Development of exchange technology of deteriorated reinforced concrete slabs

Yoshinori Wada[1]

Abstract

Replacement of floor slabs for heavily-trafficked roads such as highways generally requires large-scale construction because it involves closure to traffic at night and lane switching. The author reviewed the following to suggest a more effective construction method: whether replacement of floor slabs by half-sections is practical considering it requires only lane closure, and whether the joint section has enough fatigue endurance because half-section replacement involves a vertical joint.

Introduction

The reinforced concrete (RC) floor slabs of highways are deteriorating because of the effect of anti-freezing agents in addition to fatigue caused by heavy vehicles. The replacement of RC floor slabs generally becomes a large-scale construction project requiring closure to traffic and lane switching at night. Therefore, in this research, the author reviewed whether replacement of floor slabs by half-sections is practical considering it requires only lane closure, and in addition, the author reviewed whether the joint section has enough fatigue endurance because half-section replacement involves a vertical joint. The author reviewed them to suggest a more effective construction method.

Pic. 1 Deck deterioration situation

[1] Researcher, Road Research Department Bridge Division, Nippon Expressway Research Institute Co., Ltd., Tokyo

Pic. 2 Construction status during road closure

Construction methods

Generally, the replacement of floor slabs is done by full-section replacement as shown in Fig. 1 after the road is closed and an alternative route is prepared. However, in the case of heavily trafficked roads, the option of road closure and an alternative route is not practical. Therefore, the option of replacement by half-sections only with lane closure as shown in Fig. 2 was reviewed.

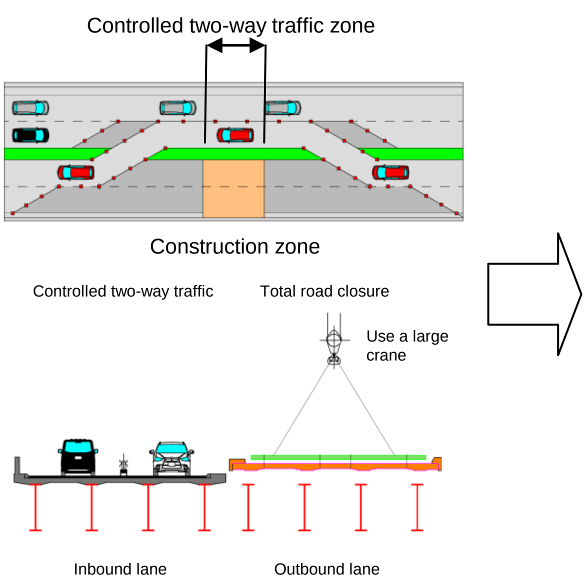


Fig. 1 Example of switching lanes

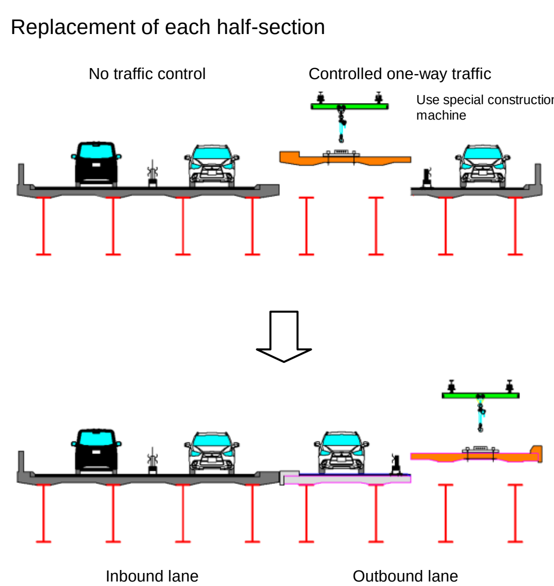


Fig. 2 Example of replacement of each half-section

Replacement of floor slabs typically requires an auxiliary girder and post-cast concrete as shown in Fig. 3. Considering the construction process, the author concluded it is a very difficult method because of limitations on time. In addition, the cost will be high even if the process is simplified.

