Design and Construction for Replacement of Deck Slab using High Strength Lightweight Precast PC Slab
— ICHIKAWA OHASHI Bridge on BANTAN Access Road —

高強度軽量プレキャスト PC 床版を用いた床版取替工事の設計・施工
— 播但連絡道路 市川大橋 —


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Synopsis
The existing reinforced concrete (RC) slab of the Ichikawa Bridge was replaced due to remarkable deterioration caused by chloride attack by deicing salts in addition to damage with aging. A high strength lightweight precast prestressed concrete (PC) slab with a two-way PC structure, "HSL Slab," was selected as the replacement slab to reduce the load on the steel main girder and piers by slab weight reduction and minimize cracking under the severe environment due to deicing salt. This report describes the preliminary study of design and outline of the construction.

Structural Data
Structure: single-span steel composite plate girder bridge
Bridge Length: 40.0m
Span: 39.2m
Width: 19.6m
Owner: Hyogo Prefecture
Contractor: IHI Construction Service Co., Ltd.
Location: Hyogo Prefecture, Japan

1. Introduction
The bridge is a single-span steel composite plate girder bridge on the Bantan Access Road. A general drawing is shown in **Fig.1**. The existing RC slab was replaced due to remarkable deterioration caused by chloride attack by deicing salt in addition to normal damage associated with aging. A high strength lightweight precast PC slab with a two-way PC structure, "HSL Slab" (hereinafter,

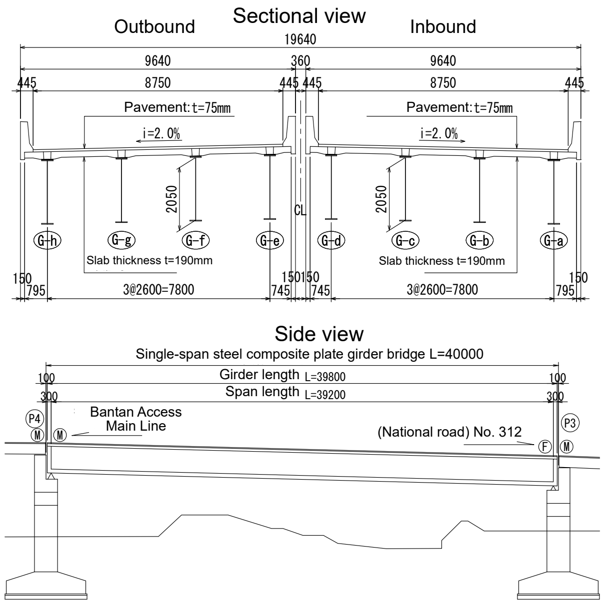

Fig.1 General view of bridge

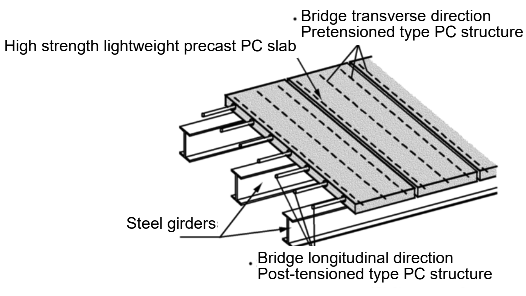

Fig.2 Basic structure of lightweight PC slab

lightweight PC slab), was selected as the replacement slab to reduce the load on the steel main girder and piers by slab weight reduction and minimize cracking under the severe environment due to deicing salt.

This report describes the preliminary study of design and construction and outline of the construction.

2. Features of Lightweight PC Slab

The basic structure of the lightweight PC slab is shown in **Fig.2**. Weight is reduced by about 20% in comparison with a conventional plain concrete precast PC slab by using high strength lightweight concrete with unit weight of 18.5kN/m^3 or less and design strength of 50N/m^2 or more with artificial lightweight coarse aggregate (expansible shale). This weight reduction effectively reduces the stress load increment on the existing steel main girder and substructure.

Sufficient freezing/thawing resistance is secured in the concrete by using artificial lightweight aggregate with a moisture content of 2.0% or less before mixing. High durability is realized by using a pretensioned PC structure in the bridge transverse direction and post-tensioned PC structure in the longitudinal direction.

