local people:

- Boulder size – approximately 1.0m diameter

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Effect of Seismic Isolation Bearings on the Potential Pounding between Adjacent Girders for Long-Length Girder Bridge Systems

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Abstract

Research on seismic-isolated bridges concerning potential pounding between adjacent units remains limited to date, especially for long-length girder bridge systems consisting of several long-span girder bridges where the wave passage effect is of great significance. To investigate the effect of seismic isolation bearings on the potential pounding between adjacent girders considering the wave passage effect, a finite element model of a bridge system consisting of two box-girder bridges and one long-span hybrid truss-box girder bridge is developed. The results show that under uniform excitations the seismic isolation bearings can reduce the relative displacement at expansion joints and thus improve the performance against pounding. However, the wave passage effect can increase the deformation demands of the expansion joints and improve the probability of pounding even though seismic isolation bearings are used, especially for the low apparent wave velocities.

Keywords: long-length girder bridge systems; long-span girder bridges; seismic isolation bearings; expansion joints; pounding; wave passage effect.

1 Introduction

For the conventional long-span continuous girder bridges with bearings, the prestressed concrete structure is often used for the superstructure. To date, the longest one for this type of bridge is the Varrod girder bridge with a span of 260 m in Kristiansand, Norway, built in 1994 [1]. Nowadays, the span capacity of the long-span continuous girder bridges with bearings is further increased by using hybrid structures, e.g. truss-box girder hybrid bridge, arch-beam hybrid bridge. Considering the importance of long-span bridges in a traffic net, post-earthquake functionality, as well as require a high cost for repairing, seismic isolation design rather than ductility design will be employed. To mitigate the seismic inertial force from girders to the piers, various isolation bearings have been developed to elongate the structural natural periods and reduce the force [2, 3]. Friction pendulum bearing (FPB) is one of the most popular isolation bearings for long-span girder bridges, due to its isolation period independent of superstructure mass, as well as outstanding re-centering capacity and durability character [4].

For long-span bridges, the spatial variation in ground motions has a great effect on the seismic response of the bridge, especially the wave passage

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Seismic Vulnerability Study of Precast Segmental Piers with Bonded Tendons

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Abstract

The widely applications of precast segmental bridge piers in high-seismicity areas are hindered for their insufficient capacities of energy dissipation. In this study, precast segmental piers' seismic behaviours were investigated, focusing on the connection of "grouted sleeves/bonded tendons". Four piers were cyclically loaded, of one cast-in-place pier, one precast segmental pier, and two prestressed precast segmental piers. Experimental results showed that bonded tendons apparently enhanced the pier's lateral strength, ductility, energy dissipation capacity and reducing residual drift. Of particular, bonded tendons prevented the shear-induced slip between the shaft and footing segments. Furthermore, seismic vulnerability assessments of the bridge piers are obtained in terms of fragility curves. Residual drift is adopted to define the limit states. It is suggested that bonded tendons could significantly ameliorate the fragility curves of precast segmental piers.

Keywords: precast segmental; cyclic; prestressed; pier.

1 Introduction

Precast segmental piers are gaining engineers' favours due to strengths of accelerated construction, reduced traffic disturbance and enhanced quality control [1], compared to the cast-in-place counterparts. From aspects of seismic design, dividing a pier into several segments could mitigate massive concrete spalling/crushing and excessive residual drift [2], and therewith, enhance the seismic resilience. However, it is acknowledged that this technique is hindered in high-seismicity regions, due to insufficient capacity of energy dissipation [3].

Balancing seismic resilience and energy dissipation is vital to accelerate precast segmental piers into high-seismicity areas. Over the past few years, researchers have proposed various connection types between segments, e.g., high-strength rebars [4], high-performance concrete [5] and prestressing tendons [6]. Among them, prestressing tendons, either unbonded or bonded, could rise the energy dissipation capacity and reduce the excessive residual drift to a remarkable level simultaneously. Although numerous experiments have been performed, it is still necessary to further explore the seismic behaviours of precast segmental piers, especially with the "grouted sleeves/bonded tendons"

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Reconnaissance Report on Damage of Bridges in 2021 Maduo, China, Earthquake

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Abstract

A powerful earthquake occurred in Maduo, Qinghai Province, China, on May 22, 2021. Bridges at the earthquake-stricken area were damaged or even collapsed. Post-earthquake field investigations of damaged bridges were conducted by the authors during May 28-30, 2021. This is a reconnaissance report on the damage to two typical girder bridges near the epicenter as well as possible damage mechanisms. It is found that the velocity pulse effect of near-fault ground motions could trigger excessive longitudinal displacements and severe pounding of superstructures of long multi-span girder bridges. Abutments could effectively reduce longitudinal seismic damage of short girder bridges through providing sufficient translational restraints.

Keywords: Maduo earthquake; reconnaissance report; damage mechanism; girder bridge; velocity pulse effect; near-fault ground motion; abutment.

1 Introduction

An earthquake struck Maduo, Qinghai Province, China, at 2:04 am (local time) on May 22, 2021. According to China Earthquake Administration (CEA), the magnitude of the Maduo earthquake was 7.4. As the most powerful earthquake occurred in China since the 2008 Wenchuan earthquake, the Maduo earthquake caused damage and even collapse of several bridges near the epicenter, resulting in severe traffic disruptions.

Post-event field investigations on damaged bridges are of great significance, through which damage/failure mechanisms of bridges under seismic loads can be obtained and lessons can be learned for seismic design of bridges in the future. the Maduo earthquake happened at high altitude cold areas. Seasonally frozen soils and liquefiable soils are detected near damaged bridges. It is important to investigate how bridges located in such complex geotechnical conditions behaved during the earthquake.

A reconnaissance team jointly established by Institude of Engineering Mechanics of CEA, Tongji University and Qinghai Earthquake Agency visited the earthquake-stricken area during May 28~30, 2021. In this paper, the damage to two representative girder bridges near the epicenter: Yematan Second Bridge and Heihezhong Bridge, are reported and discussed.

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Experimental Study on Scour Depth Monitoring of Bridge Foundation Based on Ultrasonic Wave

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Abstract

Foundation scour phenomenon is the result of the water current erosion, which could lead to the removal of streambed materials around the foundation of bridge pier or abutment. The structural damage caused by foundation scour usually has no obvious foreboding. It will easily lead to bridge collapse without early warning. Therefore, it is necessary to conduct the real-time monitoring of the foundation scour for bridges. This paper proposed an ultrasonic-based scour monitoring method for the bridge foundation. The local scour test model based on ultrasonic wave method is established by using the glass box in the laboratory. In the test, the possible scour pit is simulated by shaping the fine gravel in the glass box. An acoustic detector made by our research group was used for signal transmitter and receiver in the test. In addition, the influence of different inclination angles of the scour pit on monitoring result is also investigated in this study.

Keywords: bridge; foundation; scour; monitoring; ultrasonic wave.

1 Introduction

The bridge number of China is increasing day by day with our rapid economic development. Meanwhile, the corresponding number of bridge collapses is also increasing in past decades[1]. One of the main causes of bridge collapses or severe damages is the bridge foundation scouring. Liu et al. [2] have made the statistics on the bridge collapses due to flood scouring in China from 2007 to 2015. Their research found that of the 44 bridges damaged by flood-induced scouring, only two bridges were older than 50 years. In another words, when most of collapsed bridges lost their structural functions, they were far from reaching their design service life. Recently, Xiong et al. [3] summarized the existing research achievements and methods of hydraulic bridge failure and indicated that scour is the primary cause of hydraulic bridge failure, principally resulting in the failure of beam, truss, and arch bridges. The scour degree of the bridge is significantly correlated to service time, structural state, and annual mean runoff. In addition, the flood-Induced scouring was also deeded to be the main cause of bridge failure around the word[4-6].

In fact, the soil and riverbed around the bridge foundation will form a continuously developing scour pit under the action of flood scouring effect. It would further decrease the bearing capacity of the bridge foundation. Usually, the flood-induced scour failure mode of the bridge foundation is very sudden and so difficult to monitor in extreme flood event. In order to identify the actual scour depth in time during the bridge’s service life, it is necessary to assess and evaluate the bridge safety through in-time monitoring. Many scholars at home and abroad have studied the scour depth

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Parametric Analysis and Performance Evaluation of Tuned Mass Damper Inerter (TMDI) to Mitigate the Vortex-Induced Vibration of a Long-Span Bridge

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Abstract

In this paper, an inerter is incorporated into the conventional TMD system, and the performance of the novel inerter-based system, namely tuned mass damper inerter (TMDI), for the VIV mitigation of long-span bridges has been studied. A suspension bridge is taken as a numerical example to verify the performance of TMDI, and the optimal parameters of TMDI are determined by the genetic algorithm. A parametric analysis of the control effect of TMDI is conducted to investigate the influence of the mass ratio and inertance ratio of TMDI on its static deformation, control effect, stroke and control force. The results show that with the same mass ratio, TMDI is slightly less effective than TMD, but it can still significantly reduce the vibration amplitude of the bridge deck. The static deformation and stroke of TMDI are much smaller than that of TMD, which saves installation space and makes it more suitable for the vertical vibration control of long-span bridges.

Keywords: long-span bridge; vortex-induced vibration; tuned mass damper inerter; vibration control.

1 Introduction

With the technical advancement of bridge construction, long-span bridges become more and more flexible, thus the abnormal vibration of bridges occurs frequently at low wind velocity. Vortex-induced vibration (VIV), a typical wind-induced vibration, has a great influence on driving comfort and safety, and a lot of control schemes have been devoted to the problem. Tuned mass damper (TMD) is one of the most effective schemes and has been widely adopted in long-span bridges due to its reliability. However, the application of TMD on the vertical low-frequency VIV control of bridges is limited since the static deformation is excessive.

Recently, a novel two-terminal device named inerter was applied to the vibration control of engineering structures. Smith [1] first proposed the concept of inerter in 2002. Ikago et al. [2] proposed a new seismic control device, tuned viscous mass damper (TVMD), and derived a closed-form optimum design for the TVMD vibration control system. Garrido et al. [3] proposed a rotational inertia double-tuned mass damper (RIDTMD) by replacing the viscous damper in conventional TMD with the TVMD. They demonstrated that RIDTMD is more effective at the same mass ratio, especially near the resonant frequency, and the suppression band is wider than TMD. Marian and Giaralis [4] introduced inerter into TMD to achieve enhanced performance in mitigating the response of the primary structure subjected to white noise

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Seismic Analysis of High-Speed Railway Irregular Bridge-Track System under Obliquely Incident Waves

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Abstract

This study mainly explores the influence of different seismic incident angles on the damage of irregular bridge track systems in complex topography regions. The seismic ground motions of the V-shaped canyon site were simulated through SH wave theoretical analysis. Nonlinear seismic response analyses of irregular simply supported railway bridge–track systems were performed under the different incident angles of seismic (0°~ 60°). The effects of different seismic incident angles on the seismic response of the bridge-track system are analyzed. The results show that the seismic displacement responses of piers top, transverse movable bearings, and fasteners are significantly different under different seismic incident angles, and the unfavorable seismic incident angle is 60°. Underestimate the maximum 37 % seismic displacement response of pier top, transverse movable bearings, and fastener without considering the influence of incident angle.

Keywords: incident angle; topography effect; seismic damage; irregular bridge; asymmetric V-shape; analytical solution; ballastless track.

1 Introduction

Railway bridges are inevitably built near faults along with high-speed railway extending to the western complex mountainous areas and high-intensity seismic regions in China. At this time, the ground motion input of the railway bridge cannot assume the vertical incident of ground motion as the far-field earthquake due to the existence of the incident angle [1, 2]. Moreover, different seismic incident angles in mountainous topography cause the spatial variability of ground motion, resulting in significant differences in ground motion input of different piers of railway bridges [2]. And then cause seismic damage of the bridge-track system is incorrectly evaluated and threatens the safety of train operation.

There have been many studies on the influence of different seismic incident angles on the seismic damage of tunnels [1, 3, 4], dams [5-7], and highway bridges [8, 9]. The results show that the seismic response of the structure is underestimated without considering the seismic incident angle, and the damage underestimation range is about 30% - 200% due to different structural forms (bridge, tunnel and dam types, etc.) [2, 8, 10, 11]. However, the influence of the spatial variability of ground motion caused by the incident angle of ground motion on the seismic damage of railway bridges in mountainous areas with track structures is the insufficient study [2, 12], which causes incorrect assessment of the seismic damage of railway bridges and threaten the safety of train operation. Therefore, the seismic ground motions of the V-shaped canyon site were simulated through SH wave theoretical

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Dynamic analysis of large-span suspension bridge under earthquake excitations using ANSYS-MATLAB co-simulation

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Abstract

Under strong excitations, such as earthquake, the effect of the geometric nonlinearity of the suspension bridge is significant. Traditional train-bridge interaction analysis method usually cannot simultaneously consider both geometric nonlinearity and spatial wheel-rail contact. In this paper, an ANSYS-MATLAB co-simulation method is proposed to analyze the dynamic responses of the train-suspension bridge system under earthquake excitation. The two software platforms are coupled through the interaction between track and bridge, and then the dynamic response of the whole vehicle bridge coupling system is solved. the dynamic response of the train-bridge system of a railway suspension bridge under the action of an earthquake is analysed, taking into account the effect of peak ground acceleration and characteristic period on the geometric nonlinearity of the bridge and the safety of trains running on the bridge.

Keywords: long span railway suspension bridge; co-simulation method; geometric nonlinearity; spatial rolling wheel-rail contact; seismic; running safety.

1 Introduction

With the development of high-speed railway construction, the demand for the construction of long-span railway bridges will increase day by day. Suspension bridges have become one of the structural forms considered for long-span railway bridges due to their stronger spanning capacity, more flexible side span layout and cost advantages[1], Due to the frequent occurrence of earthquake disasters in my country, the earthquake has a significant impact on the dynamic response of bridges and the safety of vehicles on the bridge[2], Therefore, studying the dynamic response of suspension bridges under earthquake action and the safety of trains on the bridge has important reference significance for engineering design.

