Structural behavior of reinforced concrete slab rigid frame bridge with h-shaped steels

STRUCTURAL BEHAVIOR OF REINFORCED CONCRETE SLAB RIGID FRAME BRIDGE WITH H-SHAPED STEELS

S. FUKADA[1], Y. KAJIKAWA[2] and M.TOKUNO[3]

ABSTRACT : The authors proposed a reinforced concrete slab bridge with H-shaped steels, which has high load-carrying capacity, in order to reduce the construction cost. Our past study clarified that H-shape steels without stud dowel and concrete could compose hybrid section, and static load was equally distributed each H-shaped steel in elasticity stage. Considering the described above, it is possible to design this type of bridge as composite. Moreover, it clarified that the cyclically loaded this type bridge has the high fatigue capacity and load-carrying capacity as same as the statically (non-cyclically) loaded that bridge. As next step, the authors proposed a reinforced concrete slab rigid frame bridge with H-shaped steels in order to reduce the maintenance cost and to increase seismic performance. Especially, the rigid connection method of H-shaped steel and re-bar in the abutments was proposed. Then the static loading test was carried out to grasp load-carrying capacity. As the results of the experiment, destructive behavior of the reinforced concrete slab rigid frame bridge with H-shaped steels was clarified and also, the validity of the connection method was clarified.

KEYWORDS: Reinforced Concrete Rigid Frame Bridge, H-shaped steel, Load-carrying capacity

1. INTRODUCTION

The reinforced concrete slab bridge with H-shaped steels as shown in Fig. 1 is constructed with the feature as described below.
1) Low cost, 2) Short construction term, 3) Low height of the webs, 4) Easy conveyance of beams, 5) Easy Construction, 6) Little maintenance expenses in the life time.
Considering construction and weight of the concrete, this bridge can be applied up to 20m span.

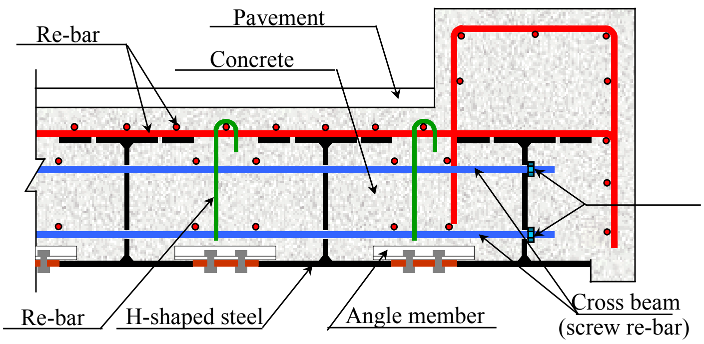

Figure 1. Reinforced concrete slab bridge with H-shaped steels

Authors clarified that H-shaped steels without stud dowel and concrete could compose hybrid section, and static load was equally distributed each H-shaped steel in elastic stage [1]. Considering the above,

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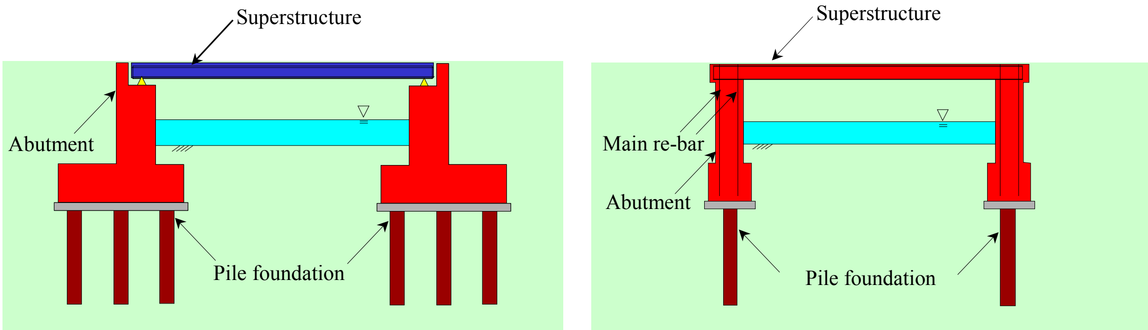
it is possible to design this type of bridge as composite structure. Besides, it is clear that this type bridge under cyclic load has the high fatigue capacity and load-carrying capacity as same as the statically (non- cyclically) loaded one [2].

