

PAPER • OPEN ACCESS

Study on Reinforcement of Transverse Prestressed Carbon Fiber Slab for Assembled Skew Hollow Slab Bridge

To cite this article: Lanlin zou *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **563** 022044

View the [article online](#) for updates and enhancements.

Study on Reinforcement of Transverse Prestressed Carbon Fiber Slab for Assembled Skew Hollow Slab Bridge

Lanlin zou¹, Rui Cai¹, Yaohui Wu¹

¹ Wuhan University of Science and Technology, Wuhan, 430000, China

e-mail: 351958447@qq.com

Abstract. Assembled skewed hollow slab bridge can improve the line shape of the road and adapt to the complex and changing urban street conditions, making the whole route smooth, thus shortening the route and bridge length and improving economic benefits. Assembled skewed bridges are more complicated due to their forces, which leads to more prominent problems in the hinged joints of inclined bridges. When lateral prestressing is applied to the two straight sides of the skewed bridge, it is difficult to achieve the effect of prestressing at the ends. Aiming at this problem, a scheme of reinforcement with transverse prestressed carbon fiber slabs is proposed, and a solid model of fabricated oblique slab bridges is established by ABAQUS finite element software. The results show that the method of transverse prestressing CFRP plate reinforcement is effective for Assembled Skew Hollow Slab Bridge.

1. Introduction

In recent years, with the rapid development of China, the transportation industry has also flourished. As the throat of transportation, the bridge plays a vital role in ensuring the daily operation safety of transportation and the stable development of the national economy [1]. As the Assembled Skew Hollow Slab Bridge can improve the road alignment and adapt to the complex and changeable urban street conditions, make the whole route smooth, shorten the route and bridge length, and improve economic efficiency, so the Assembled Skew Bridge is widely used in high-grade highway and urban three-dimensional engineering [2]. However, in actual use, the stress of Assembled Skew Hollow Slab Bridge is more complex than that of orthogonal slab bridge, which leads to more serious problems of hinged joints of skew bridge. In order to solve the problem of hinge disease, many scholars have done a lot of research and practice by optimizing the joint structure, changing the grouting material and strengthening the diseased bridge [3]. Most of the reinforcement improvement measures currently used are passive methods, which cannot fundamentally control the occurrence of cracks. At present, the more effective measure is to adopt transverse prestressing CFRP plate reinforcement scheme to make the hollow slab produce prestressing stress at the hinge joint, eliminate the tension stress which may be produced by various effects, and improve the crack resistance of bridges, so as to avoid the occurrence and development of hinge joint diseases [4].

2. Bridge overview and finite element modeling

A standard designed Assembled Skew Hollow Slab Bridge consists of 7 hollow slabs, each with a width of 1.25 m, a width of 8.74 m, a span of 13 m, a skew angle of 45 degrees, a beam height of 0.80 m and a calculated span of 12.6 m; The thickness of concrete pavement on bridge deck is 100 mm and the concrete is C40. The transverse joints between slabs are connected by concrete hinge joints.



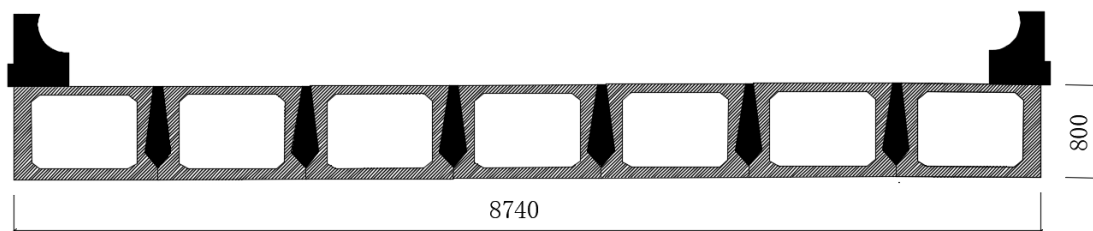


Figure 1. Full bridge cross section (unit: mm)