3. Design Study

(1) Slab Structure and Form

The slab geometry is shown in **Fig.3**. Prioritizing prevention of cracks and improved durability, an axially post-tensioned PC structure (SWPR19L 1S19.3, 400mm pitch) was adopted, and prestress was introduced in two directions. The tensile stress limit under dead load and design load was set to full prestress in both the longitudinal and transverse directions.

A PC structure was adopted in the axial direction to reduce the thickness of the new precast slab to the same thickness (190mm) as the existing slab. Use of the lightweight PC slab reduced the slab weight of the bridge from 193t to 165t, achieving a weight reduction of about 30t compared with using the plain concrete precast slab, and reducing the load on the main girder and piers.

Longitudinal prestress was introduced after laying the lightweight PC slab and filling the parts between precast sections with shrinkage-compensating mortar. **Fig.4** shows the geometry of the filling part. As the filling length in an axial PC structure was about 30mm, reinforcing steel/form assembly work could be omitted. In comparison with an RC structure, the work time could be shortened, even considering PC steel insertion/tensioning work, and a unitary joint structure

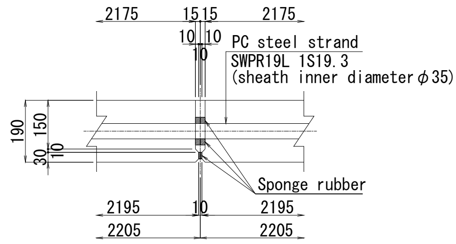

Fig.4 Geometry of filling part

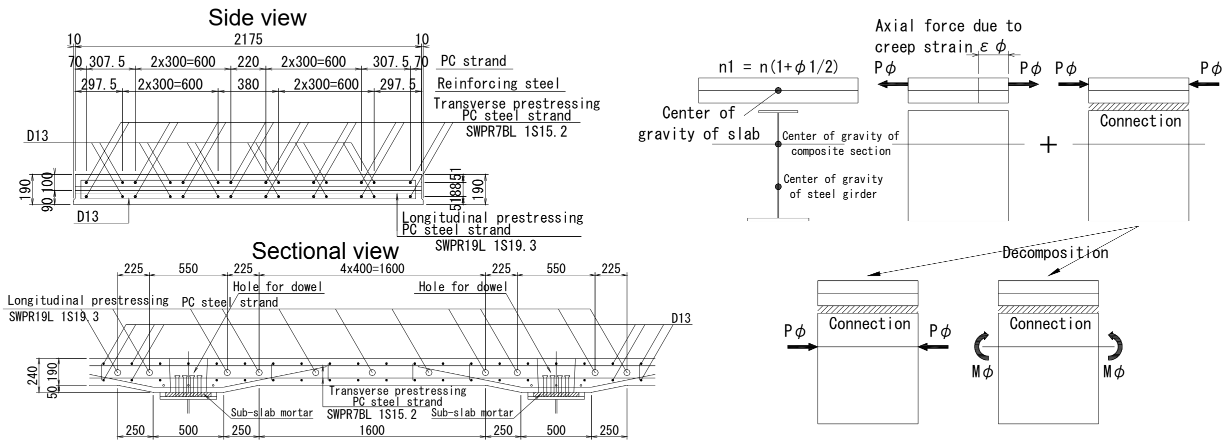

Fig.3 Geometry of slab

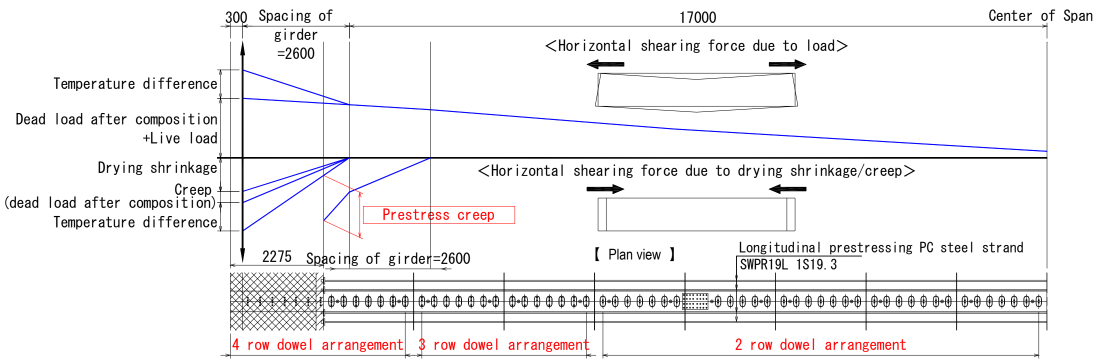

Fig.5 Image of creep strain and distribution of horizontal shearing force

could be secured by prestress, eliminating the potential weak points at joints.