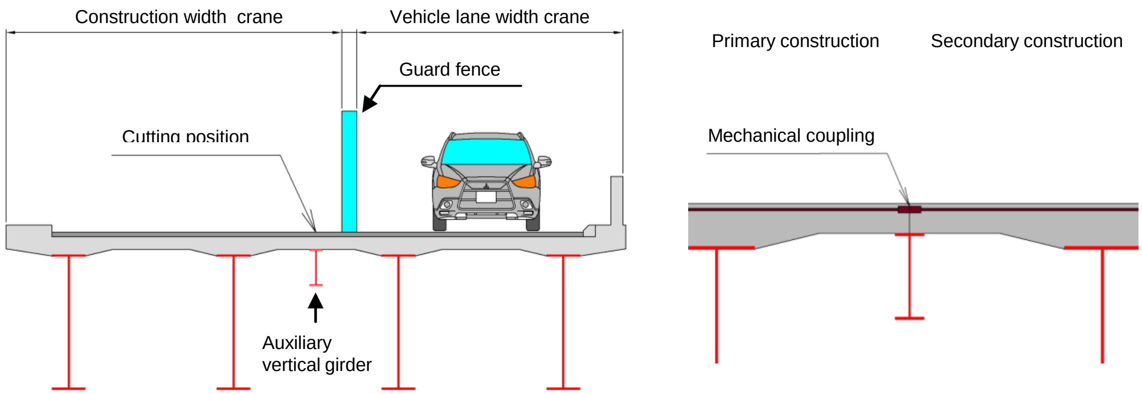


Fig. 3 Common example of construction

Therefore, by adopting the structure shown in Fig. 4, a firm joint even under vibrations from passing vehicles without post-cast concrete becomes possible. And because it uses a butt joint, post-joint concrete casting can be omitted and the road can be opened to traffic sooner.

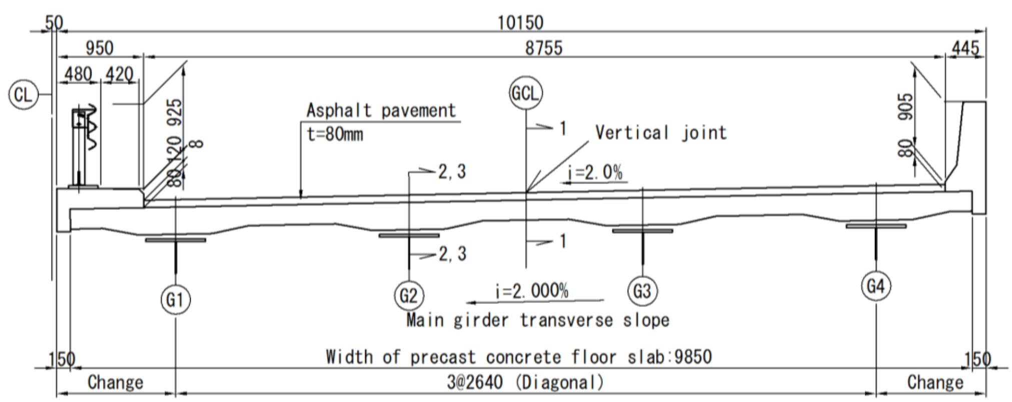


Fig. 4 Drawing of structural replacement, half cross-section

Vertical joint structure in the case of replacement by half-sectional method

For the precast floor slab joint method, a vertical joint with a concrete joint key and a steel joint key was adopted as shown in Fig. 5. In addition, epoxy resin adhesive was used for the joint surface of the vertical joint and the introduction of pre-stress realizes a one-piece structure.

