Renewal of Railway Steel Bridges by Integration with Concrete Slab

Masamichi Saito
Researcher
Railway Technical
Research Institute
Tokyo, Japan
msaito@rtri.or.jp

Masamichi Saito, born 1980, received his engineering degree from the Tokyo Institute of Technology in 2007. Since 2007 he has been researcher of Structures Technology Division.

Ichiro Sugimoto
Laboratory head
Railway Technical
Research Institute
Tokyo, Japan
sugimoto@rtri.or.jp

Ichiro Sugimoto, born 1964, received his Dr. Eng. in 1997 from Tokyo Institute of Technology.
Since 2005 he has been head of Steel & Structures Laboratory, Structures Technology Division.

Yusuke Kobayashi
Assistant senior researcher
Railway Technical
Research Institute
Tokyo, Japan
kobayasi@rtri.or.jp

Yusuke Kobayashi, born 1975, received his degree of Dr. Eng. in 2004 from Tokyo Institute of Technology. Since 2007 he has been assistant senior researcher of Structures Technology Division.

Summary

Railway steel bridges, which exceed their design lifetime, are increasing in Japan and some of them have problems such as corrosion, fatigue and noise. In this study, we proposed a method to improve a structural system of the steel bridges by integration with concrete decks. This method improves the load-carrying capacity of the girders, extends the service life, and reduces the noise. This paper describes the proposed method of concrete deck installation, connection between steel girders and concrete decks, and loading tests of girder-deck connection.

Keywords: existing railway steel bridges, structure improvement, integration with concrete decks

1. Introduction

More than half of railway steel bridges in Japan have been still in service beyond their designed lifetime. Some of them face necessity of replacement mainly because of degradation of load carrying capacity due to corrosion. However, the replacement requires high cost and the time during which the train operation has to be stopped.

As a method to improve the load carrying capacity of the bridges without replacement, we proposed the idea to integrate the steel girders with a concrete deck, as shown in Fig. 1. This method changes the structural system of a steel girder into a composite girder and increases its load carrying capacity. In addition, this method is also possible to mitigate accumulation of fatigue damage by reducing stress at the girders and to reduce noise due to vibration of the bridge members.

In this paper, we first estimated the stress reduction by the integration with concrete decks. To realize this technology, increase of dead load and method of deck installation should be duly examined. Focusing on the dead load, applicable range of this method was estimated. As for the deck installation, the key points would be time required for installation and connection between girders and decks. Then we proposed a short-time installation method using precast-concrete decks and evaluated the resistance of the girder-deck connection by loading tests.

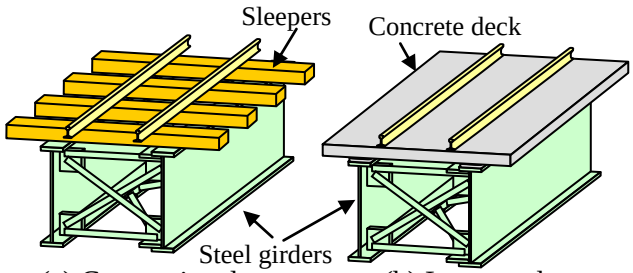

Fig. 1: Integration with concrete deck

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2. Change of stress by integration with concrete deck

2.1 Stress reduction of steel girders

Many of the existing railway steel bridges have sleepers directly set on the girders. There often occurs corrosion of upper flanges at the contacted areas with the sleepers. Thickness reduction of the upper flanges due to corrosion leads to degradation of load-carrying capacity of the girders. Through design calculation, we examined the stress of the girder before and after the deck is installed. As for a typical existing railway bridges, which has simple girders with span of 10m, stress of upper flange can be reduced by approximately 80% and stress of lower flange can be reduced by 20%, under the condition that the concrete deck is fully integrated with the girder after installed. Reduction of stress leads to increase of load carrying capacity of the girders.

2.2 Increase of dead load and stress of supports

When the concrete deck is installed onto the existing bridge, increased dead load acts directly on the supports of the bridge. We calculated the bearing stress of the concrete of the supports, before and after the deck is installed. As a result, in the bridges with span of more than 40m, bearing stress of the concrete of the supports exceeds the allowable stress. Then we found out that this method is applicable to the bridges shorter than 40m.

3. Installation of concrete decks

For installation of concrete decks on steel girders, we have to consider time constraint. On the lines with heavy traffic, stop of train operation is not acceptable. Then the installation should be finished within a given time of night work. Then we proposed a method of integration using precast-concrete deck. In this method, multiple precast concrete decks are installed on the girders and decks can be installed in a short-time work at a site. Furthermore, the installation work for longer bridges can be carried out by separating the long work into several short time night works for each precast deck.

4. Connection between steel girders and concrete decks

Focusing on the installation method with precast concrete decks, it is necessary to examine the resistance of the connection between girders and decks. Then we proposed a system of connection of steel girders and precast-concrete deck by steel fasteners and mortar filler. Then the strength of the connections was evaluated by loading tests. The connection by fasteners was found to have enough resistance against vertical and transverse force. The connection by mortar filler was found to have enough resistance against the shear force applied by live loads. However, at the end of the girders, it needs more shear resistance against the shear force caused by temperature difference of girders and decks.

5. Conclusion

In this study, a method of structure improvement of existing railway steel bridges by integration with concrete decks was proposed, and the applicability of the method was evaluated through design calculation and loading tests. The deck installation method using precast concrete decks is applicable to short time night work. However, in order to integrate the precast concrete deck completely with the girders, it is necessary to install extra shear connections at the ends of the girders.