Most of the completed suspension bridges are highway suspension bridges, therefore, there are not many studies on the safety of trains on railway suspension bridges under earthquakes.

Lei Hujun et al [3] used the virtual beam method to establish a bridge model and carried out a study on the safety of a kilometre-class high-speed railway suspension bridge under earthquake action based on a self-programmed train-track-bridge-earthquake analysis system program; Xiao et al [4] used the modified Lagrangian equation and the principle of virtual work to establish the nonlinear equations of motion of the vehicle-cable system in incremental form and, on the basis of the implicit Wilson-theta method Seung et al [5] proposed a new iterative solution algorithm based on the Newmark mean acceleration algorithm and the Newton-Raphson

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Seismic Fragility of Double-Deck Curved Girder Bridge Based on Artificial Neural Network and Lasso-Logistic Regression

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Abstract

Double-deck curved girder bridges are frequently used to satisfy the demands of traffic lines to accomplish quick ascents. However, damage to this type of bridge has a significant impact on the entire transportation network. Therefore, it is necessary to study the seismic fragility of this type of bridge. The seismic demand model and the multidimensional seismic fragility model of a double-deck curved girder bridge are established using the artificial neural network and the Lasso-logistic regression method. The following conclusions are drawn: 1) The gap value has a significant impact on the fragility of the bearing and limit device. 2) The impact of the friction coefficient of bearing and concrete strength on component fragility reduces as the damage level increases. 3) The ground motion intensity is the most important factor in pier damage.

Keywords: Double-deck curved girder bridge; fragility; artificial neural network; Lasso-logistic regression.

1 Introduction

Seismic fragility quantifies the seismic performance of a structure using the probability method and describes the relationship between the ground motion intensity and the degree of structural damage [1], which promotes the development of performance-based seismic concepts and serves as an important research means for uncertainty transmission. The fragility curve is the primary indicator of seismic fragility. Hwang et al. [2] introduced in detail the systematic analysis method of fragility curve of reinforced concrete structures under earthquakes, and drew the fragility curve of a concrete continuous beam bridge on an expressway in the Middle East of the United States. Moschonas et al. [3] established the seismic fragility curve of a typical bridge on modern Greek expressways, considering the uncertainties of bridge structures such as pier type, beam, connection mode between pier and beam, and the surrounding conditions of abutment. Borzi et al. [4] established the comprehensive database of seismic fragility of existing highway bridges in Italy and developed the analysis and evaluation program of fragility curve.

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Damping of long-span suspension bridges with damped outriggers

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Abstract

Long-span suspension bridges are vulnerable to vortex-induced vibrations (VIVs), e.g., the Humen Bridge and the Xihoumen Bridge in China. This study focuses on a novel strategy by using damped outriggers to control rotations of bridge deck at the junction points between the girder and a bridge tower or pier. A simplified model of a suspension bridge with damped outriggers is used for damping analysis. Considering practical parameter ranges, the maximal damping ratio provided by one damped outrigger to a specific mode is about 1.0%. Influences of bridge boundary conditions, installation position of damped outriggers, and interaction between multiple damped outriggers are studied. When multiple damped outriggers are installed, the damping effects of multiple modes can be further improved. It is shown that damped outriggers are effective in suppressing multimode vibrations of long-span suspension bridges.

Keywords: Damping; suspension bridge; damped outrigger; vortex-induced vibration; complex modal analysis.

1 Introduction

In the last decades, with the increase of bridge span, the stiffness of the bridge becomes lower. Meanwhile, the frequency and damping decrease, which makes the bridge easier to vibrate under the action of wind and vehicles [1], particularly the vortex-induced vibrations (VIVs). The vibrations could threaten the experience of bridge users, and may even endanger the safety of the bridge structure. Vibration mitigation remains a challenging issue for long-span bridges.

At present, vibration control methods for long-span bridges mainly include aerodynamic treatments, mechanical devices, and structural countermeasures [2]. The commonly used mechanical devices include direct energy dissipation dampers and tuned mass dampers (TMD). TMD can be connected to a structure at an arbitrary position to control the absolute displacement [3]. However, it can only be optimized to a certain vibration mode. Compared with a TMD, direct energy dissipation dampers need to be installed between two points with large relative displacements of the structure to achieve vibration mitigation and energy consumption. The dampers for controlling the vibration of the main girder have been considered between the tower and the girder beam [4]. It is noted that the vertical relative displacements of the bridges at the

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Performance of Simply-Supported Steel Bridge in Realistic Fires

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Abstract

This paper investigated the thermomechanical performance of a simply-supported steel girder bridge above a tanker fire by coupling the computational fluid dynamics (CFD) method and finite element method (FEM). Numerical results show that the presented method was able to replicate the inhomogeneous thermomechanical response of box bridges exposed to real fires. The girder failed due to the buckling of a central diaphragm after the ignition of the investigated tanker fire in no more than 10 min. The framework presented in this study is programmatic and friendly to researchers and can be applied to estimate bridges in different fire conditions.

Keywords: steel bridge; fire; thermomechanical performance; CFD; FEM.

1 Introduction

Fire-induced damages to bridges appear as an increasing concern as more bridges fail due to vehicle fires [1-3]. The fire threat to bridges can worsen along with the prominent development of transport of inflammable products. By reducing the material strength dramatically, fires can result in partial or total collapses of bridges. Famous examples include MacArthur Maze, the I-65 overpass, and the more recent railway bridge in Tempe town in the USA.

Exposed to fires, steel bridges deflect seriously and can reach the ultimate state at high temperatures. Previous studies simplified the fire condition as the temperatures increased over time for building structures, such as the ISO834 curve and ASTM119 fire. However, bridge fires usually have no air limitations. Therefore, adopting prescriptive curves for bridges can underestimate surrounding temperatures and make the safety estimation unconvinced.

Comparatively, coupling the computational fluid dynamics (CFD) model of the fire scenario and the finite element (FE) model of the exposed structural portion can provide a more realistic insight into the thermomechanical behavior of the bridges in fire conditions [4]. However, the

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Flutter Behavior and Stability Evaluation of Suspended Footbridge through Wind Tunnel Experiments and Aeroelastic Flutter Analysis

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Abstract

Suspended footbridges are set apart by being much more lightweight and slender compared to conventional highway bridges. For this reason, the stiffness and damping of the bridge system are significantly lower, causing an outsized influence of wind load. Therefore, a precise evaluation must be performed to secure the wind stability of the suspended footbridge. However, design specifications are not documented, and reported studies are insufficient. In this study, a conventional 2-DOF section model test was conducted to estimate the flutter wind velocity of the suspended footbridge and observe the flutter behavior. Frequency domain step-by-step flutter analysis was performed to identify the flutter generation mechanism of examined suspended footbridge. It was deduced that the decrease of torsional damping due to the torsional-driven vertical vibration and coupled aeroelastic force induced the torsional flutter.

Keywords: suspended footbridge; flutter stability; section model test; aeroelastic flutter analysis; flutter behavior.

1 Introduction

Suspended footbridges are gaining interest worldwide with rising demand for their construction. In particular, the title for the longest suspended footbridge is in fierce competition to promote local tourism. The suspended footbridge is a highly flexible structure because the deck contributes little to the rigidity of the structural system, and the main cable supports the entire bridge. As an indicator of flexibility, the aspect ratio, the main span length/width ratio, can be used [1]. The 516 Arouca Bridge of Portugal, the world's longest suspended footbridge built in 2020, is 516.5 m long and 2.1 m wide, with an aspect ratio of 246 [2]. It is significantly higher than the aspect ratio of 45 of the world's longest suspension bridge span of the 1915 Çanakkale Bridge. It can be seen that the suspended footbridge is a much more flexible structure than the conventional highway bridge. The slenderness and lightweight characteristics of suspended footbridges cause the vibration response induced by dynamic loads to occur relatively larger than highway bridges [3-5]. In particular, flutter instability is an important structural problem that must be resolved at the design stage due to suspended footbridges being mainly installed in mountainous or coastal terrain

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Effect of Firewall on a Suspension Bridge under Vehicle Fire

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Abstract

In this study, a firewall was proposed as such countermeasure against the risk of vehicle fires on a suspension bridge, and the effect of the firewall was investigated by CFD analyses considering the proposed firewall. CFD analyses results, it is observed that temperatures exceeding the regulation of PTI standards (300℃) occur in the tanker fire scenario. Thus, countermeasures are required in this case. Therefore, analyses of the cases with firewall were performed, and it was confirmed that installing a firewall reduces the maximum temperature of the cable. Finally, the optimal dimensions of the firewall were suggested through a parametric study of a series of CFD analyses. In the future, if additional CFD analyses for various scenarios and assessment of wind stability considering the firewall installation are performed, it is expected that the cable members of the actual cable-supported bridges can effectively be protected from vehicle fire.

Keywords: firewall; suspension bridge; vehicle fire; fire test; heat transfer analysis; CFD analysis.

1 Introduction

Until recently, fire accidents on bridges have been occurring frequently worldwide. Vehicle fires affect bridges, the consequent damage is serious, and large fires can lead to the bridge collapsing [1]. With the development of construction technology and the high strength of materials, bridge spans are increasing, and numerous suspension bridges are in operation around the world. Figure 1 show the case of a fire accident that occurred in The New Little Belt Bridge in Denmark in 2013. If a vehicle fire occurs on a suspension bridge, damage to the main member may occur and cause the bridge to collapse. If the suspension bridge collapse, it can cause enormous human casualties and economic loss, so fire protection countermeasures are needed. However, fire accidents such as vehicle fires on the suspension bridge are currently not sufficiently protected. Therefore, in this study, a firewall system was proposed to protect the main members of the bridge from vehicle fires occurring in the suspension bridge, and the installation effect of the firewall was analyzed by CFD analyses considering the proposed firewall.

Figure 1. Fire accident on suspension bridge

2 Firewall system proposal

Fire tests and heat transfer analyses were conducted to investigate the fire resistance performance of the proposed firewall system.

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Analysis of Lateral Torsional Buckling of Steel I-Beams within Preflexed Beams in Pre-Bending Stage

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Abstract

In order to study the lateral torsional buckling (LTB) law of steel I-beams within preflexed beams in pre-bending stage, the traditional Rayleigh Ritz method was applied, and the modified Rayleigh Ritz method was proposed by considering the restraint effects caused by lateral braces. A large number of finite element models were established by ABAQUS. The theoretical and simulation results show that the modified Rayleigh Ritz method proposed in this paper can reduce the maximum relative error of traditional Rayleigh Ritz method by about 13%. The effects of different parameters on the LTB of steel I-beams were obtained through parameter analysis. The study in this paper can provide reference value for the analysis of LTB of steel I- beams and the parameter selection of preflexed beams in pre-bending stage.

Keywords: lateral torsional buckling; steel I-beam; lateral brace; modified Rayleigh-Ritz method.

1 Introduction

In recent years, with the application of preflexed beam in traffic engineering, the technical standard for preflexed composite beam bridges (CJJ/T 276-2018) issued in 2018 summarized the relevant construction technology of preflexed composite beam: Firstly, prepare a curved steel I-beam, and pour the first stage concrete after the steel I-beam is subjected to pre-bending loads. Secondly, remove the pre-bending loads, and the pre-compressive stress is applied to the first stage concrete which is in the tension zone. Finally, the second stage concrete is poured to form the preflexed composite beam [1-2].

The steel I-beam in preflexed composite beam usually adopts two concentrated loads in pre-bending stage [3-5]. In pre-bending stage, the lateral torsional buckling of steel I-beam is easy to occur. Therefore, it is necessary to arrange lateral

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Numerical Investigation on Anchorage Zone Capacity of Post-Tensioned RPC

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Abstract

The bearing capacity of the anchorage zone is involved in prestressed structures, which is a problem for the local compression zone. This paper used ABAQUS software to simulate the local compression of reactive powder concrete (RPC) under various conditions, according to RPC's deformation characteristics and mechanical properties. The damage parameters are filled in according to the constitutive model. The specimens with the duct have been simulated with different bearing plate lengths, stirrup spacing, and various reinforcement ratios and were studied. The load-displacement curves and ultimate bearing capacity were obtained. The summary and analysis showed that the stirrup spacing could provide a beneficial behavior in controlling the cracks. Moreover, the steel stirrup reinforcement can dissipate the energy in the specimen, and the RPC specimen's local compression bearing capacity is improved by increasing the bearing plate's length.

Keywords: reactive powder concrete (RPC); ABAQUS; bearing capacity.

1 Introduction

Reactive powder concrete (RPC) is a unique type of ultra-high-performance cement-based material with remarkable toughness, super-high compressive strength, and good durability. The combination of prestressed and reactive powder concert structures has become a research priority to meet the building's steady transition to super high-rise and large-span structures.

These structures not only have the strength and seismic performance of the prestressed concrete structures, but they also have the properties of RPC, such as high durability and high ductility, high tensile and compressive strength, and high toughness [1, 2]. Furthermore, post-tensioning can be an elegant assembly method for constructions built of pre-cast prestressed components. As a result, the subject of how to design safe end blocks for post-tensioning tendons is essential. Therefore, exploring the anchorage zone of prestressed RPC is significant. The behavior of steel fiber post-tensioned anchorage zones by enhancing the fiber's tensile strength with ducts, reinforced by the orthogonal ties, and high-strength steel spirals has been investigated by Wei et al. [3-5]. Li et al. [6] studied RPC members' prestressed anchorage zone under various curing conditions and steel fiber ratios. The test results showed that steam curing increases the local bearing capacity of RPC members. Compared to natural curing, results showed that the bearing capacity gradually decreased when the steel fiber ratio exceeded 3%. A recent study was conducted to validate the possibility of extrapolating design specifications for concrete strengths between 80 to 120 Mpa; results showed that high concrete strength could decrease the stress under the concentrated load to a rate corresponding to the starting of the first cracks on

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Analytical Study on the Effect of the Condition of Cable Members on the Structural Safety of a Long-Span Suspension Bridge

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Abstract

We have studied on an evaluation method to assess the structural soundness of the long-span suspension bridges taking into account of the condition of the suspender ropes, such as the break of the suspender rope.