Commonly used models for reinforced concrete structures are separate, combined and integral. Because the hollow slab bridge is under the load, the bridge deck structure is in the elastic working stage. To simplify the calculation, this paper adopts the integral model and uses the homogenized reinforced concrete to calculate the elastic modulus. The homogenized reinforced concrete conversion elastic modulus E_R is calculated according to the following formula:

$$E_R = E_C \left(1 + \mu \frac{E_S - E_C}{E_C} \right) \quad (1)$$

E_R is the average elastic modulus of reinforced concrete, E_C is the modulus of elasticity of concrete, E_S is the elastic modulus of steel, μ is the reinforcement ratio.

The main beam, the hinge joint and the deck pavement layer in the hollow slab bridge adopt three-dimensional solid elements, and the unit division method adopts Free. To ensure accuracy, the length ratio of solid elements is close to 1:1:1. The boundary condition of the hollow slab bridge is the three-way restraint ((X, Y, Z) applied in the case of a fixed support, and the Z-axis is free, and the X-axis and the Y-axis are fixed in the case of moving the support. Applying a constraint to the lower edge node of the finite element model section at the theoretical support line.

3. Unfavorable load effect on Hinge Joint Failure

The main factors that usually affect the failure of the joint are the vehicle load and the gradient temperature effect [5]. In order to understand the adverse effects of the above loads in the fabricated skewed hollow slab girder bridge, a finite element model is established and the vehicle load and gradient temperature field are applied to the bridge model. The lateral stress distribution of the most unfavorable position of the joint section calculated by the model is shown in Fig. 2.

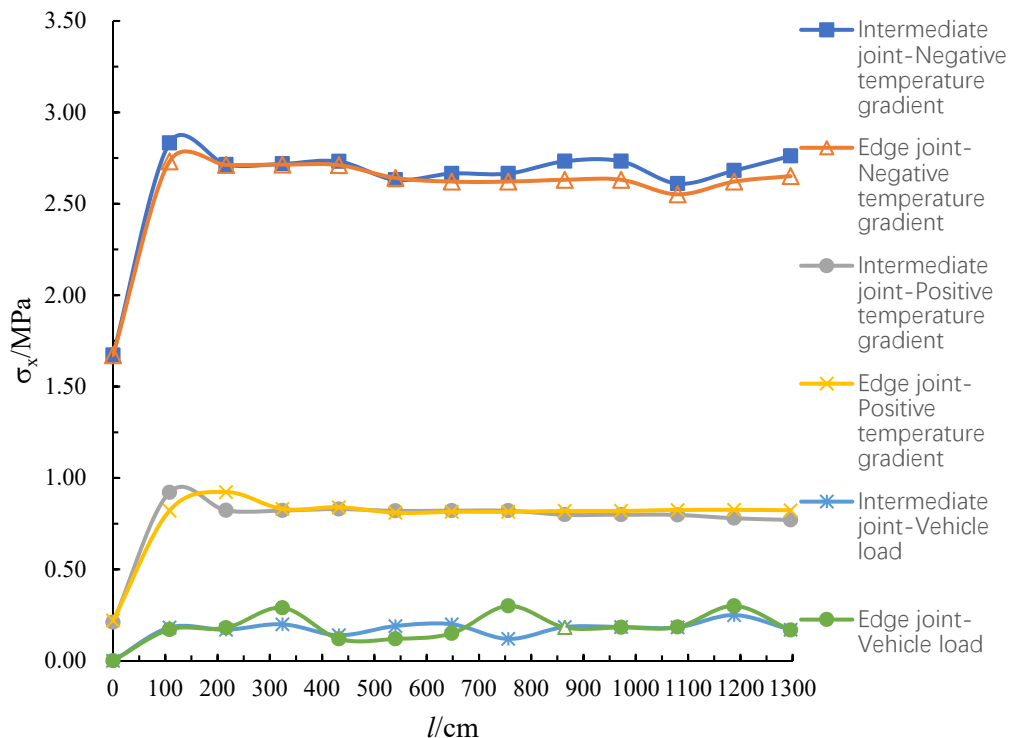


Figure 2. Transverse stress distribution at the most unfavorable position of the joint section under the combined action of vehicle load and gradient temperature