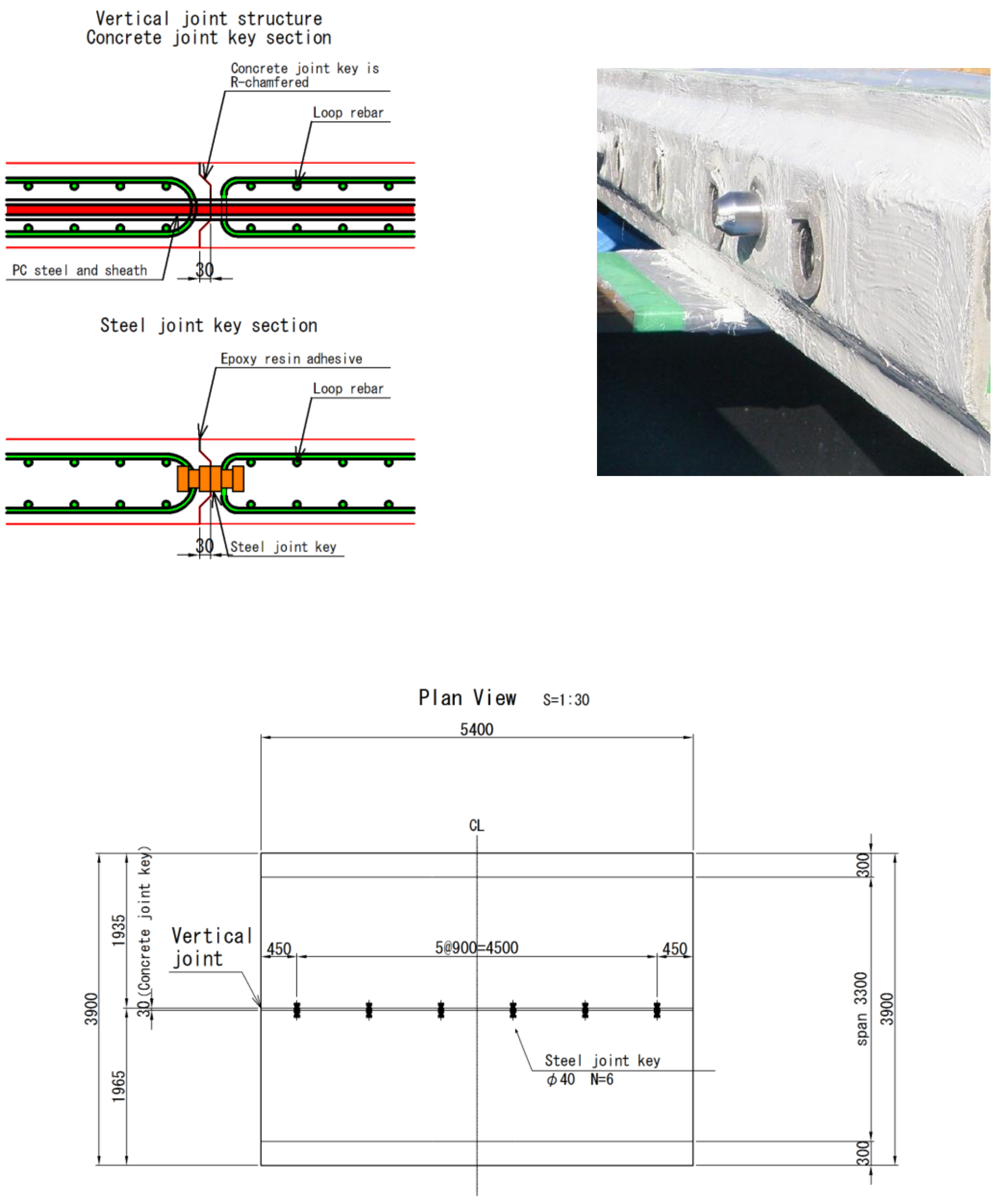


Fig. 5 Vertical joint structure diagram

Verification of fatigue durability by testing the vertical joint structure model

A model of a floor slab as shown in Figures 6 and 7 was built, and the wheel load loading tester owned by NEXCO Research Institute was used to verify the fatigue endurance of the model.