This paper reports that an analytical study for Innoshima Bridge which is a long-span suspension bridge with a central span length of 770m, focusing on the effects of the modelling of the entire bridge model, the condition of cable members, and the analysis method.

Keywords: long-span suspension bridge; finite displacement analysis; break of suspender rope.

1 Introduction

In Japan, since 2014, regular inspections of road assets such as bridges and tunnels are carried out every five years through close visual inspection [1]. However, there are some problems such as budget and personnel shortages for the close visual inspection for all the structural members of the highway bridges. Furthermore, the soundness and the progress of deterioration of the bridges are not completely grasped only by the close visual inspections [2]. The trend can be seen particularly in cable supported bridges which are composed of many structural members of the same functions and the members that are not easy to see in close proximity, and the optimization of the periodic inspections is required.

In recent years, small suspension bridges in Japan and abroad have been aging, and there have been cases of accidents and failures such as cable rope, hanger rod, and strand breakage due to corrosion damage and bridge collapse accidents due to cable breakage, for example [3].

Therefore, it is important to optimize the inspection of suspension bridges, i.e., to rationalize and improve the reliability, in order to maintain them in the future.

The changes in the condition of the cable members may include cross-sectional reduction, rupture, and creep due to corrosion and other factors.

These studies on state changes include: a study of center stays, which are assumed to rupture during earthquakes in design [4], and a recent analytical study that clarified changes in stress state and vibration characteristics by analysis that takes into account creep phenomena in cables, which greatly affects deformation in small- and medium-scale non-reinforced suspension bridges [5].

However, it is considered insufficient to evaluate the effects of changes in the condition of the cable members on the function of the bridge.

In light of this situation, this paper focuses on long-span suspension bridges, which are representative of suspension bridges, and discusses analytical methods to be applied to evaluate the effects of

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Influence of Time-Varying Mean Winds on the Nonlinear Buffeting Responses of a Super Long-Span Suspension Bridge

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Abstract

The cosine function and two modulation functions are separately selected to generate the time-varying mean wind and fluctuating wind speed, and their effects on nonlinear buffeting responses of a super long-span suspension bridge were investigated in this paper. Firstly, two non-stationary wind speeds models were validated by the classical power spectrum density, and could effectively simulate the non-stationary characteristics. Secondly, the time histories and RMS values of three displacement responses of the bridge deck under two non-stationary wind speeds with three different values of γ and θ were compared, respectively. Results show that the torsional and lateral displacement responses under the non-uniform modulation function are larger than those under the uniform modulation function. Moreover, the RMS values in three displacement responses of the deck gradually become larger with the increase of γ or the decrease of θ.

Keywords: Super long-span suspension bridge; time-varying mean wind; uniform modulation function; non-uniform modulation function; non-stationary wind speed; buffeting responses.

1 Introduction

Super long-span suspension bridges are highly susceptible to wind loads owing to structural flexibility and low stiffness[1]. The strong typhoon disease frequently occurred in China in recent years, for example, the 16 level typhoon events of Pigeon in 2017 and Lekima in 2019. As a prominent characteristic of strong typhoon, the non-stationary wind speed has great effect on the wind-induced vibration behaviours of super long-span suspension bridges, especial for the buffeting response which could lead to the comfortability of passengers and structural fatigue damage of bridges [2-3]. In order to accurately predict the buffeting performance, it is necessary to basically study the influence of non-stationary wind on the nonlinear buffeting responses of a super long-span suspension bridge.

The non-stationary wind speed was generally divided into the time-varying mean wind speed and fluctuating wind speed. Recently, some scholars studied the influence of time-varying mean wind speed and fluctuating wind speed on buffeting performance of long-span suspension bridges. Based on the measured typhoon data, Xu et al [4] extracted the time-varying mean wind speed from

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Experimental and Numerical Study on the Seismic Performance of Precast Bridge Column with an Improved Grouted Corrugated Duct Connection Design

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Abstract

In this paper, an improved connection design of the precast bridge column is proposed, including new design of grouted corrugated steel duct and a shallow recess pocket at the top of footing connection for the assembly of precast concrete bridge columns, which has a good seismic performance, durability and facilitate constructability. The improved grouted corrugated steel duct which can increase the bonding mechanism and facilitate constructability expected to perform better than conventional corrugated galvanized steel ducts used for post-tensioning applications. Finite element analysis is then conducted. It is found that the confining effect (support and friction force) provided by recess sidewall keeps the connection in good integrity. It also prevents early deformation and early development of transverse cracks along the connection interface, which further avoids the damage concentration at connection joint, transfers the plastic hinge region.

Keywords: prefabricated concrete bridge column; grouted corrugated duct connections; seismic performance; quasi-static cyclic test; finite element analysis.

1 Introduction

Precast bridge has attracted increasing attentions in the past decades, due to the fast construction speed, slight traffic interruption, high structural robustness, minor environmental impact, and low cost [1]. The majority of the research activities has focused on low seismic regions [2, 3], while studies on the seismic performance at medium-to-high seismic regions are limited.

The grouted ducts and sleeve couplers are favorable choices due to the construction convenience and low cost. Grouted corrugated duct connection (GCDC) are used for the connections of column-cap and column-footing, and the performance (grout strength, embedded length and duct properties) is promising [4, 5]. Good strength and displacement capacity are found in the substructures with GCDC [1, 6-9]. It was reported that structures with these types of connections and the corresponding cast-in-place (CIP) benchmarks showed equivalent strength but lower displacement capacity [6, 10-13], which can be improved by allowing debonding of reinforcing bars [14].

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Experimental study on the influence of gust-wind on a high-speed railway train-viaduct system

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Abstract

As the high-speed railway emerges in Eurasia, a comprehensive understanding of the aerodynamic problems – particularly extreme wind events – is vital to the success of the safety, operational efficiency, and transportation industry. Such knowledge of the effect of extreme wind on the train and bridge system has been hindered by a lack of available field test data. In light of limited field measured data to arrive at a consensus on quantifying key parameters characterizing the non-stationarity winds, accuracy associated with wind velocities is carried out using wind tunnel experimental approaches in this study. Compared with atmospheric boundary layer winds, which are customarily treated as stationary, winds associated with gust-fronts originating from a thunderstorm/downburst/tornado exhibit rapid changes during a short period which changes in direction may accompany. To realistically capture the characteristics of gust-front winds and their attendant load effect, a new gust-wind generator was presented, built in the CSU wind tunnel. Under a condition of the combined operation between a gust-wind generator and wind tunnel, the gust-front wind characteristics and effects on the train-bridge system were analyzed.

Keywords: high-speed railway; train-viaduct system; gust wind; wind tunnel test; aerodynamics

1 Introduction

Over the past 20 years, China's high-speed railways have grown from 0 to more than 40,000 kilometers[1]. A high-speed expansion of railway construction in and around cities has made this development trend even more evident in recent years. The geography and climate are vital environmental factors that must be considered for the intensive exploitation of railway transport, and the developing trend puts a high demand on design and research in the railway field. Especially climate change poses multiple threats to the railway, one of the effects of climate change the worldwide is that there will be more extreme weather. In addition, the expanding railway network is a consequence of the need to pursue speed and convenience; therefore, train shuttles through various terrain scenes have become widespread. Hence, the main issue is the environmental effects of extreme climate and geography on railway aerodynamic behavior. These increases in extremes are significant from the perspective of the train–bridge system because of the complexity have to face. First, the viaducts have majorities in both the railway and transportation network, and the situation has been particularly noticeable in China. It means the risk of a train running on the

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Numerical Simulation of the Nonlinear Flexural Behavior of Pretensioned Void Slabs with Different Concrete Constitutive Laws

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Abstract

To investigate the numerical simulation for the nonlinear flexural behavior of pretensioned void slab beams, the three-dimensional finite element models (FEM) of the existing pretensioned void slabs were established and verified through tests. Firstly, based on the concrete constitutive laws in Chinese code and *EN 1992-1*, the damage factors in concrete damaged plasticity (CDP) models derived from energy equivalent model were incorporated. Meanwhile, the constitutive models of reinforcement and prestressing tendons were calibrated in accordance with the yield strength and tensile strength data obtained from the tests. Then, the flexural loading history of the beams were numerically analyzed, and the simulation outcomes were compared with the test results. Finally, the impact of constitutive laws and the damage factors on the calculation accuracy and efficiency of numerical simulation analysis were studied.

Keywords: concrete structure; pretensioned void slab; flexural behaviour; nonlinear analysis; concrete damaged plasticity; test verification.

1 Introduction

Pretensioned void slab has been widely adopted in highway and municipal bridges because of its low deck height, cost effective and convenient construction. It can offer a depth-to-span ratio as low as 1/20. However, the de facto overloading in many road traffic network may render the slab decks into cracking or even nonlinear response to some extent [1]. Accordingly, effective and accurate nonlinear analysis of void slab should be further developed for the whole loading history.

Extensive research efforts have been made to study the nonlinear behavior of concrete slabs using finite element analysis method. Azizian et al [2] investigated punching shear in solid and void slabs, and established their nonlinear finite element models (FEM) validated based on a comparison with experimental specimens under static loading to predict their punching response. Attia et al [3] studied the flexural behavior of a new one-way concrete slab system, and adopted the finite element analysis model to predict the nonlinear structural behavior of the slab strip. Khouzani et al [4] studied the bending behavior of a new biaxial voided slab system proposed, and compared the moment capacity results of numerical simulations with the results through various concrete codes. Nguyen et al [5] conducted shear tests of precast, prestressed concrete hollow core slabs. Also, Finite element models considering concrete damaged plasticity were developed to simulate the web-shear responses of slabs and study the influence of design variables on web-shear behavior of slabs numerically.

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Characteristics and Research Progress of Frost Heaving and Frost Pulling of Pile-soil System

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Abstract

The frost uplift of pile foundation or other rod-shaped structures along with the frost heave of foundation soil, is a kind of frost damage widely existing in cold region engineering. These damages have always been the main problems of railway and highway subgrade, and they are controllable factors affecting the technical indexes of subgrade in cold regions. This paper explores the evolution law, cause, characteristics, and influence factors of frost heave and uplift of pile-soil system during the freezing process. The interaction between pile and soil and the mechanism of frost heave and uplift are revealed. With the analyses on distribution at pile-soil interface and influencing factors of freezing strength, the distribution law of freezing strength at pile-soil interface is clarified. Based on the previous experimental methods of frost heaving force and uplifting force, this paper discusses the problems and limitations using current methods.

Keywords: frost heave; frost uplift; freezing strength; permafrost.

0 Introduction

Permafrost is a special type of geology, usually defined as rocks and soils that are below zero degrees Celsius and contain ice. According to the length and continuity of its freezing period, frozen soil is divided into three types: permafrost, seasonal permafrost, and short-term permafrost.

Foundation freezing is a common engineering disease in permafrost region and seasonal frozen region. The uneven uplift of piles caused by freezing causes the superstructure to tilt or collapse, resulting in serious consequences. At least more than half of the piles of canal buildings, small and medium-sized Bridges and culverts in Heilongjiang Province suffer from frost pulling, and the amount of pile pulling can even reach tens of centimeters per year[1]. In terms of transmission lines, 56 piles on Fengyi Line and Fengda Line, which were put into operation in 1999, were pulled up and could not be used[2].Numerous examples show that this is an urgent problem to be solved.

It is the primary condition for scientific prevention and control of frost heaving and frost pulling disease to explore the characteristics and influencing factors of pile and soil system in freezing process. This article through studies the freezing process under different influencing factors of pile soil interface frozen force

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Investigation on Extreme Temperature Gradient Action of Composite Girder Bridges Considering Regional Difference

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Abstract

To reach an accurate calculation of the effect of composite girder bridges under extreme temperature gradient action, long-term temperature measurements and finite element simulations were performed on a composite girder segment in Huangnan Prefecture, Qinghai Province for more than one year. By setting the maximum thermal self-stress and secondary stress as indexes and considering different sunshine conditions between interior and exterior girders webs of composite girder bridges, 3 temperature gradient patterns were established for multi-girder bridges. Based on the long-term historical meteorological data collected from 839 weather stations in China, a "layer-by-layer drawing method" was put forward to the isoline map of extreme temperature gradient values. Compared with the current specification, the temperature action values provided are more suitable for the Limit State Design Method.

Keywords: bridge engineering; extreme temperature action; steel-concrete composite girder bridge; regional difference; isoline map.

1 Introduction

Bridge structures are subjected to temperature actions caused by solar radiation, annual temperature variations, daily temperature variations in a complex operating environment. Temperature gradient is one important temperature action generating high thermal stresses, further causing concrete cracking and seriously affecting the operational safety and durability of bridges [1-2]. In recent years, at an average altitude of 5,000 m above sea level, approximately 125 km of the Qinghai-Tibet Highway has been constructed in the form of composite girders [3]. The effects of extreme temperature actions on bridges will be even more severe in these high-solar radiation areas.

Early scholars usually assumed a vertically linear temperature distribution along the bridge girder. Later scholars have proposed different non-linear temperature gradient patterns for concrete box girders, including the 5 times parabolic pattern firstly proposed by Priestley [4], the double folded pattern of the American AASHTO Code [5] and the

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A Bayesian Regularization Neural Network Model for Fatigue Life Prediction of Concrete

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Abstract

The fatigue life of concrete is affected by many interwoven factors whose effect is nonlinear. Because of its unique self-learning ability and strong generalization capability, a neural network model is proposed to predict concrete behavior in tensile fatigue. Firstly, the average relative impact value was constructed to analyze the importance of parameters affecting fatigue life, such as the maximum stress level S_{max}, stress ratio R, failure probability P, and static strength f. Then, using the backpropagation neural network improved by Bayesian regularization, S-N curves were obtained for the combinations of R=0,1, 0,2, 0,5; f=5, 6, 7MPa; P=5%, 50%, 95%. Finally, the tensile fatigue results obtained from different testing conditions were compared for compatibility. Besides utilizing the valuable fatigue test data scattered in the literature, insights gained from this work could provide a reference for subsequent fatigue test program design and fatigue evaluation.