On the other hand, the authors developed the reinforced concrete slab rigid frame bridge with H-shaped steels in order to reply the demand from society for the cost reduction of construction and maintenance, improvement of the seismic performance. Though it was well known that rigid frame bridge is excellent in cost and structural performance compared with the simple girder bridge, that bridge was rarely constructed for the short span bridge by the complicated structural design of the rigid connection.

Then the authors improved the structural rigid connection for easy construction. In particular, the rigid connection method of H-shaped steel and re-bar in the corner of the rigid frame structure was proposed. In this study, static loading test was carried out to grasp load-carrying capacity in the rigid connection.

2. OUTLINE OF REINFORCED CONCRETE SLAB RIGID FRAME BRIDGE WITH H-SHAPED STEELS

A cost of the substructure in the simple girder bridge with short span (up to 20m) is generally more expensive than that of the superstructure. Because although the cost of superstructure becomes cheap in proportion to the length of bridge span, that of substructure is not dependent on the bridge length. And then, since the size of the abutments of the bridge is determined by dead load and earth pressure of the backfilling, the cost will also become higher in proportion to the height of abutments. While the abutments of a simple girder bridge (Fig.2 (a)) are independent of each other, those of the rigid frame bridge (Fig.2 (b)) are unified. Therefore the earth pressure of the backfilling acting on each abutment is canceled through the superstructure. The size of the substructure can be made smaller comparing the simple structure. Especially in the case of the pile foundation, the number of the piles can be reduced. The following advantages are mentioned by comparing the rigid frame structure with the simple structure. 1) Simplification of the shoes, expansion joints and the device for falling prevention of bridge, 2) Short construction term, 3) Low cost, 4) Reduction of the substructure



(a) Simple structure (b) Rigid frame structure

Figure 2. Comparing the structure

The authors proposed a reinforced concrete slab rigid frame bridge with H-shaped steels in order to reduce the maintenance cost and to increase seismic performance. Especially, the connection method of H-shaped steel and re-bar in the corner of the rigid frame structure was proposed for easy construction. Old studies [3] in Japan proposed Perforated Bond Lib method (German: Perfo-Bond Leisten) for constructing of the rigid connection. The PBL method comprises penetrating re-bars of the transverse direction through the perforated plates installed in the upper and the lower flanges as shown in Fig.3. The authors proposed the method that passing the main screw re-bars in the abutments from the hole of the lower flange to that of upper flange and then being anchored by nuts as shown in Photo 1.

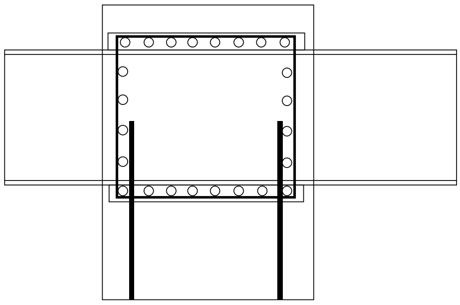


Figure 3. PBL method

(a) Cross section (b) Plane

Photo 1. Joint of the main screw re-bars and H-shaped steels

3. OUTLINE OF THE TEST BRIDGE

A Reinforced concrete slab rigid frame bridge with H-shaped steels as shown in Fig. 4 was made. This bridge has span length 6.00m, total height 1.80m and width 1.20m using 2 H-shaped steels (height of webs: 0.25m) at intervals of 0.6m. This bridge was designed using the design load of 98kN as real scale composite bridge. Concrete design strength of the footing, abutment and superstructure are 24,30 and 30 N/mm^2, respectively.

