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Development on precast PC slab with a new type of joint for reinforcing bars, combination of lap splice and mechanical anchorage

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ABSTRACT

Bridges constructed in the high-growth period in Japan, the steel-concrete composite reinforced concrete (RC) slab was damaged with larger increase in vehicle traffic, and become a serious problem. The development of the precast prestressed concrete (PC) slab that the rapid construction is possible has been advanced as a replacement of the RC slabs that received damage, and the RC joint that partial replacement is possible has been adopted as a method of connecting in longitudinal direction. Thus, authors have developed a new type of joint that is combination of lap splice and mechanical anchorage fixing the steel pipe on the tip of the reinforcing bar can be applied to the slab that the length of the joint part is short, and thin slab. Results from the experimental investigation of the wheel loading fatigue test, the precast PC slab with this new lap-splice joint has enough fatigue durability.

Keywords. Precast PC slab, Lap-splice joint, Mechanical anchorage, Wheel loading fatigue test, Replacement of RC slab

INTRODUCTION

Bridges constructed in the high-growth period in Japan have already passed 40 years or more, the steel-concrete composite RC slab was caused damage with larger increase in vehicle traffic, and it becomes the serious problem. The considerable increase in damage of the RC slab was reported from about 1965, thus the Specifications for Highway Bridges of Japan were revised in 1972. Main causes of damage were the passage of heavy vehicles over design load, excessive prescribing of allowable stress for reinforcing bar, causing excessive deflection for the lack of the thickness and the lack of distributing reinforcing bar, etc.

The development of the precast PC slab that the rapid construction is possible has been advanced as a replacement of the RC slabs that received damage, and the RC joint that partial replacement is possible has been adopted as a method of connecting in longitudinal direction. Loop splice joint that can reduce the joint part is generally used for RC joint of precast PC slab, but the thickness is limited from the bending shape of the reinforcing bar.

Thus, a new type of lap-splice joint that is combination of lap splice and mechanical anchorage fixing the steel pipe on the tip of the reinforcing bar that was called End-band-bar (Fig.1) can be applied to the slab that the length of the joint part is short, and thin slab has been developed. This new lap-splice joint is provided by a combination of headed bearing on mechanical anchorage and bond between reinforcing bar and concrete. The precast PC slab with the new joint is called SLJ slab that means Short Lapped Joint slab.

Figure 1. End-band-bar

The experimental investigation to establish the length of a lap-splice, statics bending test, statics punching shear test and bending fatigue test were executed. Consequently it was confirmed to have a necessary performance in the lap-splice length of 15 times of the reinforcing bar diameter. In addition, the SLJ slab had confirmed which sufficient bending strength and fatigue durability. This paper presents the experimental investigation of the wheel loading fatigue test on the SLJ slab.

TEST PROGRAM

Specimen. The test specimen is shown in Fig.2, and the situation of the joint is shown in