Keywords: concrete; fatigue life prediction; neural networks; Bayesian regularization.

1 Introduction

As a complex multi-phase composite material, concrete exhibits significant discreteness in fatigue life [1]. Moreover, since the mapping relationship between fatigue life and its influencing factors is nonlinear, fatigue life estimation has become the emphasis of concrete fatigue research [2]. The conventional method of analyzing fatigue life fits fatigue test data to a specific function relationship. The parameters considered in the fatigue life equations initially contained only the stress level S. Later, the stress ratio R, the loading frequency n, and the failure probability P were gradually integrated for practical applications. Despite their extensiveness and complexity, the proposed equations cannot be applied to all fatigue analyses and are difficult to ensure accuracy [3].

The artificial neural network, which is automatically approximated from the training data [4], does not need to make assumptions about the function form. It is feasible to improve the applicability and prediction accuracy of multi-parameter fitting of fatigue life. Lu and Song [5] used four factors of S_{max}, R, n, and P to train the backpropagation neural network (BPNN) and realized the fatigue life prediction of concrete. Xiao et al. [6] developed a portable fatigue life prediction model, using R and S_{max} as input, with engineering application value. Abambres and Lantsoght [7] used the minimum stress level S_{min}, the geometric mean of fatigue life, and the concrete compressive strength as inputs. They obtained the S_{max} as output for structural design and evaluation purposes. Statistically, the proposed model predicts more accurately than the code equations.

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Mixed Mode Fatigue Crack Propagation Mechanism of the Diaphragm Cutout Detail in Steel Bridge Deck

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Abstract

Based on the extended finite element method (XFEM), finite element model of a typical steel bridge deck was established to analyze the fatigue crack propagation of diaphragm cutout detail. It was considered the parameters of welding residual stress, vehicle load and initial crack in the fatigue mechanism analysis. Residual tensile stress in the cutout edge of the diaphragm of two types of cutout was calculated. Cutout with higher residual tensile stress provided the welding residual stress field for calculation of fatigue crack propagation. Under coupling action of vehicle load and welding residual field, the fatigue crack in diaphragm cutout edge was mixed mode crack of Modes I, II, dominated by Mode I.

Keywords: steel deck; welding residual stress; fatigue crack; crack growth simulation; XFEM.

1 Introduction

Steel bridge deck has been widely used due to its characters of high capacity, light weight, and fast fabrication [1]. However, fatigue damage is found in welded connections of steel bridge decks due to long-term traffic load, residual tensile stress, and environmental corrosion [2, 3]. Fatigue cracks appearing in weld connections will further expand as time goes by, which seriously threatens the safe operation of the bridge.

Cut holes are placed in the diaphragms of modern steel decks, so that the U-ribs pass through the diaphragm continuously and the fatigue stress at the connection between the longitudinal ribs and the diaphragm can be significantly reduced. However, the cut hole reduces the stiffness of the diaphragm. Under the out-of-plane stress and in-plane stress, the stress concentrating at the edge of the cutout is large, plus influenced by factors such as the welding residual stress and initial crack. More research is need to investigate the fatigue performance at diaphragm cutout.

Extensive fatigue test of this detail has been carried out. For example, Haibach performed fatigue tests on the fatigue strength of various types of cutout and applied a new type of cutout[4]. Fryba et al. carried out tests on the type of cutout for open rib diaphragms and suggested that circular and apple shape cutouts should be used in OSD [5]. Wang et al. studied the influence of the shapes of cutout and geometry on the stress distribution at cutouts by static test and finite element analysis of a full-scale steel bridge [6]. The results showed that the stress distribution of the Haibach and circular shape cutouts were rational. Wang et al. carried out full-scale fatigue tests for OSD. The result showed that due to the welding residual stress, cracks were found in the compressive zone, which indicates that welding residual stress plays an

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Fatigue Resilient Design of Bridge Orthotropic Steel Deck

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Abstract

It is difficult to precisely predict the fatigue life of orthotropic decks due to random initial defects and high-cycle loading conditions. Two typical fatigue failures occurr in orthotropic steel decks, which hinder both the capacity and the efficient life of modern steel bridges. The Type 1 crack is along the super-long weld joints between the cover plate and U-shaped rib, while Type 2 crack develop within the diaphragm adjacent to the fillet joints. While both cracks originate and develop from weld toes, and the Type 2 crack usually develop along the near-horizontal direction. Among the many factors contributing to the failure, the notch type, notch size, vehicle loads uncertainties related to positions, magnitudes and frequency were uncertain. Thus, it is reasonable to apply different strategies to achieve more resilient orthotropic decks. It is recommended new weld improvement has to be introduced to mitigate initial notch for type Ⅰ details, and structural flexibility has to be selected to improve the fatigue performance for type Ⅱ detail.

Keywords: Orthotropic steel deck; Diaphragm; Fatigue Crack; life prediction; Resilient;

1 Introduction

The effective operation period of several details is far below the expected within design documents and specific codes (Miki, 2007; Conor,2012; Jong, 2007). The widely deteriorate due to fatigue cracks not only limit the loading capacity of structures, but also require unreasonably high budgets. Many researches have been proposed various solution trying to mitigate the problem. it seems that the fundamental question remains open: how to meet the traffic loading demand and the durable fatigue resistance within the orthotropic steel decks.

The fatigue failure originates as a result of both cycled loadings and initial damage at joints. On the one hand, the orthotropic decks were fabricated with super long welds, which results in uncertain distributed micro damage and types, on the other hand, the vehicle loading position, amplitude and frequency are all uncertain. Therefore, it is an even difficult task to predict and manage OSD's working life.

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Parameter Analysis on Double-side Welded Connection of Orthotropic Steel Decks Based on Structural Stress

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Abstract

Rib-to-deck welded connections of orthotropic steel decks(OSD's) are prone to fatigue problems and the new type of double-side welded connection is applied for optimization. To further reveal transformation mechanism of fatigue mode, the geometrical parameters of double-side welded connection are analysed based on structural stress method. The results show that, compared with other parameters, the thickness of deck brings the greatest impact on the structural stress at the concerned position, but does not change the fatigue failure mode. The fatigue mode of double-side welded connection is related to both internal and external weld size, and the external weld size should be controlled within a certain range relatively. For the basic structure analyzed, when the external weld size is 4mm, 6mm, 8mm and 10mm, the internal weld size shall not be less than 1.5mm, 1.5mm, 3mm and 4.5mm respectively.

Keywords: OSD's; structural stress; double-side welded connection; parameter analysis.

1 Introduction

OSD's are mainly composed of deck, longitudinal ribs and transverse ribs (transverse partition), and the longitudinal and transverse stiffening ribs are welded on the lower surface of the deck cover to form a structure to bear the wheel load together[1,2]. Compared with traditional bridge deck, OSD's could make better use of the mechanical properties of the material, has the advantages of light weight and high strength, wide range of application, easy construction, etc. and is widely used in large span bridges. The structural system and the forming method contribute a lot to outstandingly advantageous of OSD's, but at the same time the construction is complex, with many welds and fatigue cracking problems[3-4]. According to research based on 7000 OSD's with closed longitudinal rib in

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Fatigue Crack Propagation Characteristics of the Deck to Longitudinal Rib Weld in Orthotropic Steel Bridge Deck

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Abstract

In order to investigate the fatigue crack propagation characteristic of the rib-to-deck joint considering welding residual stress, the finite element model of the orthotropic steel bridge deck was established for the typical box girder of a cable-stayed bridge. Considering the effect coupled with the residual stress field, the initial crack and the fatigue load, the fatigue crack propagation at the rib-to-deck joint was simulated based upon the extended finite element method (XFEM). The simulation result of the residual stress shows that there is a large residual tensile stress in the welding area of the rib-to-deck detail, and the peak value of the Von-Mises stress at the rib-to-deck joint close to the yield stress of Q345 material. The results of fatigue crack propagation behaviour display that the fatigue crack at the weld toe is led by mode I, which could keep in the plane during the crack propagation. And the fatigue crack at the weld root is mix mode I-III crack led by mode I, which cannot keep in the plane during the crack propagation, but slightly deflection.

Keywords: orthotropic steel bridge deck; rib to deck weld joint; numerical fracture simulation; XFEM; welding residual stress; fatigue crack.

1 Introduction

The orthotropic steel bridge deck is widespread applied in the large and medium span municipal and highway bridge construction due to its convenient construction, excellent mechanical properties, light weight, and beautiful appearance[1]. However, the fatigue problems of orthotropic steel bridge deck are remarkable[2,3],due to wheel load, many weld joints and several initial cracks[4]. Moreover, fatigue cracks are prone to be growth at the weld joint of rib to deck, and difficult to be detected. And the crack has propagated a large length when it comes to be found. It has been one of the complicated cracking modes in the structure of the orthotropic steel bridge deck. Therefore, it is significant to research the fatigue problems at the welding joint of rib-to-deck.

Fatigue tests were widely applied in the research of steel bridge fatigue problems and anti-fatigue design[5,6]. However, anti-fatigue design and steel bridge maintenance cannot be suited by Fatigue tests research due to its need of large man power and material resources. Hence, numerical simulation based on fracture mechanics theory was applied in the fatigue research gradually. Zhu[7] made the 2D fatigue crack propagation simulation at U-rib to deck joint of the Orthotropic Steel Bridge Deck. Liu[8] established the 3D finite element model of rib to deck of orthotropic steel bridge deck, and researched the fatigue crack propagation characters of this detail. The element near crack

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Risk Management Methodology on Road Infrastructure (GRDR). Application on Mountain Tunnels and Bridges, Valparaíso Region, Chile

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Abstract

After the extreme weather events of 2015 and 2017 in the north of Chile involving heavy rain and debris flood, the Ministry of Public Works launched a Risk assessment program on road infrastructure in order to reduce the risk and provide a list of structures in the national network that could be affected by natural hazards. From 2015 to 2019, GRDR methodology was proposed considering the identification of the damage index (vulnerability) and the frequent natural and made-man hazard (debris flood, flood, fire, among other) applied on tunnels, bridges and other road structures. The GRDR was applied as complement of the current inspections and studies of probabilistic method to identify the hazards. From 2019 a collaboration between MOP and Pontificia Universidad Católica de Valparaíso updated the GRDR methodology including automatization of the acquisition data, review of the algorithm of weight and the study of specific natural hazards. Within this framework, it was determined that the Valparaíso Region of Chile would be the pilot plan in order to apply and calibrate the updated GRDR. This paper presents the results of the application and calibration of the GRDR on two critical roads of Valparaíso Region. An analysis of the inspection using UAV, Thermal camera, GRDR platform among other is carried out. The results of the methodology implemented on Las Palmas Tunnel, Pudehue Bridge (Road Bridge converted from railway structure) and structures in Quebrada Alvarado (gorges) are presented. Also, final comments to improve the GRDR are carried out.

Keywords: bridge; tunnels; inspection; climate change.

1 Introduction

At present, there are around 7,000 bridges in Chile and over 85,000 km of routes providing continuity to the roadway network. Due to the geography of the country, any collapse in the road network connectivity results in a critical situation affecting the commercial system, the social and human development if towns become cut off.

Hence, a system monitoring the actual condition of the structures is of the essence to provide an early response (maintenance), and also to be aware of

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Influence of Environmental Variables on Chloride Ion Distribution on Concrete Surface under Dry-Wet Cycle

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Abstract:

In order to study the effect of environmental variables on the chloride concentration on the concrete surface under the action of drying and wetting cycles. Firstly, the influence of environmental variables such as monthly average temperature, monthly sunshine duration, and monthly rainfall on the dry-wet time ratio in Haikou and Wenchang was analyzed, and the dry-wet cycle mechanism of the Puqian Bridge was established. Then, according to the dry-wetting cycle mechanism, the influence of multiple factors on the distribution of chloride concentration on the surface was discussed, and a model of the chloride concentration distribution on the surface of unsaturated concrete under the action of multiple factors was established. Finally, the distribution model is compared with the experimental data in the literature to verify the rationality of the distribution model.

Keywords: environmental variables; concrete; surface chloride concentration; dry-wet time ratio.

1 Introduction

During the service period of seaside concrete structures, the corrosion of steel bars, concrete cracks and other durability deterioration phenomena occur. The main reason for this phenomenon is the penetration of chloride ions, which causes passivation of steel bars and leads to corrosion of steel bars [1].

Since the chloride concentration gradient between the concrete surface and the interior is the main driving force for the transfer of chloride ions from the externally exposed environment to the interior of the concrete. Therefore, it is great significance to study the chloride concentration model of coastal concrete surface. Yang et al. [2] established a multi-factor model of chloride concentration on concrete surfaces in oceanic atmospheric regions based on two-stage multiple linear regression analysis. Akiyama et al. [3] established an empirical model for the distribution of chloride concentration on the concrete surface under multi-factor conditions based on field data. For the seaside concrete structure in the gradual wave area, due to the characteristics of alternating dry and wet in the gradual wave area, it naturally becomes the most serious area of harmful medium erosion, which seriously threatens the safety of the structure. Therefore, it is necessary to analyze the distribution law of chloride concentration on the surface of

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Comparative Analysis of Carbon Emission of Special-Shaped Concrete Pier Constructed by 3D Printing and Traditional Construction

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Abstract

3D printing technology has the sustainable advantages of saving formwork, labor and time, reducing pollution and so on, so it is gradually applied to the field of bridge engineering. In order to explore the advantages and potential of 3D printing technology in carbon reduction, this paper makes a comparative analysis on the carbon emission of 3D printing and cast-in-situ construction in the materialization stage of complex shaped pier. The results show that the carbon emission in the materialization stage mainly comes from the production stage of building materials, and the proportion of carbon emission in the construction stage and transportation stage is very small; The combination of 3D printing shell and cast-in-situ construction has less carbon emission than using one of the construction methods alone; Compared with traditional construction, the application of 3D printing technology reduces the carbon emission of this example by more than 20%.