Stud dowels were used to connect the slab and main girder. After introduction of axial prestress, the slab and girder were joined by performing stud dowel welding, placing the sub-slab mortar and pouring secondary concrete for the dowel holes in that order.

(2) Study of Dowel Arrangement

Longitudinal prestress causes horizontal shearing force in the dowels due to creep strain of the precast PC slab after dowel connection. The number of dowels was decided considering that horizontal shearing force and the horizontal shearing forces due to main loads (dead load and live load after composition), temperature difference and drying shrinkage. **Fig.5** shows the distribution of horizontal shearing forces. Assuming that the horizontal shearing force due to prestress creep is distributed from the fixed end of the axial PC steel, the distributed length was set to the main girder spacing following Specifications for Highway Bridges II 12.5.2[1]. Because the horizontal shearing forces due to loads and due to drying shrinkage/creep occur in opposing directions, the number of dowels was not increased for prestress creep.

4. Construction Study

(1) Verification of Main Girder Stress during Erection

Constructions of precast PC slab were performed by advancing a rafter crane and transport trailer on the bridge. The target bridge was a composite structure. However, during replacement of an existing RC slab, the slab is cut by a concrete cutter, and the load bearing capacity to support this heavy equipment must be secured by the steel main girder only. Therefore, stress verification was performed with a grid-frame model assuming load sharing by only the steel girder as a non-composite structure. It shows that the flexural compressive stress of the upper flange exceeded the design value.

Countermeasures such as installation of vents to reduce the bending moment and reinforcement with external cables to increase the main girder bearing capacity were considered, however installation of additional intermediate sway bracing was adopted from the viewpoints of workability and economy. The installation work is shown in **Photo 1**.

The allowable flexural compressive stress of the compressive flange of a steel main girder is reduced by buckling. Increasing the number of sway braces reduced the distance between the fixed points of the compressive flange against buckling by half, and thereby increasing the allowable flexural compressive stress[1]. Because the additional sway braces also increase the load bearing capacity in normal service, the braces were retained after construction.

5. Outline of Construction

(1) Overall Process

Fig.6 shows the steps in the construction process. First, the pavement was removed and the existing slab was cut at 4.5m intervals in the longitudinal direction. After drilling holes necessary for hoisting and installation of wire saws, the curb sections were lifted, cut and completely removed. Square steel pipes were arranged on the intermediate sway bracing to prevent the slab from falling when the intermediate slab sections were cut, and the slab was cut with a cutter. After cutting, anchors were placed in the drilled holes, and the slab sections were hoisted and removed. Finally, the remaining concrete on the girder flange was cut with a wire saw at each stud dowel.

After the curbs were removed, construction entered the cycle from removal of the slab to installation of the lightweight PC slab. One cycle took 3 days, and two slabs were replaced in each cycle.

Photo 1. Installation of additional intermediate sway

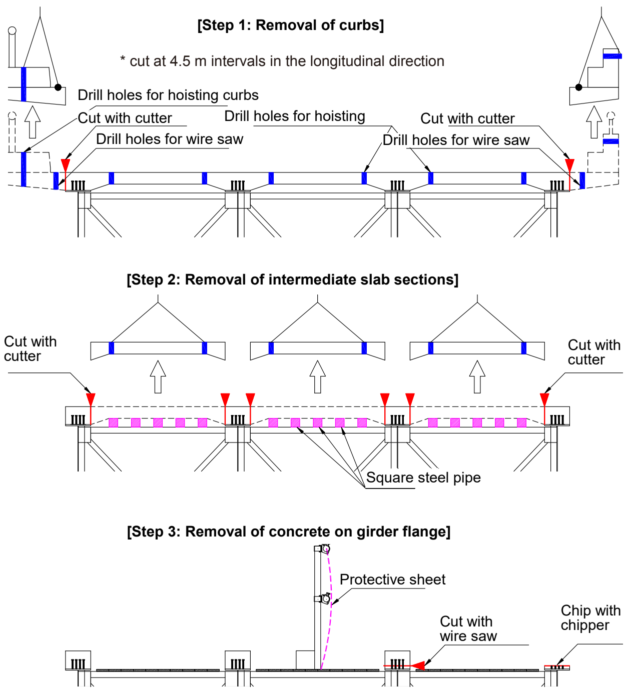

Fig.6 Steps in removal of existing curbs and slab

(2) Removal of Existing Slab

Because removal of a composite structure slab by the jack-up method, etc. is difficult due to the large number of stud dowels, the intermediate slab sections were removed first. **Photo 2** shows the removal work. After slab removal, the remaining concrete on the girder flange is normally chipped with a breaker. However, the following problems arose in this project.