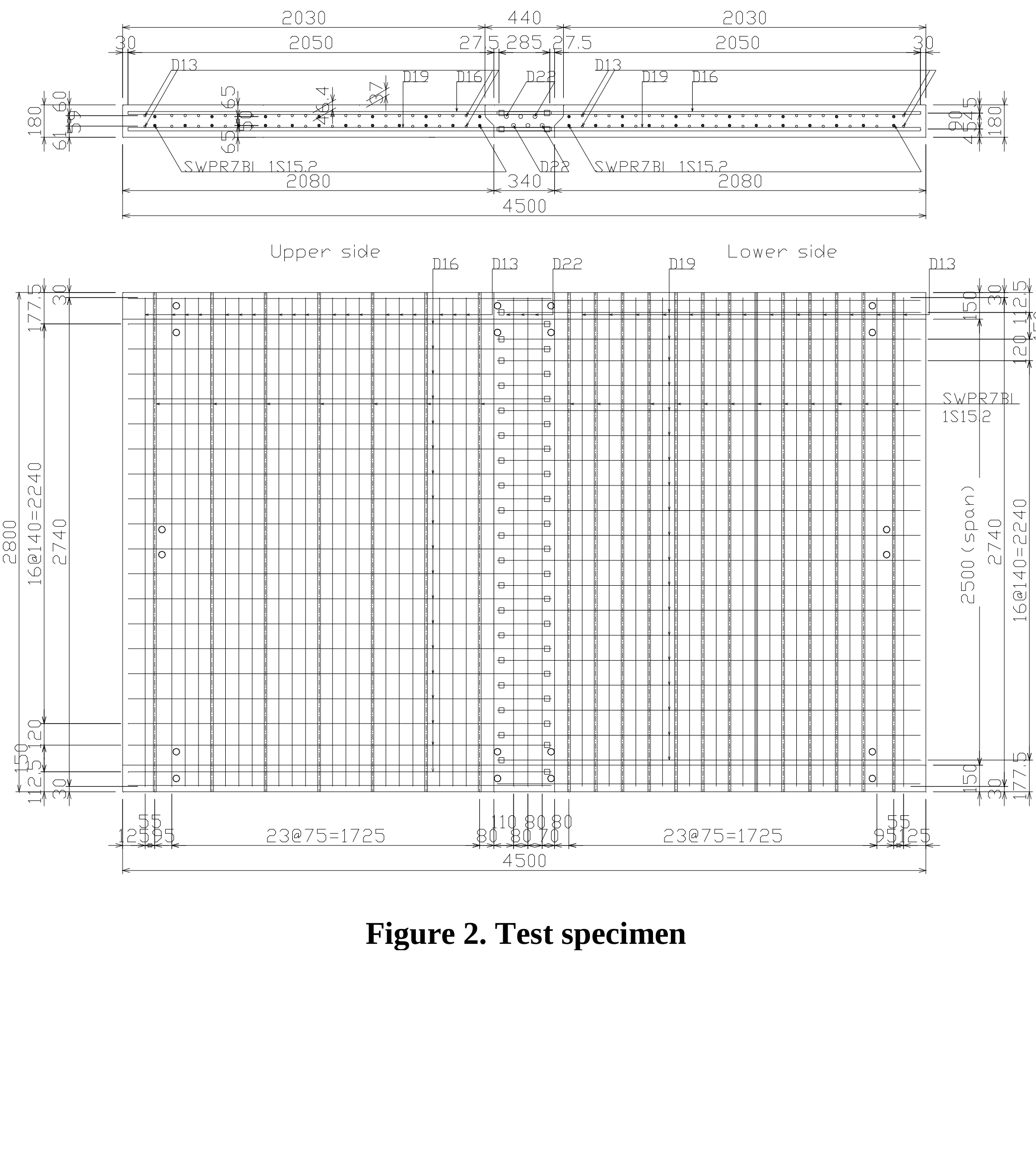

Figure 2. Test specimen

Fig.3. The test specimen was the precast slabs that consist of the RC structure in longitudinal direction and PC structure with one series of pretensioning tendon in transverse direction that were connected by the cast-in-place new lap-splice joint. The test specimen was designed as a continuous slab with span length of 3.0m and displaced a simply supported slab with span length of 2.5m that equivalent design bending moment will act on. The test specimen was the width of 2.8m, the length of 4.5m, and the new lap-splice joint was at midpoint of the test specimen. It was the same size as the examination of the wheel loading fatigue test that had been experimented on so far in incorporated administrative agency Public Works Research Institute of Japan. In addition, the slab thickness that was calculated as continuous slab with span length of 3.0m according to the Specifications for Highway Bridges of Japan published in 2002 was 180mm.

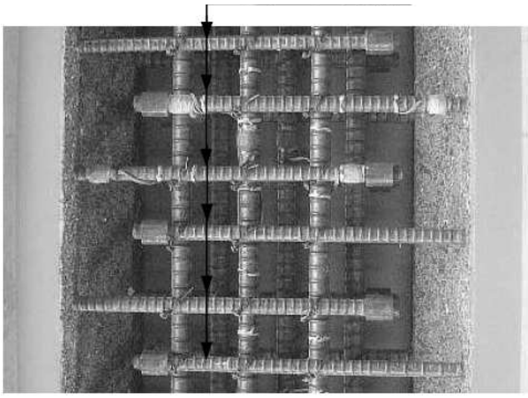

Figure 3. New type of lap-splice joint

Subsequently, the details of the specimen were decided as follows. The precast PC slab in transverse direction was introduced a prestress by pretensioning system with strand of 15.2mm that was located with 300mm spacing at upper side and 150mm at lower. In order to avoid any tensile stress in concrete at service, prestressing force was equal to approximate 7MPa compressive stress of concrete at the superior margins and 11MPa at the inferior. Longitude reinforcing bar consisted of 16mm diameter at upper and 19mm at lower with 150mm spacing and the cast-in-place joint in transverse direction was consisted of 22mm reinforcing bar.