Keywords: 3D printing concrete; carbon emissions; formwork; materialization stage.

1 Introduction

In recent years, the application of concrete 3D printing technology in the field of civil engineering has developed rapidly[1]. Its highly automated characteristics improve productivity and construction accuracy, reduce construction safety risks and reduce environmental pollution[2]. This paper lists the world-famous 3D printed bridge engineering examples, and introduces their respective characteristics and innovations. 3D printing technology can produce complex modeling structures that are difficult to complete in traditional construction in a short time. Therefore, in order to explore the distribution characteristics of carbon emissions of 3D printing special-shaped concrete structures and the advantages of carbon reduction compared with traditional construction methods, this paper divides a designing bridge construction scheme into the following three types: 1. 3D printing scheme for full section of pier structure (hereinafter referred to as 3D printing scheme), that is, the reinforcement is erected manually, and the concrete section is made by 3D printer; 2. 3D printing + traditional construction scheme (hereinafter referred to as mixed scheme), that is, after 3D printing the concrete shell, pour concrete inside; 3. The traditional cast-in-situ construction scheme (referred to as the traditional scheme) is to erect the concrete construction formwork and place the reinforcement before pouring the concrete. The research route of this paper is as follows: 1. The topology optimization of the bridge substructure is carried out by using the finite element analysis software ANSYS Workbench; 2. Use BIM software Rhino to process the boundary of the rough model after topology optimization; 3. Carry out static and dynamic checking calculation, and count the quantities after ensuring the safety

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Design Consideration Including Construction Stage Analysis for the Cable Stayed Bridge (FB01-Marina Bridge) in Port City Colombo Project, Sri Lanka

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Abstract

Port City Colombo developed by CHEC Port City Colombo (Pvt) Ltd through China Harbour Engineering Company (CHEC) is a pristine city development in Colombo, Sri Lanka, spanning 269 hectares. Port City Colombo, built as an extension of Sri Lanka's vibrant capital city Colombo, once completed, would be South Asia's premiere residential, retail and business destination.

Atkins, a member of the SNC Lavalin Group, was appointed by CHEC Port City Colombo (Private) Limited to provide Consultancy Services for the design of all Infrastructure and Landscape works, public realm and associated infrastructure in Colombo Port City. This paper discusses the design criteria of the marina cable stayed foot bridge (FB01) in depth including the construction stage and service stage analysis and design checks.

Keywords: fixed arch bridge; cable stay; pedestrian footbridge; steel orthotropic deck; long span; tuned mass dampers; cable tuning analysis.

1 Introduction

The approved masterplan of Colombo Port City Project requires a very attractive pedestrian footbridge near the mouth of the canal entering the Port city. This is depicted in Fig-1.

Fig 1: Master plan of Port City Colombo

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Cultural Expression of Long-span Bridge Structure - Landscape Design of Zhangjinggao Yangtze River Bridge

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Abstract

Zhangjinggao Yangtze River Bridge, located in Jiangsu Province, China, will be the longest suspension bridge in the world. Taking the landscape design process of Zhangjinggao Yangtze River Bridge as an example, this paper discusses the landscape design principles and methods of the long-span bridge, along with how to combine the regional cultural elements with the bridge structure, therefore create an identifiable and iconic bridge architectural landscape. This paper puts forward an effective idea and method for the engineering aesthetic design and cultural connotation expression of long-span Bridges.

Keywords: long-span bridge; bridge landscape; bridge culture; Zhangjinggao Yangtze River Bridge.

1 Introduction

Bridge is one of the most important symbols of national and regional economic development. With the expansion of human economic activities and the continuous strengthening of ties, bridges become more and more closely related to people's life as well.

In China, the design of long-span bridges does not pay enough attention to the expression of culture and art.

The landscape design of Zhangjinggao Yangtze River Bridge discusses the significance and practical methods of cultural expression for long-span bridges.

2 General Instructions

Because of the special status of long-span bridges, they often become one of the most prominent buildings in the environment. The aesthetic expression and cultural expression of long-span bridge engineering have also become an important component in the structural design of long-span bridges. Proper way to better combine bridge culture and bridge structure has also become a new problem faced by bridge engineers.

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Compassion: Essence of Beauty from Triunity of Bridge-CAD

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Abstract

In the research process of bridge-CAD, through the analysis of the results from penman's new concept for bridge triunity, it is concluded that the essence of beauty is compassion originally being "karun!a" in Sanskrit, and this conclusion is primarily verified. This study is of positive significance to the cultural self-confidence of Chinese nation.

key words: bridge-CAD; triunity; essence of beauty; compassion; cultural self-confidence

1 Introduction

In his conclusion on the nature of beauty, "beauty is difficult", the Aesthetics of Bridge Design [1] states the condition of Socrates' judgment on the nature of beauty 2400+ years ago: "This beauty itself, when added to anything, makes that thing beautiful".

2 The Trinity of Bridge CAD: The nature of beauty is compassion

In his "Ten Books on Architecture" [2], Vitruvius pointed out the three attributes of architecture: solid, useful, beautiful. As a kind of architecture, the Department of Bridge Engineering of Tongji University is a trinity of the School of Civil Engineering, the School of Transportation Engineering, and the School of Architecture and Urban Planning, and it is quite trinitarian.

In order to analyze the trinity of bridge CAD and based on the overpass as the main bridge type, I proposed a new concept: あ =Wichtigkeit (Shape/Function)=Vitruvian3/(Vitruvian2, Vitruvian1), the parameter あ is the ratio of the importance of the bridge components or even the shape of its collection compared to its function ∈ [0 ,1], Vitruvian3|2|1 corresponds in turn to the 3rd|2|1 attributes of the building, i.e., aesthetics, suitability, and robustness. Take the prestressed concrete box girder as an example, the あ values of the prestressing bundles outside the box, inside the box and inside the ribs are about 1, 0.5 and 0. Then take the Beijing Xizhimen Interchange as an example, it has a large functional defect in traffic engineering, so it can be seen that its Vitruvian2 is not valid, i.e. Vitruvian2=0.

If any one of the Vitruvian1|2 properties does not hold, the Vitruvian3 property is meaningless, i.e., あ = ∞ = x/0 = Vitruvian3/(Vitruvian2, Vitruvian1). According to Koo's words, "the whole life of Chinese people is an emotional life", and the West believes that 'love' is the highest emotional state, so we might as well emotionalize the 3 attributes of architecture: solidity, applicability, and beauty, and based on what Venerable Hong Yi said "Love is compassion". The author believes that: the nature of beauty is also compassion, compassion in line

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Application And Innovation of High-Strength Concrete in High-Rise Building Structures

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Abstract

In the process of popularization and application of high-strength materials, it is often difficult to design their strength and ductility. Starting from the seismic design of complex high-rise building structures, this paper proposes a performance-based design method based on the predetermined yield mode, which can comprehensively consider the strength and ductility of structural members. On the basis of this seismic design method, a high-strength concrete high-rise energy dissipation structural system and a high-performance assembled high-rise building structural system are proposed that can give full play to the strength of high-strength materials and the ductility of energy dissipation members. The research results can provide technical support for the application of high-strength concrete in high-rise building structures.

Keywords: high-strength concrete; high-rise building; strength; ductility; predetermined yield mode; application; innovation

1 Performance-Based Design Method Based on Predetermined Yield Mode

1.1 Design Process

The basic process of the seismic-performance-based design method based on predetermined yield mode is shown in Figure 1.

Considering that the “three-level” fortification target is the most basic requirement of structural seismic design in China, the predetermined yield mode should also be based on the minimum standard.

1.2 Advantages of the Method

The seismic-performance-based design method based on predetermined yield mode has the following advantages:(1) The failure sequence of the structure is gradually controlled. At the same time, the design process is simpler and more reasonable, and complex internal force adjustment is avoided. (2) The obtained stiffness reduction coefficient of structural members can reflect the real stress state of the structure. (3)

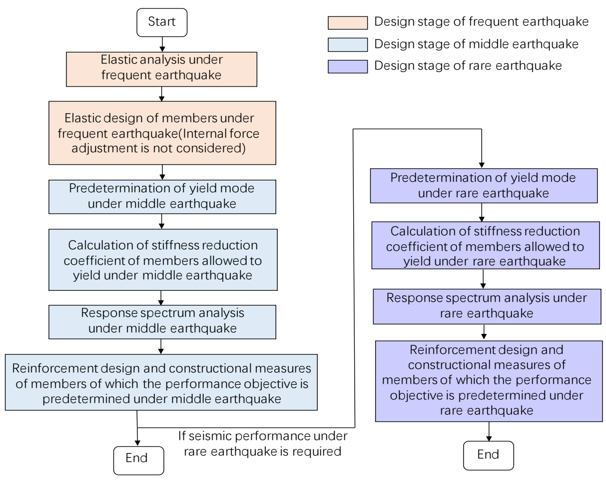

Figure 1. Seismic design method based on predetermined yield mode

Long Span Structure Design of Beijing Daxing International Airport Terminal Building

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Abstract

Beijing Daxing International Airport Terminal has been named as the top of the New Seven Wonders by the Guardian. The 8 C-shaped columns in the central area of the terminal are organically combined with the roof structure to achieve the amazingly architectural effect. The new base and interlayer combined seismic isolation system is proposed to build the world's largest seismic-isolation building which also becomes a new benchmark of isolated structure. This terminal is the first completed project in the world that integrated high-speed rail transit and terminal, and vibration caused by high-speed trains is also controlled to an acceptable level.

Keywords: long-span structure design; parametric surface forming; seismic isolation; base-interlayer isolation; C-shaped column; progressive collapse; vibration control.

1 Introduction

Beijing Daxing International Airport Terminal (BDIAT) is located in the Daxing District of Beijing. The terminal is 996m long from north to south and 1144m wide from east to west.

Figure 1 Aerial View of the Terminal Building

The floor area of this terminal is around 800,000m^2 with a direct roof projection area of 350,000m^2. It is the world's largest airport terminal and has been named as the top of the New Seven Wonders by the Guardian. BDIAT is the first completed project in the world that integrated high-speed rail transit and terminal.

2 Free-formed surface space steel structure supported by C-shaped columns

The roof of the terminal is an irregular free-formed surface. A set of multi-disciplines fully-parametric curved surface forming system which integrates roofing, skylight, curtain wall, and steel structure has been developed to solve the difficulty of forming and position roof steel structure primary control grids on the curved surface. In the central area of the terminal, 6 groups of C-shaped columns with centrifugal openings and the roof of the central zone create an arch-shell structure, which offers a 180-meter-diameter column-free space and realizes a perfect integration of architecture and structure. The combined supporting system

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Xiong'an Railway Station: A Supersized Railway Station in High Seismic Intensity Zone

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Abstract

Xiong'an Railway Station is the super-large elevated railway station located in the high seismic intensity zone. The reinforced concrete frame structural system is adopted for the rail-bearing floor and the lower floors, while the steel structural system is adopted for the large span roof. H-shaped steel frame beams are adopted for the elevated waiting hall, while double flange H-shaped steel beams are adopted in the area of great forces. Plane trusses are arranged bi-directionally between the frame beams to facilitate the laying and maintenance of equipment pipelines. The main span of the elevated waiting hall is 78m, and the variable-height box beams are adopted. The platform canopies are supported by special shaped steel pipe columns, and the roof frame beams are connected to the top of columns through spherical bearings. Structural innovations have been carried out in terms of semi-embedded column bases, stepped wall thickness steel pipe columns with special section shape, large-span stiffened thin-walled box beams, and bi-direction large displacement bearings.

Keywords: high speed railway; railway station; SRC Frame; large span steel structure.

1 Main structure

The rail-bearing floor is 606m long from north to south and 307.5m long from east to west. The main structure below rails adopts the reinforced concrete frame structure system, the standard column grid size of railway station is 20~23m × 24m, and the maximum column spacing along the rail direction is 30m. SRC columns with cross-section size of 2.7m×2.7m are adopted in order to improve the seismic performance of the rail-bearing floor. The SRC beams are adopted for the frame and rail bearing beams, the cross-section size of rail bearing beams along the rail direction is 1200mm×2400mm, and the cross-section size of rail bearing beams perpendicular to the rail direction is 1400mm×3000mm.

Fig.1 Xiong'an Railway Station

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Rapid Design and Construction Management of Emergency Hospital During the COVID-19 Epidemic

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Abstract

In order to control the spread of the COVID-19 epidemic across the country, China has used all available resources to build infectious disease hospitals in various ways. These hospitals include three modes and adapt to different disease levels: temporary emergency hospitals; makeshift hospitals by transforming public buildings; and existing general wards transformed into infectious wards. Through the practice of several projects, on the basis of the original standard system, China urgently issued a series of relevant standards and guidelines to guide the construction of temporary hospitals. As one of the earliest cases of temporary emergency infectious disease hospital, the Thunder God Mountain Hospital adopted a prefabricated modular design concept in plan design, plane design and component design, and also combined the application of Building Information Modeling (BIM) and Computational Fluid Dynamics (CFD) technology. Based on industrialized module processing and manufacturing, combined with an efficient on-site construction management system, the problem was solved of completing the construction in a very short time, which played a key role in controlling the epidemic situation.

Keywords: Thunder God Mountain Hospital; rapid design; standard production; prefabricated construction; construction management.

1 Construction Concept of Emergency Hospitals

With the spread of COVID-19, a large number of emergency hospitals have been built, transformed or expanded all over the country. These hospitals can basically be divided into three categories: temporary emergency hospitals; makeshift hospitals; and the transformation of existing hospital wards.