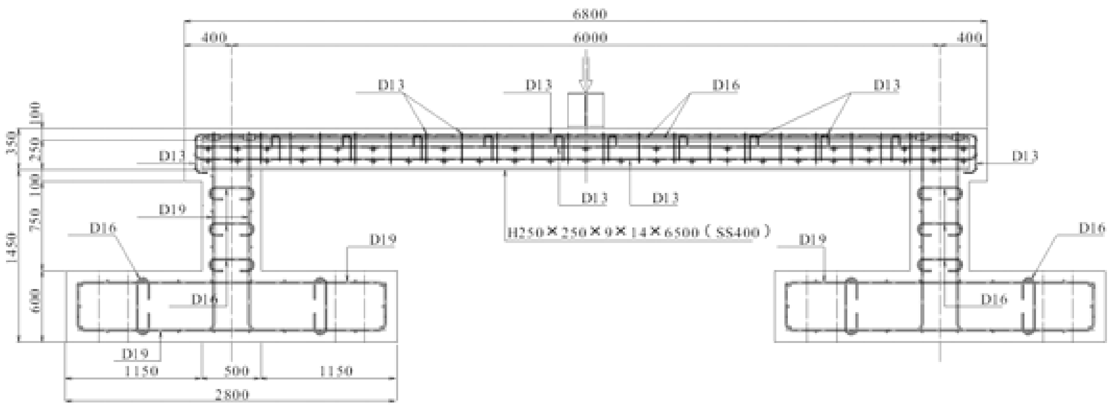


Figure 4. Test bridge

4. LOADING TEST

Loading test was carried out to grasp the structural behavior of the whole bridge and the joint of H-shaped steels and re-bars until the ultimate state. The situation of the loading test is shown in Photo 2.

Photo 2. Situation of the loading test

5. RESULTS OF EXPERIMENTS

The profiles of cracks are shown in Fig. 5. The failure is that the upper surface of the concrete at the mid-span is crushed by the compression as following. 1) Cracks at the upper surface of the concrete in the corner are opened. 2) Cracks at the lower surface of the concrete in the mid-span are opened. 3) Construction joints of the superstructure and abutment are opened as shown in Photo 3. 4) Cracks in the corner and the mid-span develop. 5) Cracks at the abutments (1/2 height) in the horizontal direction are opened. 6) Cracks at the joints develop. 7) Upper surface of the concrete at the mid-span is crushed.

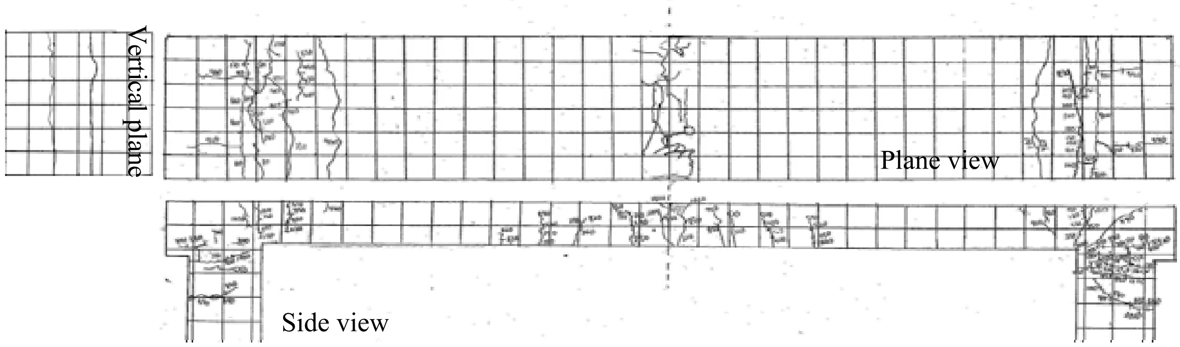


Figure 5. Profiles of cracks

Photo 3. Opened crack at construction joint

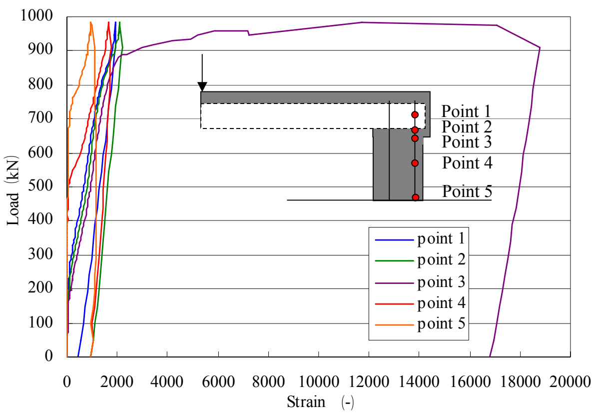


Figure 6. Strain of re-bar in abutment

Fig. 6 shows the relation between the strain of the re-bars in the abutment and load with loading at mid-span. Because the construction joint is opened, the re-bars at that point are yielded at 900 kN. It is not confirmed that the joint of the H-shaped steels and the re-bars in the abutment are yielded.

6. RESULTS OF ANALYSIS

Non-liner analysis used structural analysis program UC-win/FRAME (3D) is curried out to grasp the structural behavior until failure. Analytical model is made as frame model with fiber elements as shown in Fig. 7. Material properties of the concrete, the H-shaped steels and the re-bar are shown in Fig. 8.