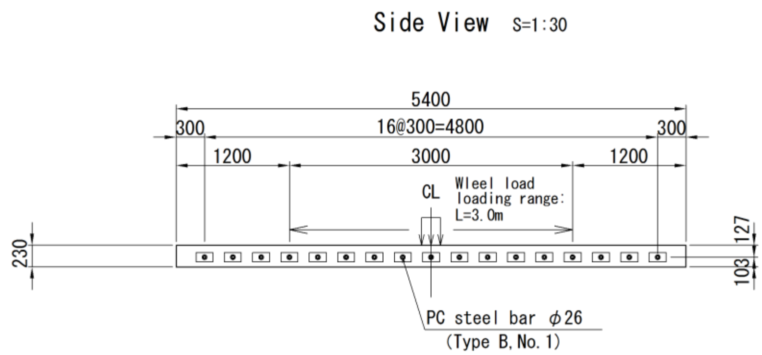


Fig. 6 Model of vertical joint structure: side view

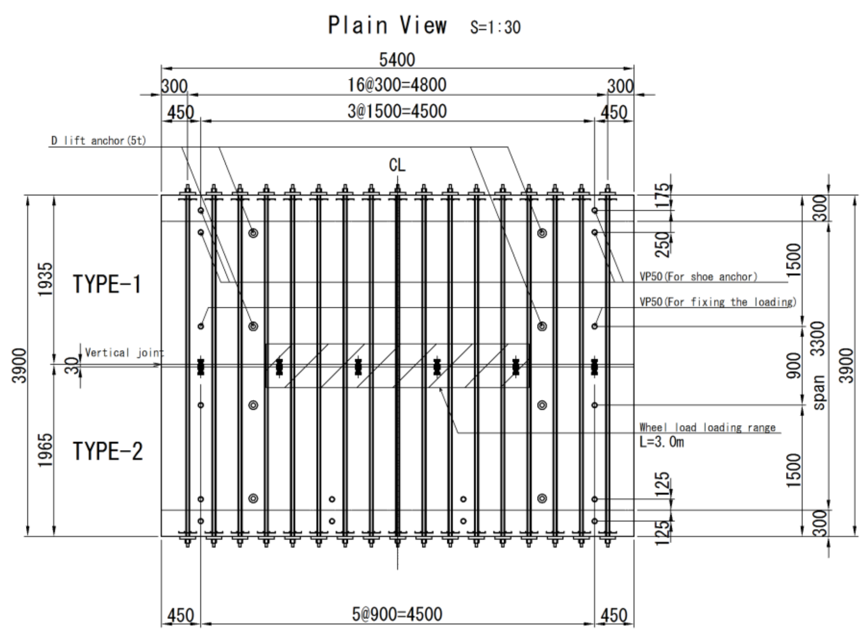
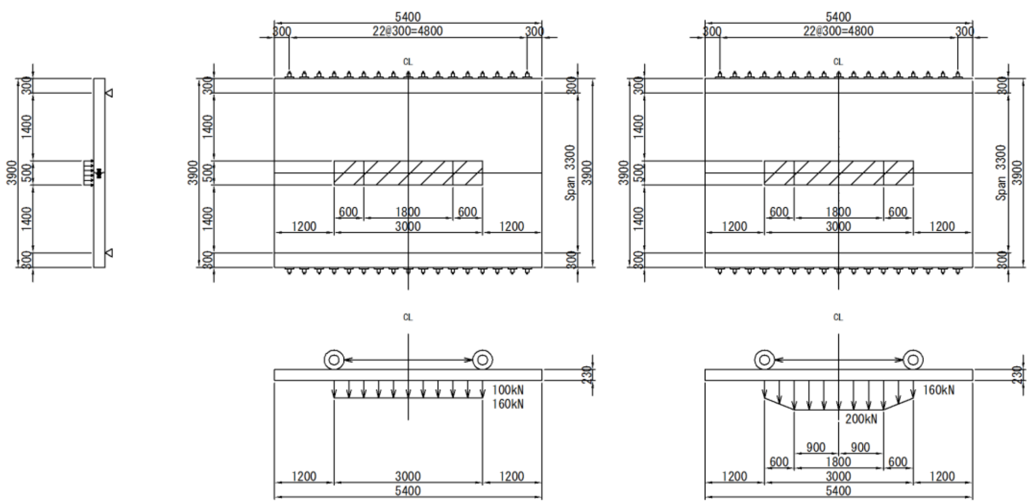


Fig. 7 Model of vertical joint structure: plain view

It was determined to use the wheel load loading tester in the conventional way.

Three wheel loading steps, basic wheel loading (100kN), excessive loading (160kN) and double wheal loading (200kN) were set, and running stress tests were repeated for 820,000 cycles, which is equivalent to 100 years of service. Then, the tensioning force was reduced by half and the running stress test was repeated for 80,000 cycles.

Fig. 8 shows the loading steps and the patterns for the range of 3m. For the loads of 100kN and 160kN, constant loading was used. And for 200kN, the trapezoid loading pattern was used; 160kN was applied from the edge to 60cm and it was changed to 200kN and kept in the inner range of 1.8mm. The wheel load loading position was the middle point of the span.