2 Relevant Design Guidelines and Standards

The existing national standard system for infectious diseases hospitals in China, which includes standards for the construction of medical facilities and technical standards for prefabricated buildings, is relatively complete. In the process, some new standards and guidelines on emergency hospitals and makeshift hospitals were formulated on the basis of the existing standard system. Prefabricated light steel structures are suitable for temporary emergency hospitals, which make full use of the standardization, modularization and integration of prefabricated buildings, and this met the requirements for rapid construction in an emergency perfectly.

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Study On Stability of Single-Layer Aluminum Alloy Structure and Shear Capacity of Joints

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Abstract

The Chongming comprehensive training hall adopts a single-layer aluminum alloy spherical shell structure with a rise span ratio of 1 / 9, which is a small rise span ratio structure. Through the selection of structural system, this paper introduces the composition of single-layer reticulated shell structure, the relationship between structure and architectural modeling, indoor space and architectural lighting. Combined with the small rise span ratio structure, the elastic and elastic-plastic ultimate bearing capacity of aluminum alloy reticulated shell is studied. It is suggested that only the elastic-plastic ultimate bearing capacity of aluminum alloy reticulated shell should be checked, and the ultimate load factor should be 2.0. The failure mode and ultimate shear capacity of the joints are obtained by shear capacity test.

Keywords: single layer aluminum alloy spherical shell; small rise span ratio; elastoplastic ultimate bearing capacity; plate joint; shear capacity.

1 Introduction

The Shanghai Chongming Sports Training Bases is located in Chenjia Town, Chongming District. For the comprehensive training stadium, its roof adopts a 5m rise spherical shell structure with aluminum and steel. The roof size is 45m x 48m with a rise span ratio between 1/9 to 1/10, which is close to the preferable arch axis. For the natatorium, its roof adopts a single-layer 4.5m rise cylindrical shell structure with aluminum. The size of the roof is 45m x 48m with 1/9 rise-span ratio. The single-layer reticulated aluminum alloy shell structure is adopted for all roofs. (Fig.1 and Fig.2).

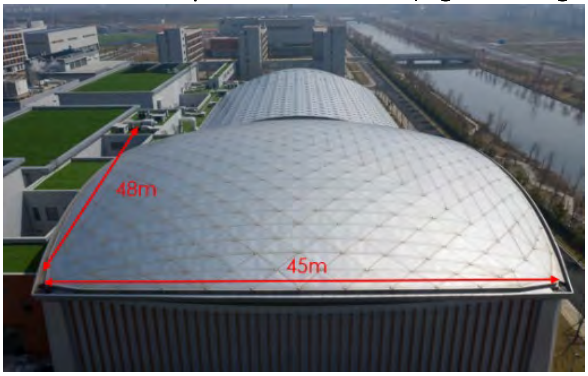

Figure 1. Building dimensions

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Jingang Cultural Center: Complex-shaped Fair-faced Concrete Structure

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Abstract

As one of the largest fair-faced concrete structures in China, the Jingang Cultural Center includes many complex-shaped fair-faced concrete structures. This study focuses on the structural characteristics of Jingang Cultural Center. Aiming at the representative components, such as a deepening design, mushroom body structure, ridge eave structure, and arch-shell structure, a series of measures are studied, and a series of methods are proposed to improve the forming quality of fair-faced concrete with complex-shaped structures and enhance the feasibility and economy of fair-faced concrete in complex-shaped structures.

Keywords: fair-faced concrete; complex special-shaped; deepening design; structural construction; construction simulation.

1 Introduction

Figure 1. The figure of Jingang Cultural Center

Jingang Cultural Center includes a large area covered by a special-shaped fair-faced concrete structure and a long large-span cantilever structure. The maximum cantilever length is 8–10 m. The representative structures are mainly divided into 35 mushroom bodies with different shapes and no repeatability, 3,080 m of oblique-plane curved hollow prismatic eaves, and a landing arch-shell structure.

2 Deepening design of fair-faced crack-segmentation

Through the application of building information modelling (BIM) technology (Figure 2), the integrity, feasibility, economy, aesthetics, and correlation with the surrounding structure of the special-shaped fair-faced structure are multi-dimensionally considered, and a set of fair-faced crack-segmentation design standards are formulated.

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Innovative Technologies for Construction of the Pingnan Third Bridge

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Abstract

The main bridge of the Pingnan Third Bridge is a half-through concrete-filled steel tubular (CFST) arch bridge with a world-largest effective span of 560 m. Due to the significant breakthrough in span and the adverse environmental features of construction site, many technological difficulties were encountered in construction of the Pingnan Third Bridge. Accordingly, systematic innovative technologies on design, construction, material and management of large-span CFST arch bridges were proposed, and fairly remarkable technological and economic benefits were achieved in this bridge. Meanwhile, considering the proposed technologies have solved several key general bottlenecks of extra-large arch bridges, especially CFST arch bridges, the technologies can also be good references for other similar bridges in the future.

Keywords: the Pingnan Third Bridge; CFST arch bridges; innovative technologies; design; construction; material; management.

1 Introduction

The main bridge of the Pingnan Third Bridge is a half-through concrete-filled steel tubular (CFST) arch bridge with an effective span of 560 m. The bridge ranks first in the world in the main span length. It started construction on August 7, 2018, and was completed on December 28, 2020.

Figure 1. Photo of the completed Pingnan Third Bridge

2 Design and construction

2.1 The background

The main span of the bridge was supposed to exceed 500 m according to the local conditions. Among the proposed bridge types, the construction cost of a CFST arch bridge was estimated to be 16% and 6% lower while the stiffness was 6 times and 1.5 times higher than a suspension bridge and a cable-stayed bridge. Moreover, an annual maintenance cost over RMB one million yuan would be saved. Thus, a CFST arch bridge was finally selected.

2.2 Bridge design

The main arch of the bridge is composed of two parallel arch ribs, with the effective span, rise-span ratio and arch axis coefficient being 560 meters, 1/4 and 1.5. A four-tube truss section is adopted for each rib, with the radial height at the arch foot section, the radial height at mid-span section and

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Wuhu Second Bridge: Development of Stayed Cable Anchorage System and Application of Structural Innovations

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Abstract

Based on the design and construction of the second Yangtze river bridge in Wuhu (hereinafter referred to as Wuhu Second Bridge), this article introduces the structure system of the full-floating cable-stayed bridge with four cable planes, single-column tower and separated steel box girders. A series of innovative structural measures have been taken to improve the safety and economy of the bridge, such as the looping stayed cable anchorage system, the diagonal damping constraint system, and the externally prestressed segmental assembled box girder used in the approach bridge. In addition, the finite element analysis software was used to study and analyse the mechanical characteristics of the bridge. The reliability of the structural anchorage system and damping constraint system was verified either.

Keywords: looping stayed cable anchorage system; diagonal damping constraint system; externally prestressed segmental assembled box girder; finite element analysis; symmetric cantilevered assembly.

1 Structural Design

The main bridge of Wuhu Second Bridge has a total length of 1622m. The span layout of the bridge is (100+308+806+308+100) m. It is a full floating cable-stayed bridge. There is no vertical support at the junction of tower and girder. Two-way sliding bearings are only set at side piers and transition piers. The bridge tower is of single-column type, and the main girder is flat steel boxes.

1.1 Looping Stayed Cable Anchorage System

The looping stayed cable anchorage system is an anchoring method of "surrounding on the tower and anchoring on the bridge deck", that is, the two ends of each stayed cable are anchored in the same direction on the bridge deck after turning around the bridge tower, see Figure. 1. Different from direct anchoring, this method gives full play to the compressive properties of concrete structures by converting the tensile force of the stayed cables to the bridge tower into radial pressure. It not only makes the bridge tower "slender", but also presses it stronger, thereby avoiding the formation of cracks in the bridge

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Steel-concrete Composite Cable-stayed Bridge—Main Crossing Bridge of Nanjing Jiangxinzhou Yangtze River Bridge

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Abstract

The main bridge of Nanjing Jiangxinzhou Yangtze River Bridge is in the form of a cable-stayed bridge with three towers and two main spans, with a total length of 1796m and a main span of 600m. The towers and main beams are all composite structures, which is the first all-steel-concrete composite cable-stayed bridge in the world. The bridge originally develops the steel shell-concrete composite tower, investigates coarse aggregate reactive powder concrete (CA-RPC), and applies it to the main girder to form a lightweight and high-performance beam. Numerous technologies have been achieved in new materials, new structures, new processes, and many other aspects. The unique structural concept has significantly increased the factory manufacturing speed, which not only reduces the work and labour cost 25% but also reduces the amount and loss of materials during construction, which has made contributions to the development of cable-stayed bridges.

Keywords: cable-stayed bridge; steel shell-concrete composite structure tower; steel-CA-RPC composite beam; bridge design; construction technology.

1 Introduction

Nanjing Jiangxinzhou Yangtze River Bridge is the world's first cable-stayed bridge with a steel-concrete composite structure for its towers and beams. It originally applied the steel shell-concrete composite structure tower, which effectively improves the structural performance, durability, and industrialization degree of the tower manufacturing. Meanwhile, CA-RPC has been developed and applied to the main girder of the bridge to form a lightweight and high-

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Innovative Design for Qingshan Yangtze River Bridge

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Abstract

Qingshan Yangtze River Bridge is a cable-stayed bridge with a main span of 938 m, which is the fifth largest cable-stayed bridge in the world. In order to cope with challenges such as long span, wide bridge deck and heavy load, the girder of the main span adopts integral steel box girders, while the side span adopts steel box-concrete composite girders. The interface of the two types of structure is located on the middle span, 18 m to the bridge tower. The main girder is 4.5 m in height and 48 m in width. The main tower is an A-shaped concrete tower with a height of 279.5 m. The stay cables are arranged in a fan shape. The main girder section near the tower is supported by No.0 cable instead of a lower beam to achieve an optimum architectural effect. The foundation of the main tower adopts a rotary bored concrete pile. The bridge adopts a fully floating structure system. A restraint system of viscous damper + limit block is adopted in the longitudinal direction, while a system of separated c-section steel dampers with shear clip tenon + vibration reduction and wind resistant supports are adopted as horizontal restraints.

Keywords: cable stayed bridge; steel box girder& steel box composite girder; main tower in a-shape; pile cap in dumbbell-shape; entirely floating system.

1 Overview

Qingshan Yangtze River Bridge is located in the northeast of Wuhan. The structure type of the 938 m span cable-stayed bridge has a double-tower and a double-cable plane, and is ranked fifth among the cable-stayed bridges already built in the world. The span arrangement of the main bridge is 100+102+148+938+102+100=1638m. The main girder adopts an integral steel box and steel box combined beam. The stay cables are arranged as a fan. The bridge tower adopts an "A"-shaped concrete tower without a lower beam. The layout of the bridge facade is as Fig.1:

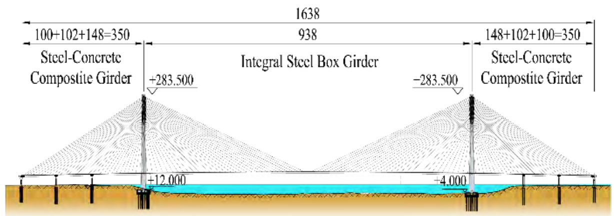

Fig. 1: Elevation of the main bridge (unit: m）

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Key Techniques for the Main Navigable Bridge of the Main Passageway of Ningbo–Zhoushan Port

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Abstract

The main navigable bridge is a three-tower steel box girder cable-stayed bridge with a span of 78+187+2×550+187+78 m. The design reference wind speed is 42.3m/s. The main navigation span can navigate 100,000-ton ships. In order to improve the overall stiffness of the bridge under unbalanced live loads, some measures are studied, such as the restraint conditions, the stiffness of the tower, the stiffness of the beam, the number of stay cables in the side and central tower, and so on. Through the wind tunnel test research, the control measures for the buffeting performance of the double cantilever are clarified. According to the IABSE vessel collision model, the vessel collision force is determined. A double-layer collision protection structure is used to protect the bridge and reduce vessel collision damage. In order to improve the structural durability, high-performance epoxy steel bars are used in the splash zone. The cable-anchor beams of the towers are made of weathering steel. Maintenance vehicles are installed in the main beam which is 1.63 km. Through the above measures, the structural performance is guaranteed.

Keywords: three-tower cable-stayed bridge; overall stiffness; buffeting performance of double-cantilever state; double layer collision protection structure; structural durability.

1 Introduction

The Main Passageway of Ningbo-Zhoushan Port (the “Main Passageway” hereafter) is located at the Zhoushan Islands in northeast Zhejiang Province, China. The Main Passageway has a design speed of 100 km/h, a standard subgrade width of 26.0 m, and a total length of 25.659 km (which covers an overwater length of 16.734 km and is configured with an overwater interchange). The total investment in the project is CNY 12.28 billion (approximately EUR 1.59 billion).

Due to the constraints on the construction project, the main navigable bridge was designed as a three-tower cable-stayed bridge with two main spans of 550 m, as shown in Figure 1. The design of the bridge needed to resolve the following key problems:

(1) Measures for ensuring the overall structural stiffness
(2) Wind-resistance performance in the maximum double-cantilever state during construction
(3) Vessel collision design of the structure
(4) Structural durability design

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Key Construction Techniques of East Tower and Anchorage of Lingdingyang Bridge in Shenzhong Link

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Abstract

Lingdingyang Bridge of Shenzhong Link is a three-span suspension bridge with a full floating system of 580 + 1666 + 580. In view of the complex construction conditions of the bridge site, the construction scheme of island cofferdam was proposed for the east anchorage, and the flexible combined island cofferdam structure of ' lock steel pipe pile + I-shaped sheet pile + parallel steel wire rope ' was innovatively adopted to transform the offshore construction into land construction. For the east cable tower, the flexible manufacturing production line of steel mesh was developed, and the integrated intelligent tower building equipment suitable for ultra-high concrete cable tower was developed, forming the industrial construction technology of ultra-high cable tower based on reinforced bar product and intelligent tower building. The key construction technology of anchorage and tower solves the construction problem of super long-span suspension bridge in offshore sea, and improves the intelligent and industrial construction level of ultra-high tower engineering.