Materials. The Precast PC slab was cast concrete by high early strength Portland cement and the joint was consisted of special super-high early strength cement. Designed compressive strength of concrete was 50MPa with 8cm slump and maximum size of coarse aggregate was 20mm. Designed value of 0.2% proof strength of the pretensioned internal strand of 15.2mm was 1,600N/mm^2 and yielding strength of reinforcing bar was 345 N/mm^2. The test vale of compressive strength and elastic

Table 1. Test results of concrete materials

	Precast slab		Joint	
	Compressive strength (N/mm^2)	Elastic modulus (N/mm^2)	Compressive strength (N/mm^2)	Elastic modulus (N/mm^2)
Test start	61.7	34096	64.5	35611
Test end	63.2	35039	64.8	35863

Table 2. Test results of steel materials

		Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elastic modulus (N/mm^2)
Prestressing strand	φ15.2	1785	1965	194
Reinfocing bar	16	378	562	185
	19	384	563	188
	22	394	594	185

modulus of concrete by cylinder specimens (diameter=100mm, height=200mm), mechanical property of reinforcing steel and presteresssing steel are shown in table 1 and table 2.

Test method. The wheel loading fatigue test was used testing equipment of incorporated administrative agency Public Works Research Institute of Japan (Fig.4).

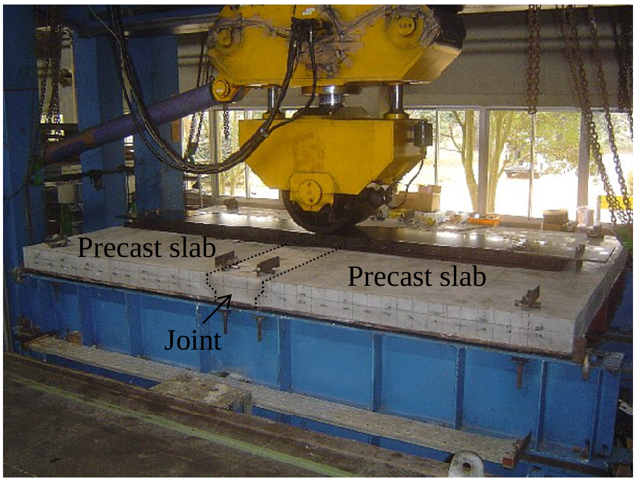

Figure 4. Wheel loading fatigue test

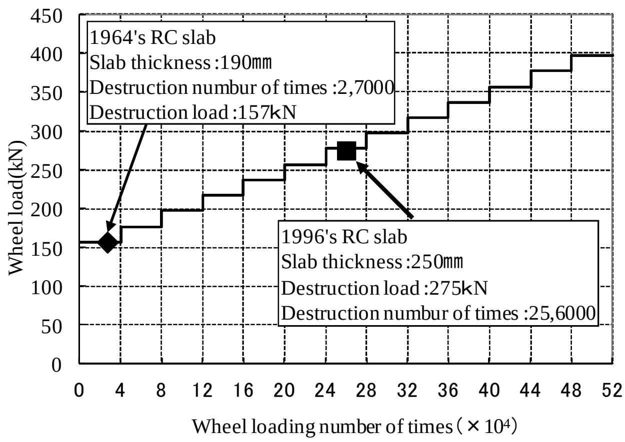

Figure 5. Relationships between the wheel load and the wheel loading number of times

The wheel load moved in the range of ±1.5m at the starting point that was midpoint of the specimen over the steel blocks (width=500mm, length=200mm) that were arranged on the test specimen. And it was the stepped load gradual increase loading which by 19.6kN increases every 40,000 times from 157.0kN of the initial load. For the purpose of acquiring data, the static loading examination was performed in the middle of the wheel loading fatigue test (at the time of load gradual increase). In addition, the static loading was conducted at the wheel loading number of times of 0 and 40,000 times. Thereafter, it was carried out just after load gradual increase as for every 40,000 times, and the loading position was at the joint in the midpoint of the test specimen.