Unfavorable combination of load under the combined action of vehicle load and gradient temperature field. The results show that: (1) the combination of vehicle load and negative gradient temperature field is more unfavorable; (2) The joint action of vehicle load and positive gradient temperature field results in tensile stress at the interface, which may lead to cracking of hinge joint. Therefore, it is necessary to apply transverse prestressing force to the Assembled Skew bridge.

4. Application of transverse prestressing scheme design and post-reinforcement analysis

It can be known from the literature [2] that the transverse prestressing application spacing of the straight portions is taken as $t=1400\text{mm}$. In order to make the pre-stress of the oblique joint of the oblique joint such as a straight line, the inclined end must be prestressed, and a prestressing force is added at the 1/3 position of the oblique side, so that most of the inclined end can be Within the scope of the transverse prestress.

Reinforced with carbon fiber sheet 50 mm wide by 2 mm thick. First, the self-leveling fine stone concrete is used to level the beam bottom, and then the installation position of the anchor is determined. After the positioning work is finished, the anchor groove is cut by the cutter, and finally the carbon fiber board is loaded into the two ends of the support, and the high-strength screw, the gasket, the nut, the stopper and the jack are sequentially installed at the tension end.

By comparing the influence lines of transverse load distribution before and after the reinforcement of hollow slab No. 1-4, as shown in Figure 3, the effect of external transverse prestressing carbon fiber slab on the reinforcement of Assembled Skew Hollow Slab Bridge can be obtained.