Keywords: suspension bridge, sea anchorage, island cofferdam, ultra-high tower, industrial construction.

1 Introduction

The Shenzhong Link Project is a world-class sea-crossing cluster project connecting Shenzhen City and Zhongshan City in Guangdong Province, which is a super large-scale integration of ‘bridge, island, tunnel and underground interworking’. The total length of the Shenzhong Link project is 24 km, of which the sea-crossing section is 22.4 km. The two-way eight-lane highway standard is adopted, and the design speed is 100 km/h. The island tunnel project and the bridge project from Shenzhen to Zhongshan are in turn. The Lingdingyang Bridge, as the key control project in the bridge project, crosses the Shenzhong Link and adopts the structural form of a three-span full floating system suspension bridge with 580 + 1666 + 580, as shown in Figurer 1.

The east anchorage of Lingdingyang Bridge is a gravity anchorage in the sea. The foundation adopts the ‘8’shaped diaphragm wall structure (107.1m in length, 65m in width and 1.5m in thickness). The concrete pouring amount of the anchorage is 34.3t, and the structure is huge. It is in the broad sea area and adjacent to the 100,000 -ton Lingdingyang waterway. The bottom of the anchorage foundation is mostly flow plastic and soft plastic silt, and the silt layer is thick and the lateral stability is extremely poor. In addition, the typhoons are frequent in the region, and the water operation time is long and the safety risk is high.

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Multimode Damping Enhancement for Cable Vibration Control: Theoretical and Technological Developments with Applications

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Abstract

Cables in cable-stayed bridges become super long, exceeding 600 m in the case of the Changtai Bridge which is under construction. Owing to their low inherent damping, cable are subjected various types of vibrations. A combination of aerodynamic treatments and supplemental mechanical dampers is required to suppressing such vibrations. However, providing sufficient damping to all the modes subjected to vibrations is still a challenge issue. This study presents full-scale measurement and field tests results of cable inherent damping and damper efficiency. Theoretical developments on multimode damping analysis of a cable with distributed dampers at different locations and cable networks formed by using cross-ties interconnecting neighboring cables are discussed. Practical measures, including by adding inerter, negative stiffness devices, and by installing both internal and external dampers for enhancing multimode damping are investigated.

Keywords: cable vibration control; multimode damping; negative stiffness device; vortex-induced high-mode vibration.

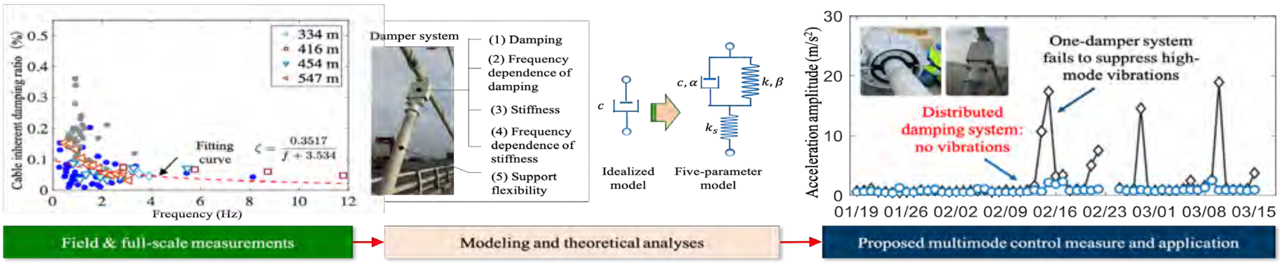

Figure 1. Graphical abstract

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Engineering Application of Self-anchored Integrated CFRP Cables

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Abstract

Carbon fiber reinforced polymer (CFRP) materials have the advantages of a high strength/weight ratio, corrosion resistance. Bridge construction with CFRP cable rather than steel cables has a wider span, better load capacity, and longer life span. Due to the anisotropy of the CFRP materials, achieving effective anchorage for CFRP cables is challenging. To address this problem, a self-anchored integrated CFRP cable has been proposed. Recently, the novel cable was adopted in a truss bridge in Shanghai. The utilization of the novel cable contributed to rapid construction and ensure structure safety, which is quite attractive for future bridge construction.

Keywords: carbon fiber reinforced polymer (CFRP); cable; anchorage; engineering application, truss bridge.

1 Introduction

Carbon fiber reinforced polymer (CFRP) materials have the advantages of a high strength/weight ratio, corrosion resistance. Therefore, the CFRP cable has good mechanical performance, durability and ease of transportation and construction. Bridge construction with CFRP cable rather than steel cables has a wider span, better load capacity, and longer life span. Due to the anisotropy of the CFRP materials, achieving effective anchorage for CFRP cables is challenging. Various CFRP cables with different configurations have been proposed in recent years [1-3]. To achieve more effective anchorage, a self-anchored integrated CFRP cable (as shown in Fig.1) was proposed and studied by the authors [4,5]. In the manufacturing process, the carbon fiber prepregs were wound continuously on steel shafts at both ends, forming a ring-shaped member similar to a conveyor belt. This paper introduces the first engineering application of the novel cables in bridge engineering, which has achieved rapid construction and installation with better performance.

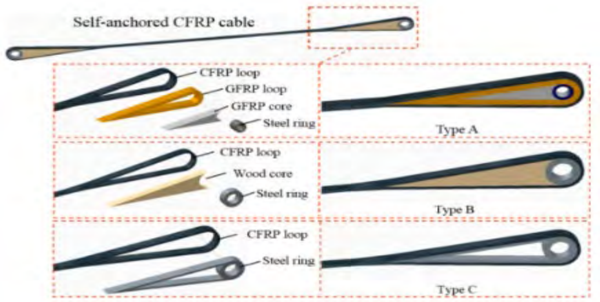

Fig.1 Conceptual diagram of self-anchored integrated CFRP cable

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A Silanized MCNT/TPU-based Flexible Strain Sensor with High Stretchability for Deformation Monitoring of Laminated Elastomeric Bridge Bearings

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Abstract

Laminated elastomeric bearings are broadly used in large bridges for adjusting the deformation and ensuring the safety of the bridge structure. Interestingly, the bridge bearing's deformation contains rich information that reflects the complex load conditions of the bridge structure. Nevertheless, the structural health monitoring (SHM) of the bridge bearings has not been carried out effectively due to the special characteristics of bridge bearings' deformation, including the large range and the existence of varied forms. Along these lines, a novel conductive polymer composite-based flexible strain sensor was fabricated by employing a facile solution-blending method. More specifically, the proposed strain sensor was composed of thermoplastic polyurethane (TPU), multiwall carbon nanotubes (MCNTs), and silane coupling agent KH550. The utilization of the KH550 not only promoted the dispersion of MCNTs within the TPU matrix but also enhanced the interfacial bonding between the MCNTs and the TPU matrix, resulting in the large strain range (~150%) of the silanized MCNT/TPU strain sensor. More specifically, the silanized strain sensor with 3.0 wt% MCNTs demonstrated extraordinary linearity, promising gauge factor (~ 8.12), and great durability under the enforcement of a tensile strain up to the value of 150% through the application of consecutive stretch–release tests. On top of that, the compressive bending sensing tests proved the stable and repeatable bending sensing capability of the proposed silanized strain sensor. Moreover, the silanized strain sensor could effectively monitor the shear and the compressive deformation of the laminated elastomeric bridge bearings. This work provides a new way for fabricating flexible strain sensors with enhanced strain range, which validates the feasibility of the strain sensor for monitoring the bearing's deformation and provides an experimental basis for developing the SHM of the laminated elastomeric bridge bearings.

Keywords: laminated elastomeric bridge bearings, bearing's deformation, structural health monitoring, flexible strain sensor, thermoplastic polyurethane, multiwall carbon nanotubes, silane coupling agent

1 Introduction

Bridge structural health monitoring (SHM) plays a vital role in ensuring both the health and the safety of long-span bridges[1] [2] . Under this perspective, it leverages modern sensing and signal processing techniques to detect structural damage and at the same time evaluate the trend of structural performance degradation. In this work, we introduced a highly facile, flexible and stable CPC

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Planning, Design and Construction of Cable Stayed Bridge on river Zuari in the State of Goa, India

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Abstract

National Highway 66 (NH 66) runs North-South in the state of Goa and is the lifeline of the state. Around the centre of this highway, river Zuari runs East-West and needs to be bridged to connect North and South. The existing bridge is 2 lanes and under repair and rehabilitation for the last 2 decades and has severely reduced load carrying capacity thereby creating a long detour for heavy vehicles to traverse North-South. Besides, the local traffic of light vehicles has also increased substantially over the last 2 decades rendering this location critical for passage of traffic. There is therefore, a perennial traffic bottleneck at this location.

1 Introduction

The demand for a wide new bridge has been there for quite some time and proposals for the new bridge have been tried earlier. Since Goa is a small and eco-sensitive state, the location of the new bridge has to be such that it creates minimum damage to environment. Thus, large scale diversion for a new alignment is not considered desirable and the challenge therefore was to find a new alignment as close as possible to the existing alignment creating minimal environmental damage and minimizing land acquisition. Further, the planning, design and construction has to be such that traffic on the bridge and in the navigational channels is not to be disturbed till the new bridge is opened to traffic after which the existing bridge could be closed to traffic and used for other purposes.

2 Details

[1] The bridge is an 8-lane wide cable stayed structure. It has 2 independent superstructures and has a configuration of 140 m. + 360 m. + 140 m. spans giving a total length. The superstructure is composite type – steel beams with concrete deck.

[2] Large diameter 2000 mms. pile foundations have been used and massive pile caps supporting not just the 2 superstructures but also a tower with revolving restaurants and viewing gallery is proposed.

[3] The bridge is in a eco sensitive zone and built over a navigational channel necessitating the large span. An existing bridge parallel to the alignment is also being maintained, although, with load restrictions, allowing only light vehicles.

3 Conclusions

This paper discusses in details the challenges faced during the entire process from planning, design, and construction.

4 References

Detail project report submitted by TPF Engineering Pvt Ltd. In 2014-15.

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Study of Aerodynamic Performance on Concrete Deck Section in Stayed Cable Bridge

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Abstract

In this study, concrete deck section design is required for a harped shape type stayed cable bridge with total span of 800m with span configuration 200m-400m-200m located at open terrain crossing Sarawak River, East Malaysia. Desktop study are performed on two different type of concrete deck section i.e. monobox section and ladder deck section on their dynamic stability with respect to two mechanisms of divergent amplitude response, galloping and flutter in a stayed cable bridge. From wind climate study of site, the design wind speed for 120 years return period is 40m/s and the aerodynamic stability wind speed at deck level is 52.5m/s. The results show that monobox section is more stable with respect to aerodynamic torsional responses and is selected for deck section for the stayed cable bridge. Section model wind tunnel test was carried out on the selected monobox section, the results show that the section has good flutter and galloping stabilities up to the design wind speed.

Keywords: concrete deck section; aerodynamic; flutter and galloping.

1 Introduction

The cable-stayed bridge has been recognized as a very cost efficient and competitive design for bridges of span ranging from 200m to 800m. Based on the fast development of high-strength materials, new cable stays systems and new construction technologies, the trend of longer span length is quite remarkable in the design of cable-stayed bridge. The long span bridges which are flexible structures are more susceptible to the wind effects and the aerodynamic stability are often one of the governing criteria in the design.

The cross section of the bridge deck is an important parameter that affects the aerodynamic characteristics of the long-span cable stayed bridge. An assessment on the significance of wind effects to the deck section is conducted for a 3 spans cable stayed bridge consists of a 400m main span and 200m back spans. The deck width is approximately 23m. The aerodynamic stability of the long-span cable stayed bridge of different types of deck section is reviewed.

2 Assessment Methodology for Desktop Study

Wind climate study referred to records of extreme wind speeds of recent 30 years from Jabatan Meteorological Station of Malaysia (Cawangan Sarawak) near the bridge site, the design wind speed for 120 years return period is 40m/s. The aerodynamic stability design wind speed at deck level is approximately 52.5 m/s, which has been derived in accordance with the methodology provided in BS EN 1991-1-4:2005 and BD 37/01.

Two options of the bridge deck are considered in this study, which is monobox type and ladder deck type shown in Figure 1. The bridge model is

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Planning, Design and Construction Aspects of Rod El Farag Cable-Stayed Bridge over River Nile, Cairo, Egypt

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Abstract

The paper presents planning, design and construction aspects of the New Rod El Farag Cable Stayed Bridge over the River Nile in Cairo, Egypt (Tahya Masr Bridge). The Bridge is most recent Mega bridge and one of the most important bridges in Egypt. New Rod el Farag Cable-Stayed Bridge is considered as the widest Cable Stayed bridge in the world, with for a total width of 67.3 meters in the main span, and up to 85 meters in the side span (east approaches). The bridge includes 6 lanes of traffic in each direction, sidewalks (including glass sidewalks). The bridge has a steel-composite deck for the main span, steel-composite portion for the upper part of the pylons where the cables area anchored, and concrete for the bridges side spans approaches. The paper summarizes the codes, main loads, and the advantages of providing supports in the side spans for the final construction stages is briefly discussed. Two intermediate piers were introduced at the land side of each pylon to reduce the deformations in the pylon, bending moments in the pylon, stress variations in the cables due to live loads, and improve the load distribution characteristics of the bridge. In fact, these auxiliary piers serve as anchors for the cable-stayed bridge, and counterweights. They have considerable advantages on the stability during construction stage of the main span.

