Study on the Stress State of Hollow Slab Hinged Joint Under Vehicle Load

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Abstract: In this paper, an experimental study on the real stress state of the hinge joint is carried out for the prefabricated hollow girder bridge. The tests were divided into three working conditions: 1) center cloth loading, 2) symmetrical cloth loading on both sides and 3) cloth loading on one side. From the test results, the measured transverse distribution values of the boards under three working conditions are all lower than that of the value calculated by Hinged Plate theory, and the distribution curve is more flat. In addition, under the three conditions, there is positive strain in the transverse direction of the concrete joints, and the strain distribution is uneven with tensile and compressive strain coexisting along the cross-sectional height of the joint. Judging from the bridge design theory and test results, the concrete joints of hollow slabs has the function of internal force transmission between the slabs, and the concrete joints are under the action of shear force and bending moment.

1 INTRODUCTION

Assembled hollow concrete beams are widely used in China's small and medium-span bridges. The traditional hinging slab method considers that the hinge joints transmit only the vertical shear force, then the internal forces of the structure can be solved out by obtaining the transverse load distribution coefficient of each hollow slab under the vehicle load. The existing research literatures and bridge experiments have proved the effectiveness of hinging slab method in engineering design (Shao Xudong, 2007; Guohao Li, 2007). However, both shear and bending moment acts on the hinge joint in practical structures, and the stress state is very complicated (Liu Chenguang, 2002). In recent years, the most typical disease of the hollow slab is cracking longitudinally of the hinge joint and its reflection on the surface of the deck pavement (Pu Guangning, 2008; Journal Huazhong University, 2008). Therefore, a better understanding of the actual stress state of the hollow slab joint is a basis for grasping its workability and structure, as well as for obtaining a reinforcement suggestion for hollow slab bridges with hinged joints.

Based on the calculation and analysis method for stress state of hollow girder bridges and the arrangement characteristics of hollow slab hinge joints, this paper studied the corresponding calculation model and revealed the stress state of the hinge joints of the hollow girder bridge concrete under vehicle load.

2 LOAD TEST OF HOLLOW SLAB JOINT REAL BRIDGE

The test bridge is a 20 m-long new prefabricated prestressed concrete hollow girder bridge with a calculated span of 19.3 m and a bridge width of 13.5 m. The test bridge consists of 9 intermediate slabs and 2 edge slabs, with a total of 10 hinge joints. The hollow slab is 1.17 m wide and 0.9 m high (Figure 1), the main beam is composed of C40 concrete.

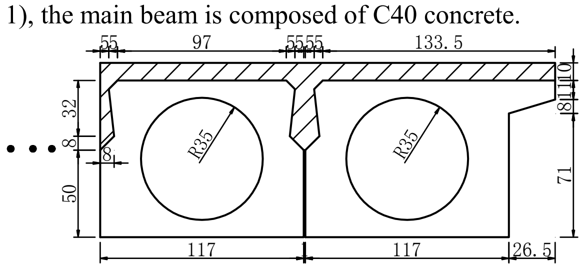

Figure 1 hollow plate cross-section (unit: cm)

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The test purpose is to observe the stress state of the joints under the test vehicle action. The test includes measuring the vertical displacement of each slab using dial indicators and measuring the joints' strain using strain gauges. Strain measuring points located at inside or outside of hinge joints, as shown in Figure 2. The external strain point of reaming joints refers to the horizontal type strain gauge installed across the joints. Because some adjacent hollow slabs are in error, the site selection is arranged at the joints of No. 2, No. 5, No. 6 and No. 7 cross sections. No. 6 slab center set transverse strain measuring point. No. 6 hinge at the cross-section stitches horizontal strain gauge. From the top to bottom is No. 1 to No. 4 measuring points, respectively.

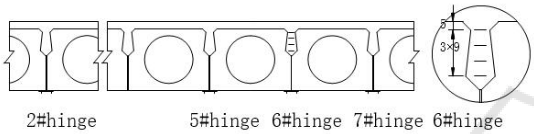


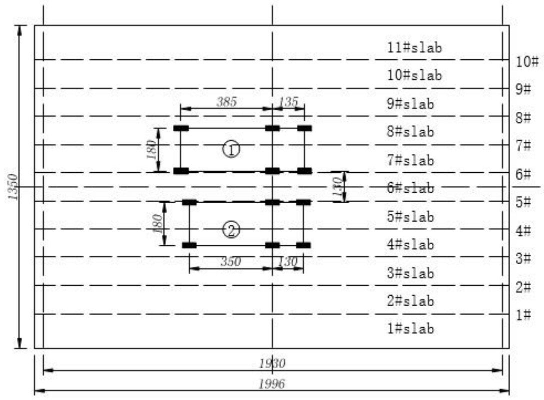
Figure 2 Hollow slab joint strain measurement point arrangement (unit: cm)

The test uses two vehicles for loading. The total weight of No. 1 loading vehicle is 30.9 t and that of No. 2 loading vehicle is 29.2 t. The test loading has three conditions, loading car size and location are shown in Figure 3.