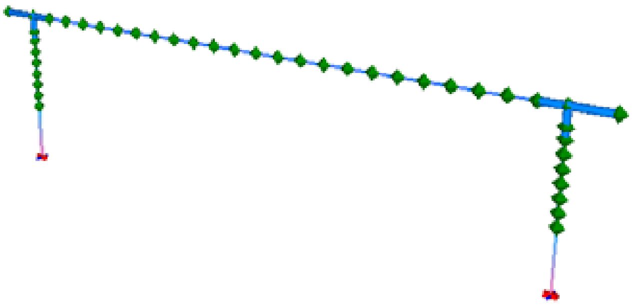
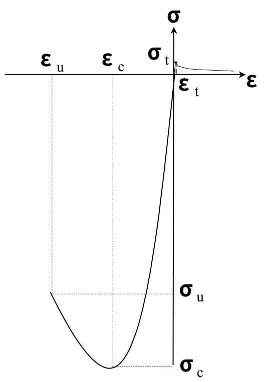
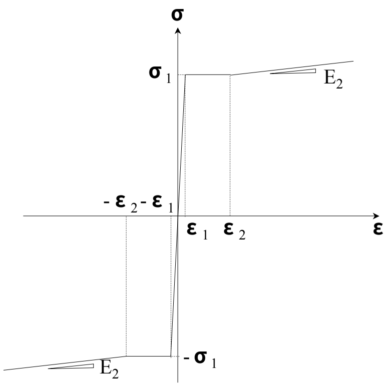


Figure 7. Analytical model



E	N/mm^2	2.8×10^4
σ_c	N/mm^2	-30
ε_c	-	-0.0021
σ_u	N/mm^2	-23
ε_u	-	-0.0043
σ_t	N/mm^2	1.2
ε_t	-	0.00009

(a) Concrete



		D19	H-Steel
E_1	N/mm^2	1.9E+05	2.0E+05
E_2	N/mm^2	1.1E+03	6.3E+02
σ_1	N/mm^2	376	293
ε_1	-	0.0020	0.0015
ε_2	-	0.0150	0.0150

(b) H-shaped steels and D19 re-bar
Figure 8. Material properties

Distribution of strain in the test bridge model by the non-linear analysis is shown in Fig. 9. The tension strain distributes at the upper surface of the superstructure in the corner of the rigid frame and at the outsides of the abutments as experiment (Fig.5). The upper surface of the concrete at the mid-span is crushed by the compression fracture as well as experimental results.

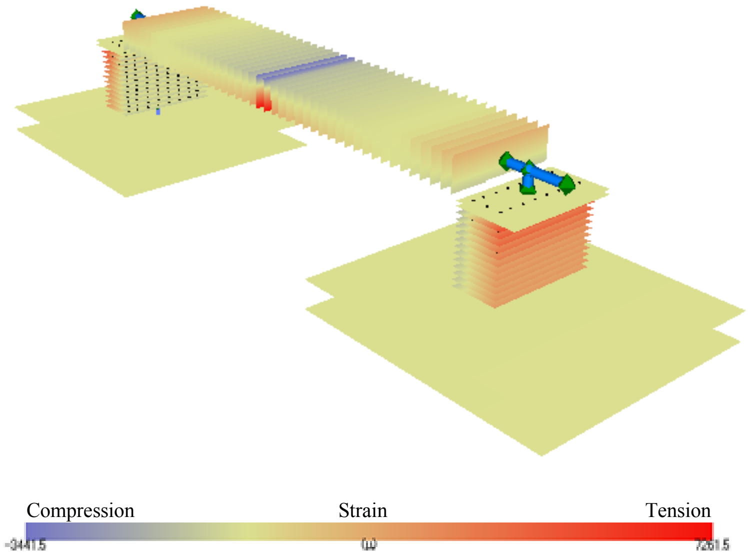


Figure 9. Distribution of strain by the non-linear analysis

7. CONCLUSIONS

This study clarified structural behaviors of a reinforced concrete slab rigid frame bridge with H-shaped steels as follows.

1. This study proposed the connection method of H-shaped steel and re-bar in the corner of the rigid frame structure in order to improve the structural rigid connection for easy construction.

2. Failure and cracks of the reinforced concrete rigid frame bridge with H-shaped steels was confirmed by static loading test.

3. Distribution of strain in the test bridge model by the non-linear analysis was similar to the experimental results.

4. It was confirmed that the re-bars at construction joint were yielded at 900 kN by the construction joint is opened. Moreover the connection of the H-shaped steels and re-bars in abutment had sufficient load-carrying capacity by confirming that the re-bar of the abutment is not yielded.

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