Construction and Building Materials 186 (2018) 709–730

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Experimental and numerical study on an innovative girder-abutment joint in composite bridges with integral abutments

Chen Liang [a], Yuqing Liu [a,*], Changjun Zhao [b], Bo Lei [b], Jieliang Wu [b]

[a] *Department of Bridge Engineering, Tongji University, Shanghai, China*
[b] *Zhejiang Provincial Institute of Communications Planning, Design & Research, Zhejiang, China*

HIGHLIGHTS

- A joint in composite FIABs is proposed to provide convenience in construction.
- The joint behavior is analyzed with model test and nonlinear FEA.
- The bending strength of the joint is 84% higher than the joint without connectors.
- The load-transferring mechanism of the proposed joint is revealed.

ARTICLE INFO

Article history:
Received 26 March 2018
Received in revised form 23 July 2018
Accepted 26 July 2018

Keywords:
Fully integral abutment bridge (FIAB)
Girder-abutment joint
Composite girder
Experimental test
Finite element analysis

ABSTRACT

For the convenience in the construction of composite bridges with integral abutments, this paper proposes an innovative girder-abutment joint. In this joint, the bottom plate of steel girder is connected to a pre-embedded plate, and the concrete at the girder end is cast after the erection of the girder. Perfobond connectors are also set on the inserted plate and the embedded plate to reduce stress concentration in the concrete abutment. Experimental test and nonlinear FE analysis were conducted to validate the joint performance in the most unfavorable condition in shear force and moment. Results show that, compared to the joint without connectors, the initial stiffness of the proposed joint is higher by 50% and 33% in shear loading and moment loading respectively, and the strength in moment loading is higher by 84%. The initial stiffness of the joint is highly affected by inserted plate connector quantity, while the strength in moment loading is highly affected by the connector quantity on both the inserted plate and the embedded plate. The failure process of the joint in moment loading can be divided with the failure of inserted plate connectors, the yielding of embedded plate edges, and the crushing of the concrete beneath steel girder. Under the design load, the perfobond connectors can take 70% of the shear force and 27% of the moment.

1. Introduction

Fully integral abutment bridges (FIABs), in which the girders are fixed to the abutments, are considered to be a solution to many durability issues at girder ends, such as girder corrosion, bearing defects, and expansion joints damage. All the more so for composite bridges. In addition, the fix condition of the superstructure reduces the sagging moment at mid-span, and leads to slender cross-sections and less intermediate supports. Therefore, composite FIABs were proposed and many have been constructed around the world [1–6].

Despite the application of composite FIABs, the steel girder-concrete abutment joint is still an area of particular concern for designers. To the authors' knowledge, several types of the joints have been mentioned in design manuals. As Fig. 1(a) shows, the Steel Construction Institute (SCI) suggested a joint in which studs and hoop type connectors are set on the top flange and the bottom flange respectively to resist the external load [7]. Web holes are required to accommodate the transverse abutment rebars in the joint. European Commission mentioned a joint in the design guide of composite FIABs [8]. As is shown in Fig. 1(b), in this joint, tensile forces were transferred through the studs on the end plate, while compressive forces were transferred through the bearing plate at the bottom. In the USA, most states recommended a joint modified from those used in concrete FIABs [9–11]. With no shear connectors, the steel girder is simply embedded in the concrete abutment,

* Corresponding author.
E-mail address: yql@tongji.edu.cn (Y. Liu).