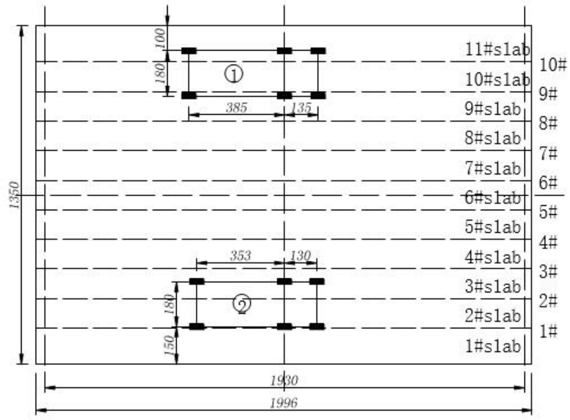
(1) Condition 1: Two loading vehicles are arranged at the center of the bridge, referred to as "loading at the center";

(2) Condition 2: Two loading vehicles are arranged along two sides of the bridge shoulder; respectively, referred to as "loading at two sides";

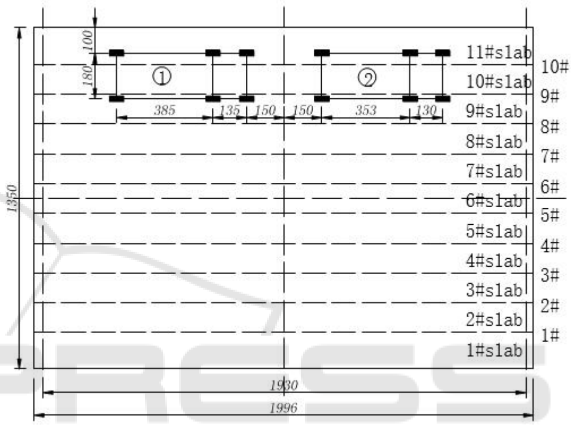
(3) Condition 3: Two loading vehicles are arranged along one side of the bridge shoulder, referred to as "loading at one side" for short.



a) Condition 1



b) Condition 2



c) Condition 3

Figure 3 Vehicle loading conditions (unit: cm)

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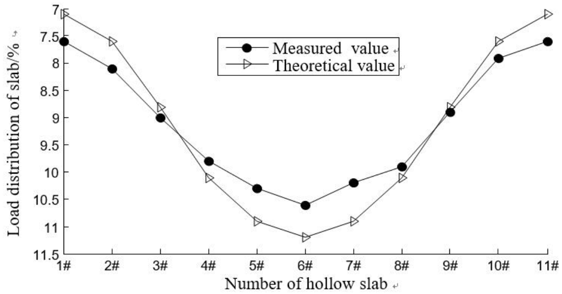
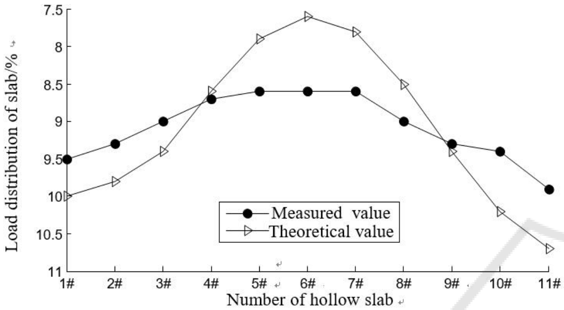
3 RESULTS AND DISCUSSION

