Simulation of Composite Deck-Girder Bridge by Solid Elements

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Summary

Among various types of highway bridges, the precast prestressed girder bridge has been one of the most popular and economical types adopted. Most analyses of this kind of composite deck-girder bridge are made by beam element. Therefore the details of behaviours such as the stress in the strands along the length of girder, the stress and deformation of concrete, especially the mechanical behaviours at the interface between the girder and slab can't be obtained exactly. In this paper it is simulated by 20-node solid element in ABAQUS. Six approaches of modelling the prestressing are introduced. Accompanying subroutine code for shrinkage and creep based on Kabir's creep compliance curving fitted according to AASHTO LRFD Bridge Design Specification (2007) is used. Whole construction procedures are modelled by "remove" deck element firstly in non-composite section, resisting the self-weight of girder and sequent wet weight of deck, and thereafter "reactivate" them into composite section, resisting additional dead load and live load. Using a "perfectly elastic element" to model the cast-in-situ deck, the deck element can be reactivated at an appropriate stage based on the deformed girder. A prism is used for the verification of the subroutine and the primary results of a single span composite girder-deck bridge are obtained.

Keywords: simulation techniques, prestressing, composite deck bridge, creep and shrinkage, 3D solid element.

1. Introduction

Among various types of highway bridges, the precast prestressed girder bridge has been one of the most popular and economical types adopted. In this paper it is simulated by 20-node solid elements in ABAQUS [1]. Six approaches of modelling for prestressing are introduced. Accompanying subroutine code for shrinkage and creep based on Kabir's creep compliance curving fitted according to AASHTO LRFD Bridge Design Specification (2007) [2] is used. Entire construction procedures are modelled by "remove" deck element first in non-composite section, resisting the self-weight of girder and sequent wet weight of deck, and thereafter "reactivate" them into composite section, resisting additional dead load and live load. Using a "perfectly elastic element" to model the cast-in-situ deck, the deck element can be reactivated at an appropriate stage based on the deformed girder. A prism is used for the verification of the subroutine and the primary results of a single span composite girder-deck bridge are obtained.

2. Modelling techniques of prestressing

Six methods are introduced and used to model reinforcement in reinforced concrete or prestressed concrete structures, which are multi-point constraints method, temperature reduction method, step-by-step method, truss element method, single rebar method and rebar layer method respectively. Each method has respective character in application. Rebar layer method provides an available method to model any arbitrary form of reinforcements in reinforced concrete or prestressing

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tendons in prestressed concrete structures and is selected in the analyses of this study.

3. Modelling techniques of slab

A duplicate of element set with respect to the original slab elements is built in the model, which has different elements number but sharing the same nodes number. One and only function of these duplicate elements is to trace the deformed shape of girder so as to the slab elements can be reactivated along the deformed position. Although the duplicate elements have the same shape with the original slab, it is required that they barely take any effect to the behaviour of the whole structure and even to themselves. Therefore they must have relatively soft stiffness comparing with the original slab element, and have a relatively small density. It recommends that the stiffness of duplicate slab elements takes about 10^{-5} times to the initial stiffness and the density takes about 10^{-8} times to the initial stiffness in magnitude. Thus we call this duplicate element as “perfectly elastic element”.

4. Modelling techniques of concrete creep

Creep and shrinkage are very essential phenomena in concrete structures. In composite deck-girder bridge, the differences in material properties of girder and slab, the age at loading between girder and cast-in-place concrete slab lead to time-dependent differential strains, which may significantly affect the stress redistribution along the span length. Thus it is important to evaluate the concrete creep and shrinkage by using an appropriate material constitutive model and proper numerical approaches for saving computing time in a complicated structure. In this study, the creep compliance, proposed by Kabir [3] and Scodelis, which can simulate the stress history effectively in spite of its simplicity in application has been adopted. The coefficients in the equations are determined by least square method according to AASHTO bridge design specification 2007. And they are stored in the subroutine for calculation of creep and shrinkage.

5. Discussion of composite deck-girder bridge

By using rebar layer method, perfectly elastic elements and curve fitted Kabir’s creep compliance, we made analyses on single span composite deck-girder bridge. It is assumed that the prestressing is transformed at age of 7 days, the deck concrete is placed 30 days later, and superposition loads are added in another 30 days. The total evaluating period was one year for considering the effect of creep and shrinkage. The displacements at mid-span section, Mises stresses distribution at transformed area, Mises stresses distribution at the whole mid-span section, normal stresses at bottom and top edge of the girder, and stresses at bottom and top edge of the deck at mid-span section are discussed.

6. Conclusions

Since composite deck-girder bridge are widely used in bridge engineering, the modelling of prestressing in solid, the completely construction procedures including the deck placement, creep and shrinkage have been in difficulty for engineers. In this study, six approaches for modelling prestress in solid are summerized and verified. The technique of “perfectly elastic element” is practical to model the deck being activated along with the deformed precast girder. A subroutine for creep and shrinkage based on Kabir’s Dirichlet series is developed for the analysis of effect of time-dependent and stress-dependent in structures. At last the primary results of a single span composite girder deck bridge modelled by techniques mentioned above are given.

References

[1] Abaqus User Subroutines Reference Manual, Version 6.8, 2007

[2] AASHTO, Bridge Design Specification, 2007(SI),pp 5.14-5.17

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