https://doi.org/10.1016/j.conbuildmat.2018.07.208
0950-0618/

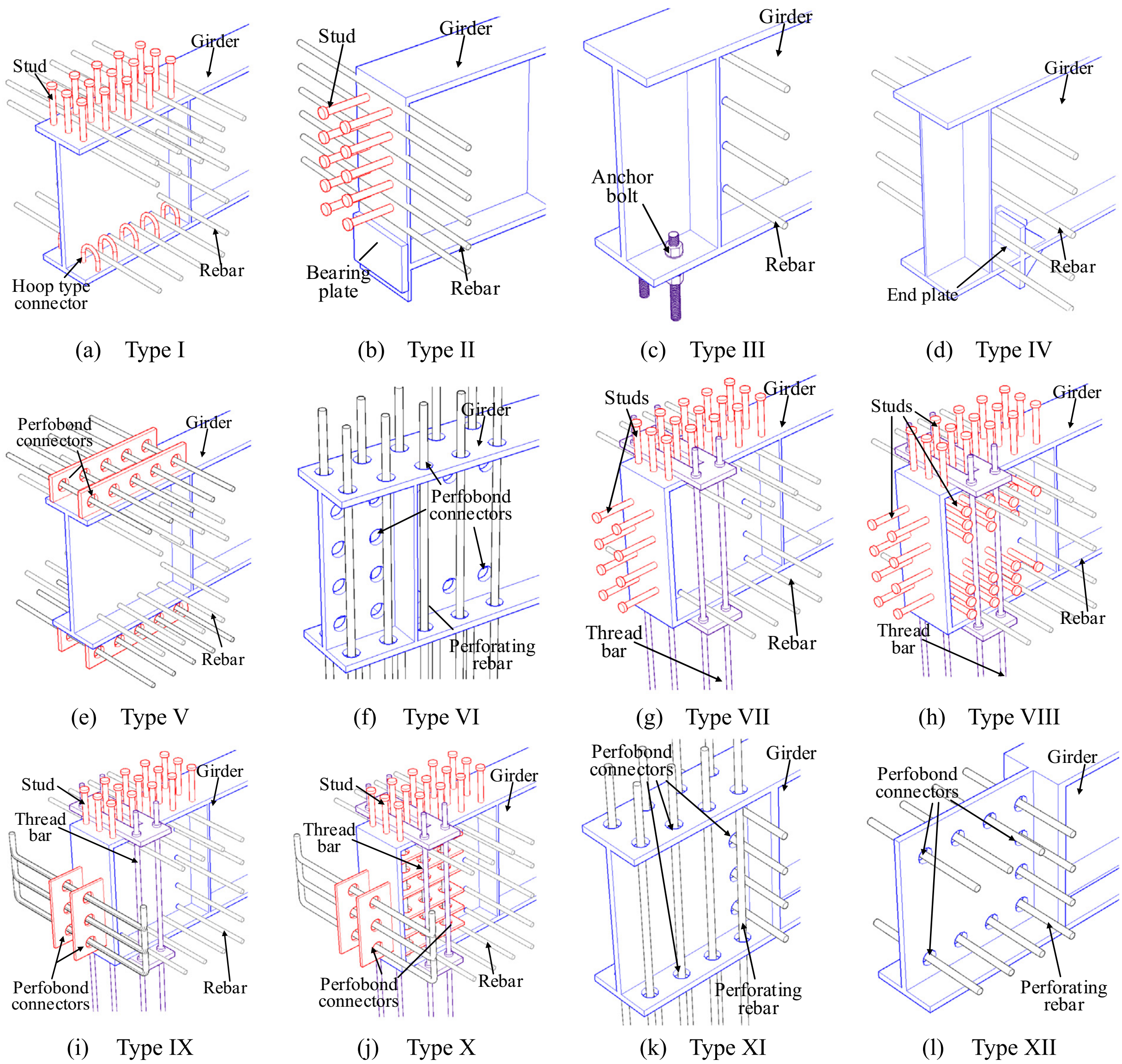

Fig. 1. Structural details of the existed joints.

with the abutment rebars going through the web holes. Some states suggested using anchor bolts in order to improve the joint performance, as shown in Fig. 1(c).

Several researchers proposed new joint details as well. Riches et al. [12] proposed a simplified joint, as shown in Fig. 1(d). Tensile forces were transferred through the abutment rebars, while compressive forces were transferred through the end plate on the bottom flange. Homma and Hirata [13], Takagi et al. [14], Elmy and Nakamura [15] conducted experimental tests on the joint shown in Fig. 1(e). Perfobond connectors were set on the top flange and the bottom flange to acquire the rigidity at girder ends. As Fig. 1 (f) shows, Ashiduka et al. [16] proposed a joint in which perfobond connectors were set on the flanges and the web. Kim et al. [17] proposed four types of joints, as shown in Fig. 1(g)-(j). Thread bars were set in all of the joints. Studs were set on the girder end of Type VII and Type VIII, while perfobond connectors were set on the girder end of Type IX and Type X. To further improve the structural performance, additional connectors were set on the web of Type VIII and Type X. Liang et al. [18,19] presented two types of joints, which is shown in Fig. 1(k)-(l). In Type XI, perfobond connectors were set on the flanges and webs, while in Type XII, perfobond connectors were only set on the web, and the top flange of the girder was removed for the convenience in concrete pouring. Despite the joints mentioned above, the rational details remain an open question.

This paper aims to present a new joint that might provide convenience in the construction of composite FIABs. A scaled model was constructed and tested to study its structural performance, stiffness degradation under cyclic loading, and the strain distribution in the most unfavorable condition in shear force and moment. Moreover, numerical study was carried out on the effect of connector quantity on initial stiffness, strength, and load bearing percentages of the joint. Finally, the load transferring mechanism of the joint was revealed.

2. Proposed joint

As Fig. 2 shows, in this type of joint, perfobond connectors were chosen for their higher shear stiffness and improved fatigue strength [20]. All of the connectors were perforated with rebars to improve ductility. Since perforating rebars are very long in actual bridges, the installation could be difficult and time-