3.1 Transverse load distribution of hollow slab

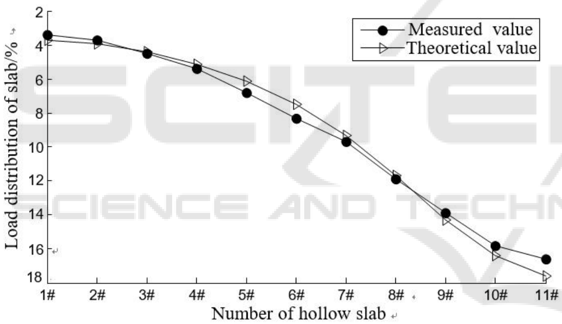
The transverse load distribution in this paper is the ratio of the deflection of each slab span measured by the test vehicle to the sum of the measured deflection of each slab. The distribution of the load is smoother along the cross-bridge, the better the structural integrity is and can indirectly reflect the bearing performance of hollow slab hinge joints.



a) Condition 1



b) Condition 2



c) Condition 3

Figure 4 cross-section of the mid-section load transverse distribution

It can be seen from Fig. 4 that there is not much difference between the curve of measured values and that of the calculated values from the hinge plate method, but the measured transverse distribution value is smaller than the calculated value and the distribution curve is flat.

3.2 Strain increment of joints concrete

Horizontal strain gauges were embedded in No. 6 hinge at the cross-section, as shown in Figure 5. In particular, it should be pointed out here that the concrete joints between the bridge hollow slabs are constructed strictly following the construction procedures and have good quality after quality inspection.

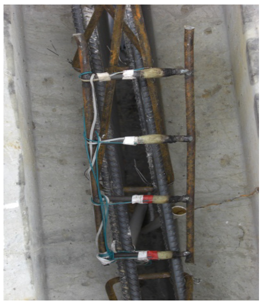


Figure 5 site buried seam strain measurement point

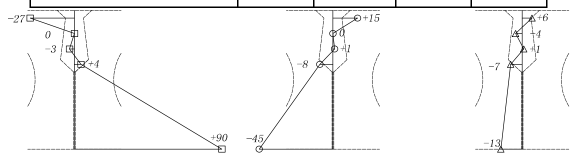
Under different loading conditions, the measured results for strain increment of joints concrete are shown in Table 1 and Table 2, the values are the strain of joints concrete under the vehicle load, "+" is the pull, "-" is the pressure. Figure 6 shows the stress values at different heights of No. 6 hinge joints.

Table 1 cross-section of the reaming measured value of external strain/με

	#2 hinge joints	#5 hinge joints	#6 hinge joints	#7 hinge joints	# 6 slab
Condition 1	-	72	90	58	5
Condition 2	-3	-48	-45	-17	-4
Condition 3	-8	-8	-13	-12	-3

Table 2 No. 6 hinge joints measured strain/με

	NO.1	NO.2	NO.3	NO.4
Condition 1	-27	0	-3	4
Condition 2	15	0	1	-8
Condition 3	6	-4	1	-7



a) Condition 1 b) Condition 2 c) Condition 3

Figure 6 Distribution of strain at No. 6 hinge joint under each working condition (Unit: με)

It can be seen from Figure 6, Table 1 and Table 2 that the normal strain exists in the transverse direction of the concrete joint under three test conditions, and the strain distribution is uneven along the height of the joint, and the tensile and compressive strain coexist. Under the condition 1, the loading vehicle is arranged at the center position of the bridge width. The upper part of the concrete joint section is the compressive strain while the lower part is the tensile strain. This proves that there is a transverse bending moment acting on the concrete joint caused by the vehicle load (The bending moment at the lower edge is positive, otherwise negative). On the contrary, under the condition 2 and 3, the loading vehicles are arranged outside of the bridge shoulder. The upper part of the concrete joint section is tensile strain while the lower part of the section is the compressive strain. This proves that a transverse negative moment actually acts on the concrete hinge joint caused by vehicle load exists.

Under the condition 1 with loading at the center position of the bridge width, the lower edge of each hinge joint bear tensile stress, in particular, No. 6 joint at the center of the bridge width has maximal tensile strain, 90 με, and the corresponding tensile stress is 3 MPa calculated using C40 concrete, which is enough to make the whole pouring concrete crack, especially the concrete joints are at the bonding between new and old concrete. As the tensile strength of the bonding interface is far lower than the concrete matrix, the joints bonding surface may have been cracked.

4 CONCLUSIONS

In this paper, the field bridge load test was carried out on the prefabricated hollow girder bridge. The experimental results show that the hollow slab joints are actually in the complex state of bearing bending and shearing together, and the shear and transverse bending moment of different joints change with the action position of the vehicle load. In particular, the horizontal middle hollow slab hinge joints bear transverse positive bending moment under the condition 1, while bear negative bending moment when under the condition 2 and 3. The absolute value of the edge stress is the largest irrespective of the conditions.

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