At 100kN and 160kN

At 20kN

Step	Load		Number of loading cycles		Remark
			Between steps	Accumulated total	
	kN		10K cycles	10K cycles	
0N		Before test	0	0	
1N	100	Basic wheel loading	2	2	
2N	160	Excessive loading	60	62	
3N	200	Double wheel	20	82	Equivalent to 100-year service
4N	200	Same as the above + water filling	8	90	
※5N	200	Same as the above + water filling + 1/2 tensioning force	8	98	

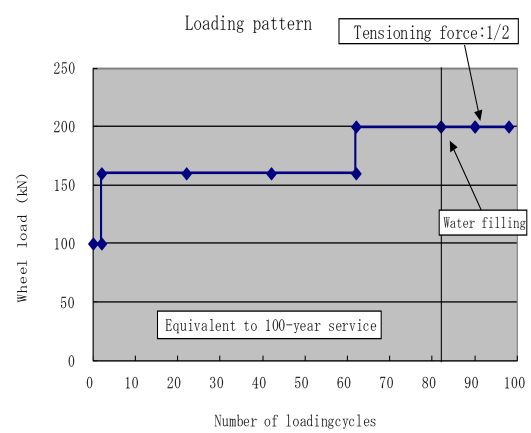


Fig. 8 Loading step and wheel load loading position

Pic. 3 Move loading test setting

Results of fatigue durability test

(1) At the steps 1N and 2N, we observed no cracks. And the measured deflection of the floor slab was equal to the calculated deflection with almost no residual deflection.

(2) At the step 3N-0, two cracks extending in the longitudinal direction (RC material direction) were observed on the floor slab; then, as the number of cycles increased, the number of cracks increased in the same direction. In addition, cracks in the axial direction (PC direction) started at the step of 3N-100K.
The cracks in the axial direction were not so severe because they closed when the load was removed. The cracks were very minor, so they were hardly visible during the period without the load. The author assumed this was because pre-stress was working effectively. The width of a crack was 0.04mm at the step of 3N-200K (equivalent to 100 years of service) and the residual deflection was 0.1mm.

(3) At the step of 4N, water was filled over the floor slabs and the loading test continued. Because there were no cracks on the top surface, there was no water leakage to the bottom of the floor slab. It was assumed that this was because there was no penetrating crack. Cracks were observed in the center of the span where bending moment becomes the largest, as well as near the vertical joint. However, cracks didn't concentrate at the vertical joint. The cracks in the axial direction were so minor and closed when the load was removed and could not be observed when there was no load. We assumed pre-stress was working effectively. The width of the crack was 0.04mm at the step of 4N-80K (equivalent to 100 years of service).

(4) We performed static wheel loading tests between the joint keys and on the joint key. As a result, the measurement results were almost the same. The residual deflection was 0.2mm.

(5) We observed no hexagonal-shaped cracks peculiar to deterioration on the floor slab surface.

Based on the test results above, the author concluded that the floor slab of the half section with a vertical joint in the center of the span has sufficient fatigue endurance against wheel load equivalent to 100 years of service.