1) Chipping was extremely difficult due to concrete and reinforcing steel around the dowel heads.

2) Care was necessary to avoid damaging the flange with the breaker tip, causing a concern of schedule delays and labor use exceeding the plan. Therefore, we applied the method that the concrete on the flange was cut horizontally with a wire saw, as shown in **Photo 3**. Cutting on one girder (4.5m axial length)was completed in about 2 hours. As a few cm of concrete remained on the flange were chipped using a chipper with a flat chisel. The dowels were then cut with a face cutter, and the flange surface was prepared with a baby sander. This had the following advantages.

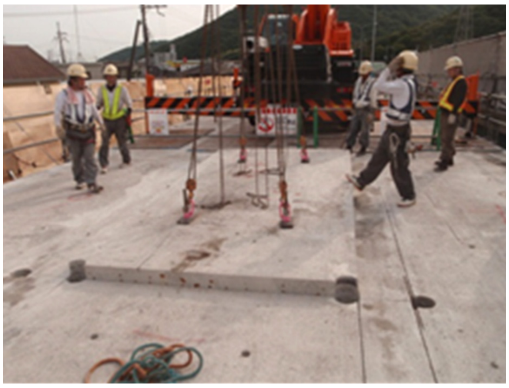

Photo 2. Removal of intermediate deck sections

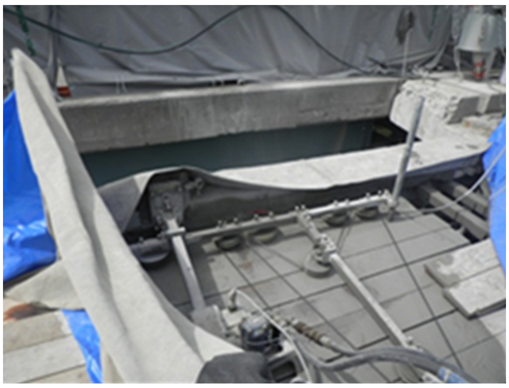

Photo 3. Cutting with wire saw (upper surface of flange)

1) Since parts cut with the wire saw can be removed as lumps of concrete, there is no fine chipping debris and cleanup time is reduced.

2) The risk of damaging the girder flange is greatly reduced by using a flat chisel.

3) Chipping efficiency is improved because the dowel heads are cut.

(3) Installation of Lightweight PC Slab

The slab installation work is shown in **Photo 4**. Installation of two slabs required about 1 hour. Slab transportation was arranged so that construction could begin immediately at the start of work, and the process from slab installation to movement of the crane and steel plates to the next section was completed before noon. In the afternoon, cutting/removal of the intermediate slabs was completed, and preparations were made to cut the concrete on the girder flange the following day.

Photo 4. Installation of lightweight PC slab

6. Conclusion

The deteriorated slab at the Ichikawa Bridge was replaced with minimal effect on the existing substructure and girder by using HSL Slab. This slab replacement method is a fundamental solution for severely damaged slabs. The authors hope to contribute to long bridge life by utilizing the design/construction know-how concerning slab replacement methods gained in this project.

References

[1] Japan Road Association: *Specification for Highway Bridges, part II : Steel Bridge Design, 2012*

概　要

市川大橋の既設 RC 床版は，経年劣化による損傷に加え，凍結防止剤の影響による塩害の劣化進行が著しく，取替工事を実施することとなった。取替え用床版は，軽量化により鋼主桁および橋脚の負担を軽減すること，凍結防止剤を散布する厳しい環境条件を考慮しひび割れの発生を極力抑制することを目的に，二方向を PC 構造とする高強度軽量プレキャスト PC 床版「HSL スラブ」を採用した。本稿では，工事に先立ち行った設計・施工上の検討内容および施工概要について報告を行う。