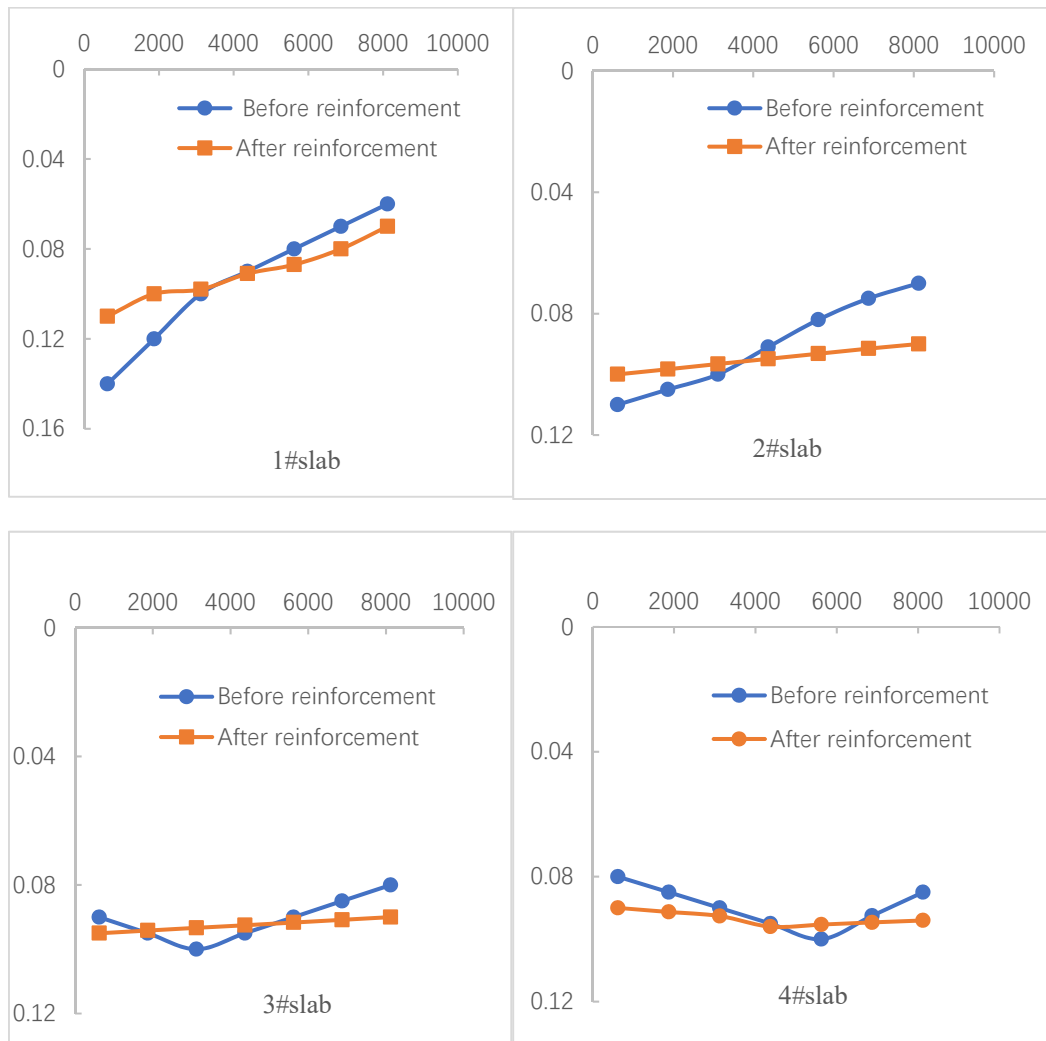


Figure 3. Lateral distribution influence line of each plate before and after reinforcement

From the analysis of Figure 3, it can be concluded that the influence line of transverse load distribution becomes smooth after the fabricated Skew Hollow Slab Bridge is strengthened with transverse prestressing carbon fiber slab, which indicates that the transverse force transfer between hollow slabs is enhanced. The bridge deck is developed by the force of the single plate to the multi-plate. It shows that the method of reinforcing the transverse prestressed carbon fiber board is effective for improving the lateral integrity of the assembled diagonal hollow slab bridge.

5. Conclusion

(1) The finite element model is established by ABAQUS, and the unfavorable load effect on the joint failure of the skewed slab bridge is analyzed. It is concluded that under the combined action of the vehicle load and the positive gradient temperature field, tensile stress is generated at the interface, which may cause the joint to crack. Therefore, it is necessary to apply lateral prestress to the assembled skew bridge.

(2) Comparing the influence diagram of the transverse distribution of load before and after the prestressed hollow slab bridge with transverse prestressed carbon fiber slabs, it can be seen that the reinforcement of the prestressed hollow slab bridge can be effectively improved by the method of transverse prestressed carbon fiber slab reinforcement. The lateral distribution increases the lateral

connection between the hollow plates and the synergy between the plates, and enhances the integrity of the assembled hollow slab bridge.

References

- [1] Lichu Fan,(2014) Bridge Engineering. China Communications Press.
- [2] Zengfeng Li, Yizhou Zhuang, Junfeng Cheng. (2017) Study on Crack Resistance of Lateral Prestress of Prefabricated Hollow Slab Bridge. Journal of Water Conservancy and Construction Engineering.
- [3] Yiqiang Xiang, Gallant Xing, Linhai Shao. (2012) Spatial Force Behavior and Reinforcement Analysis of Articulated Prestressed Concrete Hollow Slab Girder Bridges. Journal of Southeast University. 42(4):734-738.
- [4] Yunna Zhang, Huai Chen. Research on external transverse prestressing reinforcement of prefabricated oblique slab bridge. Railway Engineering. 2011(7).
- [5] Xianxi Tang, Yueyou Yin, Wei Guo. (2015) Experimental study on fatigue performance of hinged bridge hinge. Journal of Water Conservancy and Construction Engineering. 2015(1):6-10.