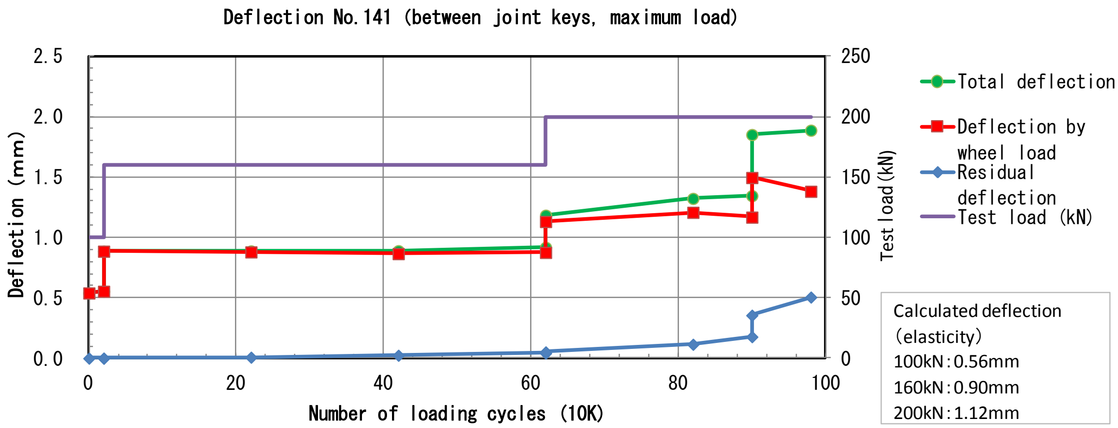


Fig. 9 Amount of deflection

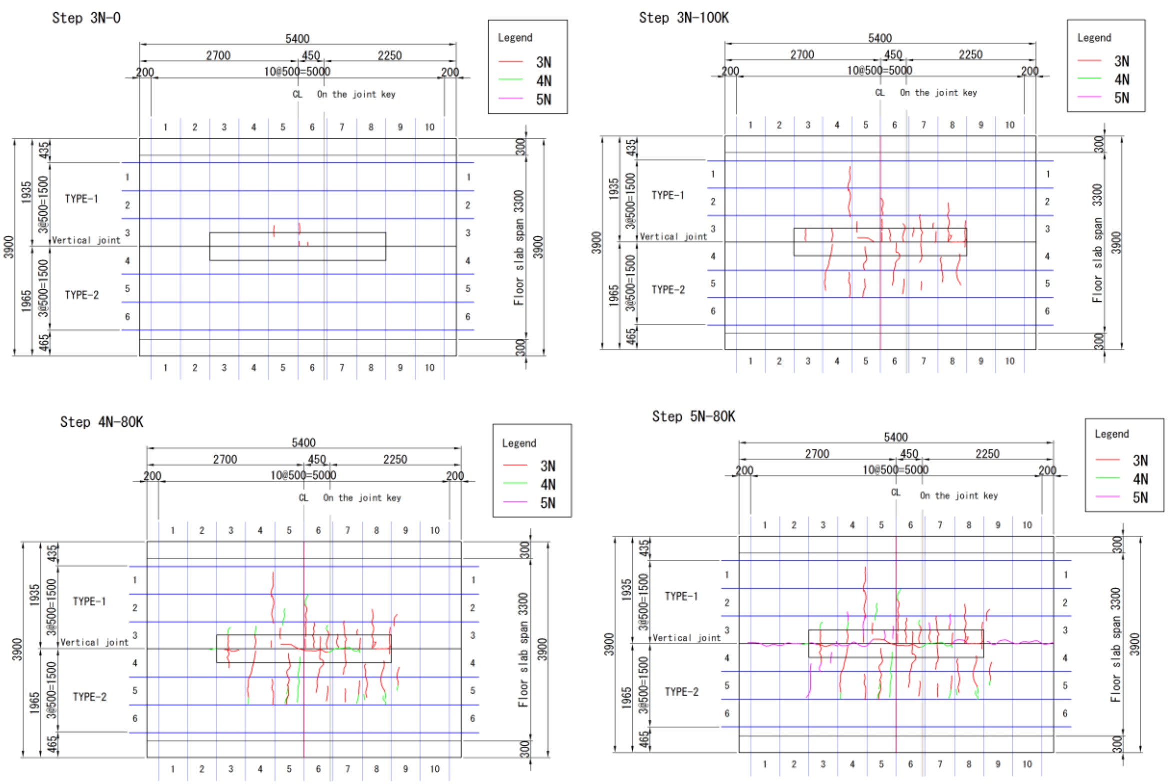


Fig. 10 Cracking of the deck underside

Future challenges

In this research the author reviewed replacement work of floor slabs by replacing a half-section each time. As a result, it was confirmed that the half-section replacement method with a vertical joint is practical. In future research, it will be necessary to review use of non-metal joint keys, though the vertical joint using steel joint keys and concrete joint keys was proved to have enough endurance, because there is a concern about deterioration of floor slabs due to salt corrosion in some areas where anti-freezing agents are used.

The following also require consideration: the temporary guard fences should have the structure to make installations to the floors slab easier without affecting the floor slabs because they are always installed for lane control. The adoptable minimum thickness of the floor slabs should be defined because the thickness actually varies for each span between the floor slabs. How to install the floor slabs of minimum thickness should also be reviewed.