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Implementation of OVM Prestressing System in Southeast European Infrastructure Projects

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Abstract

Application of prestressing technology during bridge construction impersonates challenge according to all design parameters, using of traditional materials, conditions of environment, composite of steel and concrete materials represent only some of requests which must be fulfilled and enable structure designed service life. Charasteristic examples of implementation of OVM prestressing system in southeast European infrastructure projects are described in this paper, where each of it had specific limit in the terms of opportunities of applying of different construction method: movable scaffold system, incremental launching, concrete arch, heavy scaffolding, prefabrication of prestressed girders.

Keywords: prestressing of bridges; infrastructure projects; construction method.

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Design of the Main Structure of The Pi River Water Viaduct

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Abstract

The Pi River Water Viaduct is a milestone in the Yangtze-to-Huai Water Diversion Project. From the structure point of view, it is a girder-arch composite system with a span configuration (68+110+68) m. It is the first aqueduct made of steel structures in China. And its span ranks the 1st in the world in terms of navigable aqueducts. Site selection, load features, structure type, durability are firstly discussed in the paper on the basis of construction conditions, and then a corresponding conceptual design is given. The reliability of the design solution is validated by a large number of scientific studies and tests, and guidance for detailed structural design is also summarized from the studies and tests.

Keywords: navigable water viaduct; girder-arch composite structure; composite stainless steel corrugated web; Water-filled test.

Figure 1. *Panoramic view of the completed water viaduct*

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Structural System Conception and Overall Design of a Mega Suspension Bridge with Four Main Cables

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Abstract

Hubei Yanji Yangtze River Bridge integrates the functions of expressway and urban road. It adopts the scheme of 1860 m double deck steel truss girder suspension bridge with a single span across navigable waters and fault zones. The bridge is close to the airport, and the height of the tower is limited due to the aviation height limit, so that the sag of the main cable is too small and the scale of the main cable is too large. To solve the above problems, a new suspension bridge structure system with four main cables with different sags is proposed. The main features of this system are: four main cables are symmetrically arranged on two sides, and two main cables on the same side adopt different sags. The truss girders are alternately suspended on two groups of main cables with different sags at intervals, and the main cables with different sags are staggered and anchored to ground anchors in front and back of the longitudinal direction. The new system reduces the scale of a single main cable, and has better wind stability. The midspan of lower main cable on the outside can be lowered below the bridge deck to increase the sag, which better solves the construction problem of the tower height limitation. Based on this system, the upper main cable span of the bridge is (550+1860+450) m, the midspan sag is 142.445 m, the lower main cable span is (510+1860+410) m, and the midspan sag is 153.345 m. The cable of the bridge adopts galvanized-aluminium alloy coated high-strength steel wire, the girder adopts Warren truss, the anchorage adopts replaceable prestressed anchorage system, the tower adopts gatehouse shape, and the foundation adopts bored piles.

Keywords: long-span suspension bridge; four main cables; main cable with different sag; bridge conception; overall design

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The Overall Design and Application of M280 Cable System of the Mingyuexia Yangtze River Bridge of Chongqing Donghuan Railway

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Abstract

Mingyuexia Yangtze River Bridge is a (62.5+125+425+175+75) m double-deck four-line railway steel truss girder cable-stayed bridge with high and low towers. In view of characteristics of the bridge heavy design load and prominent fatigue problems, the pressure area adopts steel-concrete combination with closed box chamber structure between the lower beam. Steel truss beam adopts regional and different internal force types of fatigue loading coefficient to improve the economy. The cable adopts the 280MPa high fatigue stress amplitude cable system to extend cable change cycle. Fatigue and safety durability of the cables are comprehensively improved by a variety of means, including improvement of the stress of cable base metal, reduction of bending stress of the transition section, improvement of clip structure, more than 70% of life span is increased compared with the M250 cable.

Keywords: double-deck four-line railway; steel truss girder; cable-stayed bridge; fatigue loading coefficient; M280 cable.

1 Project Profiles

Mingyuexia Yangtze River Bridge is a key control project of Chongqing Hub Donghuan Railway, located in Chongqing. It adopts a main span of 425m double-deck four-line high and low tower steel truss beam cable-stayed bridge, crossing the Yangtze River from south to north. It locates in the perennial return water area of the Three Gorges Reservoir. The navigation level of the river section is national level I.

2 General Design

The total length of the Mingyuexia Yangtze River Bridge is 877.5m, and the span is arranged as (62.5+125+425+175+75)m. The lower deck is the 160km per hour double-line passenger and freight common line East Ring Railway and the upper deck is a double-track intercity railway with speed of 250km per hour.

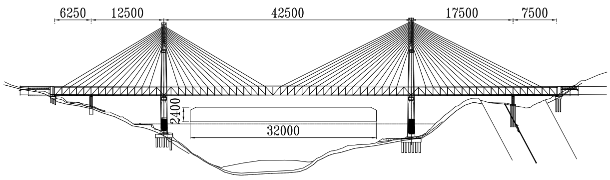

Figure 1. General Layout of Mingyuexia Yangtze River Bridge

The main girder adopts N-type parallel truss, with truss width of 17m, truss height of 14m. The upper and lower decks are all orthogonal dense beam integral deck system. Each vertical member is equipped with a horizontal connection which adopts a fully welded design. Meanwhile, the steel beam adopts high-strength bolts with dehydrogenation process.

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Key Construction Technology of Single Tower Suspension Bridge

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Abstract

In the process of road network construction in western mountainous areas of China, bridge engineers created a single tower suspension bridge in the face of deep canyon terrain. The main cable on one bank is directly anchored into the mountain, the cable saddle buttress is set in the cable tunnel, and a new type of composite cable saddle is developed, which can meet the stress and deformation requirements of the main cable saddle and splay saddle at the same time. This report takes Lvzhijiang bridge as an example to introduce the key construction technology of single tower suspension bridge.

Keywords: single tower suspension bridge; composite cable saddle; cable tunnel.

Figure 1.*Over view of Lvzhijiang bridge*

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Structural Form Selection of Nanpanjiang Bridge in Puzhehei

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Abstract

The Nanpanjiang Bridge is a control project for the Luxi- Qiubei-Guangnan-Funing Expressway. It is a cable-stayed bridge adopting steel truss girder and has main span length of 930 m, which is the largest span cable-stayed steel truss girder bridge in mountainous areas under construction all over the world. The height of the main tower is 385 m, which is the tallest bridge tower in the world. Nanpanjiang Bridge is a typical long-span bridge crossing deep valleys in mountains. The construction of the bridge faces the series of harsh factors, such as high altitude of bridge deck, turbulent wind field, strong earthquake, lack of local materials, difficult transportation, and lack of construction space. The paper focuses on the demonstration and selection process of the bridge location, bridge type, scheme of main structure component, like cable, tower, and girder, in the design stage of Puzhehei Nanpanjiang Bridge. The design points and difficulties of extra-large-span bridges in mountainous areas were also analyzed.

Keywords: cable-stayed bridge with steel truss girder; large span bridges in mountain area; bridge type comparison and selection; structure form selection.

Figure 1. *Front view of Nanpanjiang Bridge*

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Study of Intelligent Bridge Cable Technology and Maintenance Management Platform

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Abstract

As the most critical member, the service status of the cable system plays a crucial role in the longevity of cable-supported bridges. As bridges advance in age, their cable system is undergoing a process of accelerated deterioration. Hence the need for safety evaluation of cables is getting more urgent. At present, cable maintenance mainly relies on the manual inspection by engineers, which features low efficiency, high costs and risk, and potential non-inspection zone. In this context, we studied the fusion technologies between sensors and cables, and developed a maintenance management platform, which can collect data of cable corrosion, temperature and humidity, as well as water accumulation, etc. The intelligent cable products have been tested in outdoor environment since April 2020, and have been successfully applied in several bridges.

Keywords: cable system; suspension bridge; cable-stayed bridge; corrosion; intelligent monitoring; maintenance platform.

1 Introduction

The cable system has the advantages of high strength, light weight, and ease of operation. It is widely used in the field of modern civil engineering structures, including the main cables and suspension cables of suspension bridges, the stay cables of cable-stayed bridge, the hangers of arch bridge, and the cables in large venues or exhibition halls, especially in the field of bridge structures. With the continuous development of bridge structures, more and more cable system bridges have been built internationally, such as suspension bridges, cable-stayed bridges, hanger or tied arch bridges [1].

As the major load-bearing component, the cable system determines the safety and service life of the overall structure. If not detected and maintained in time, the damage such as corrosion will accumulate, which will reduce the usability and durability of the structure [2]. In severe cases, there will be accidents such as cable break or bridge collapse.

Figure 1. Corrosion of cable wire and anchorage

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Technical Research on OVM280 PSC System and a new generation of double slip resistance saddle

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Abstract

With the development of modern long-span cable-stayed bridges, due to the Parallel strand cable (PSC) being assembled on-site strand by strand, which has the advantages such as no need for large-scale equipment for cable-making, delivery, hoisting, traction, tensioning, and the corrosion protection of the cable is excellent, it is more and more favored by designers.

OVM280 is a new type of cable system with high fatigue resistance and high durability developed based on OVM250 steel strand cable. By optimizing the anchoring unit of the steel strand cable, reducing the deviation angle of the steel strand in transition section, and improving the raw material quality of the steel strand at the same time, so that the comprehensive fatigue stress amplitude can be increased to 280MPa. According to the S-N curve of the cable fatigue test, the fatigue life is nearly 4 times that of the 200MPa stress amplitude and 1.71 times that of the 250MPa stress amplitude, and the anchoring performance and fatigue resistance performance are greatly improved.

A new generation of double slip resistance saddle for OVM280DK strand cable has been developed, which solves the fretting wear problem in the saddle section. In addition, this saddle can be applied to the saddle with curvature radius less than 2 meters, which increases the ability of the saddle to adapt to different conditions.

Keywords: high fatigue strength; corrosion protection; slip resistance; saddle

Fig 1. Front view of the Mingyuexia Yangtze River Bridge of Chongqing Donghuan Railway

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Study on Anchorage Type Selection of Sichuan Bank of Sichuan Kahalo Jinsha River Bridge

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Abstract

Sichuan kahalo Jinsha River Bridge is a suspension bridge with a main span of 1030m, and the anchorages on both sides are gravity anchorages. In order to adapt to special terrain and geological conditions, anchorage of Sichuan bank pioneered the use of frame structure as the anchorage foundation. The soil and the frame structure jointly bear the vertical load and resist the horizontal component of the main cable to form a "frame soil" community and fully mobilize the role of the undisturbed soil. At the same time, the distributed grouting technology is used to strengthen the soil around the frame structure, so as to further improve the safety factor. This paper introduces the topography and geology of the anchorage position, compares and selects different anchorage foundation schemes, and explains in detail the design concept, structure size and construction technology of the frame foundation.

Keywords: Sichuan Kahalo Jinsha River Bridge; gravity anchorage with frame structure foundation; frame-soil community; grouting reinforcement.

1 Introduction

Sichuan Kahaluo Jinsha River Bridge is located in the Yongshan Branch of The Expressway along the Jinsha River. It is designed to cross the Jinsha River and connect Sichuan and Yunnan. The main span is 1030 metres. The main girder of the bridge adopts composite structural steel truss girder, the main tower adopts concrete-filled steel tubular composite bridge tower, anchors on both banks are gravity anchors, and the main cable adopts high-strength galvanized steel wire.

The traditional gravity anchorage mostly adopts the enlarged foundation, which has better adaptability under the condition of good terrain and geological conditions, and the construction is relatively simple. However, the anchorage of Sichuan bank is located in the middle and lower part of the left slope of the Jinsha River convex bank, on the front edge of the strip ridge, where the slopes on both sides of the ridge and the front edge gently slope down and then steeply up(*Figure 2*), mostly between 15° and 25°. The localised shape is steep. The terrain condition is poor, and it is a typical "Elephant nose terrain", and the geological conditions at the anchorage position are poor (*Figure 3*).

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Effectiveness of Incomplete Welds in Nodes of Bridge Truss Girder Nodes with Hollow Core Profile Members

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Abstract

Steel truss structures are a powerful and reliable type of bridge girders. The complex part of trusses are the nodes, especially if more than 4 members are converging. Such nodes include internal welds; inaccessible after completion. This study assesses whether all of the internal welds are indispensable, or alternatively, what are the consequences if they are omitted. The latter is tested for a particular bridge, consisting of hollow core profiles. After determining the member forces, including bending moments, an alternative load path is indicated, generated if the internal welds are missing. Formulas are given to determine the weld stresses. In ULS some of the welds require a small amount of strengthening if the internal welds are omitted. In addition fatigue resistance was determined. Certainly for this example internal node welds may be left out, although this does not necessarily apply to more complex node cases. This indicates omitting of some internal welds may well be acceptable

Keywords: welded truss nodes; eliminating internal welds; alternative load path; equal stress distribution in welds.

1 Introduction

Truss girders are again used both for smaller bridges and in larger roofs of buildings. This is related to the fact that designers have rediscovered the many advantages of truss girders and also due to the strong and evident character of this type of load-carrying structure. In particular, the use of hollow core profiles for the members is considered as an important asset, because of the easy connection. In addition, the latter have a neat view, in contrast to the rather complex members, produced in the 19th and early 20th century. Obviously, the simplicity of connecting the truss nodes is in favour of hollow core profiles, whether they be cold formed or assembled from plates.

If the truss bars can be simple, the character of truss becomes more complex for the nodes. The Warren-truss has the simplest nodes, since the number of members connecting at a node is maximum 4. This type of truss may also be used in arch bridges, especially of the tubular type [1]. In some trusses the number of bars, intersecting at the same node may reach 5. This occurs if Warren trusses are supplemented with vertical bars, to increase the number of nodes. In addition, hollow core profiles may collapse due to the lateral pressure or tension perpendicular to their thin walls. This additional type of stress may require complex internal stiffening of the profiles at the nodes. The latter may require optimization of this type of stiffening [2]. As a result, truss nodes often need to be welded in a particular sequence and some of the welds cannot be reached, nor inspected after completion of the steel structure. The latter certainly complicates the work, and may

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