The relationship between the wheel load and the wheel loading number of times is shown in Fig.5. The legends of “1964’s RC slab” and “1996’s RC slab” in the figure were the test results of the RC slabs that were designed according to the Specifications or Highway Bridges of Japan published each in 1964 and 1996 that had been experimented on so far in incorporated administrative agency Public Works Research Institute of Japan. In addition, “1996’s RC slab” was carried out about several types of test specimens and illustrated lowest one case.

Measurement. In the static loading examination, the deflection of the test specimen, the crack width between the precast PC slab and the cast-in-place lap-splice joint, the strain of reinforcing bar and the strain of the concrete on top face were measured. The measurement was conducted at maximum and minimum (Non-loading) load in each static loading.

TEST RESULT

Deflection. The relationship between the deflection at the midpoint of the test specimen and the wheel loading number of times is shown in Fig.6. For the reference, the relationship between the wheel load and wheel loading number of times on the test result of 1996's RC slab is also shown.

The deflection increased with the wheel loading number of times and suddenly increased at the wheel load of 353kN (the loading number of times from 400,000 times to 420,000 times) and the wheel loading fatigue test was terminated because of exceeding the deflection limit of the testing equipment. Afterwards, static loading was performed to loading load of 392kN (loading limit of the testing equipment), but did not lead to destruction.

Because the destruction load of the 1996's RC slab is 275kN (the loading number of times of 260,000 times), it was confirmed which the SLJ slab have the enough fatigue durability in comparison with the 1996's RC slab.

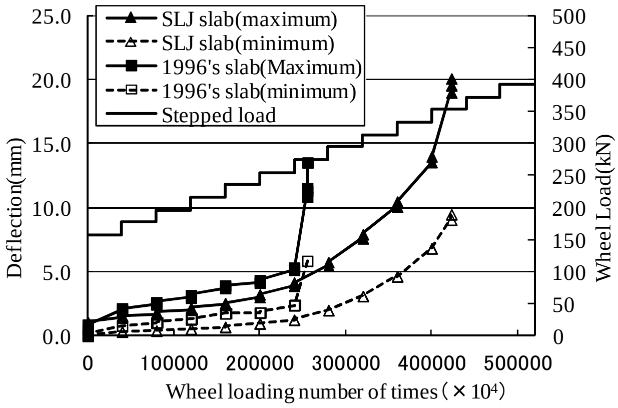

Figure 6. Relationships between the deflection at the midpoint of the specimen and the wheel loading number of times

Crack behavior. Crack pattern at the time of the wheel loading fatigue test end (the loading number of times of 420,000 times) is shown in Fig.7. Cracks were dispersed approximately equally in the precast slab and the cast-in-place lap-splice joint. Thus, the precast slab and the joint were functioned as one structure. In addition, the cracks along the longitude reinforcing bar in the joint were not; of the reinforcing bar it is thought that pulling out did not occur.

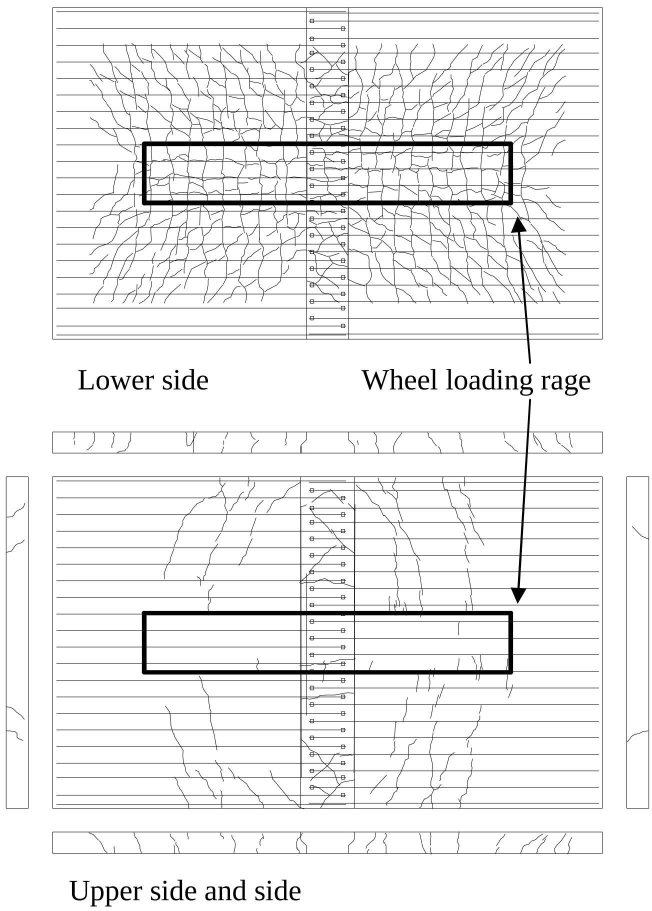

Figure 7. Crack pattern

CONSTRUCTION RESULT

After developing, the SLJ slab was adopted in Kyushu Expressway Mukaizano Bridge. The Mukaizano Bridge that is the four span steel-concrete composite RC Slab located of most heavy traffic section of Kyushu Expressway between Dazaifu IC and Chikushino IC. Because the deterioration of the RC slab was remarkable, the replacement of the RC slab was carried out using the SLJ slab. The construction situation is shown in Fig.8.

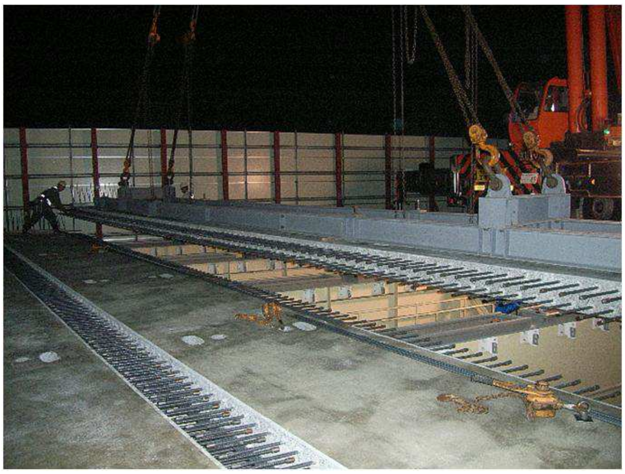

Figure 8. Replacement of Mukaizano Brige

CONCLUSIONS

The SLJ slab (the slab thickness: 180mm) did not lead to destruction to the wheel loading number of times of 420,000 times (wheel load of 353kN) in the wheel loading fatigue test. As shown in the Fig.9, this was a result more than destruction number of times of 27,000 times on 1964's RC slab (the slab thickness: 190mm) and 256,000 times on 1996's RC slab (the slab thickness: 250mm). The SLJ slab was able to confirm which it came and exceeded the fatigue durability of the 1996's RC slab for the punching shear without increasing the slab thickness of the 1964's RC slab.

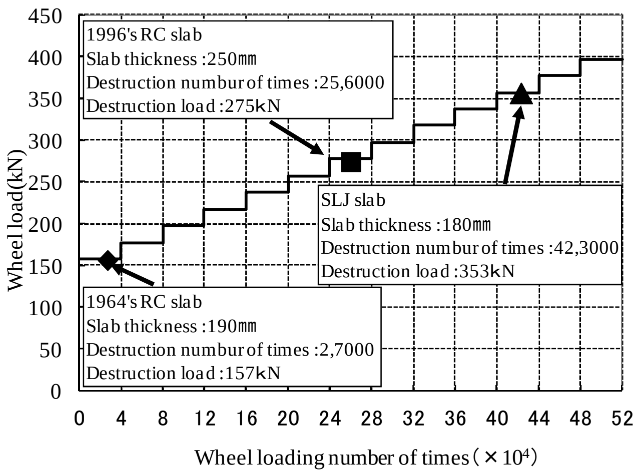

Figure 9. Relationships between the wheel load and loading number of times at the midpoint

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