Construction of Box Culvert Using Bridge Technology for Embankment Renewal — Renewal Project for the Samezu Section of Tokyo Metropolitan Expressway Route No. 1 Haneda Line (Phase 1) —

盛土構造の更新に橋梁技術を適用した函体工事 — 首都高速１号羽田線　鮫洲埋立部（Ⅰ期線）—

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Synopsis

The Tokyo Metropolitan Expressway Route No. 1 Haneda Line is an important connection to Haneda Airport and entered service 59 years ago in 1963. Approximately 1.7 km long route comprises 0.4 km built on reclaimed land (Samezu Reclamation Area) and a 1.3 km pier section above water (Higashi–Shinagawa Pier Section). Renewal works of the expressway in the Samezu Reclamation Area include soil improvement of the existing embankment structure to stabilize its foundation and construction of a box culvert structure on top of the embankment. Aggressive use of precast members with accumulated know-how and technology from bridge construction to the box culvert structure enabled on-site processes to be rationalized by reducing the amount of rebar/formwork and other on-site construction works, resulting in more efficient, labor-saving construction.

Structural Data[5]

Structure: U-shaped PC box structure with ribs (PC composite deck slab)
Box culvert Length: 434.040 m
Width: 18.200 m (effective width 2@8.0 m)
Owner: Metropolitan Expressway Co., Ltd.
Designer: Obayashi, Shimizu, Sumitomo Mitsui, Toa, Asunaro Aoki, Kawada, TTK, MMB, Miyaji JV (Type B)
Contractor: Obayashi, Shimizu, Sumitomo Mitsui, Toa, Asunaro Aoki, Kawada, TTK, MMB, Miyaji JV (Type B)
Construction Period: Aug. 6, 2015 – July 31, 2025 (approx. 10 years)
Location: Tokyo, Japan

Fig. 1 Overview

1. Introduction

The Tokyo Metropolitan Expressway Route No. 1 Haneda Line is an important connection to Tokyo

International Airport (commonly called Haneda Airport) and entered service 59 years ago in 1963. The section under renewal from the Higashi–Shinagawa Pier Section to the Samezu Reclamation Area was built above a canal and is showing conspicuous deterioration due to decades of exposure to an extremely corrosive environment and high traffic volume. Since its construction, this section had been regularly inspected and maintained, but to ensure long-term safety, its renewal commenced in 2015 as the Metropolitan Expressway's first large-scale renewal project. Approximately 1.7 km in length, the section comprises about 0.4 km built on reclaimed land and a 1.3 km pier section above water. This report focuses on the renewal of the section on reclaimed land (Samezu Reclamation Area). The expressway section is constructed on an embankment supported by retaining walls of steel sheet piles joined by tie rods spaced at 1.6 m intervals. Because of corrosion and fracture of these tie rods, embankment earth pressure has caused the steel sheet piles to bulge out on the canal side, resulting in caving and cracks in the road surface.

The following three options were considered for renewing the expressway in the Samezu Reclamation Area: an elevated structure, a structure with an improved soil embankment, and the latter combined with a box culvert structure on top of the embankment. Replacing the embankment structure of the existing road with an elevated structure would still require to have the same vertical road alignments with the existing road. Consequently, the road surface elevation would be too close to sea level to secure sufficient spaces for maintenance activities. Moreover, there is a dense distribution of tie rods in the existing road embankment, and it would have been extremely difficult to carry out foundation work for the elevated structure without affecting these tie rods. Replacing the existing embankment structure with an improved soil embankment was also considered, but this option was declined because it would have been difficult to detect in advance the type of deterioration that would have occurred in the existing structure. Accordingly, the option including soil improvement of the existing embankment structure to stabilize its foundation and construction of a box culvert structure on top of the embankment to provide space for maintenance was selected.

2. Overview of the Construction Work

This project involved replacing the existing route while it was in service, thereby imposing severe construction constraints mainly derived from very confined working space between inbound and outbound lanes. The presence of the Tokyo Monorail running parallel to the Haneda Line on its sea-facing side for the whole length of the renewal section drew more attention to keep employees and civilians safe and projects on-track. There was also a requirement to shorten the construction time considerably to enable the renewed road (Phase 1) to be open to traffic by the start of the 2020 Tokyo Olympic Games. **Fig. 2** shows a conceptual illustration of the renovated section on completion.

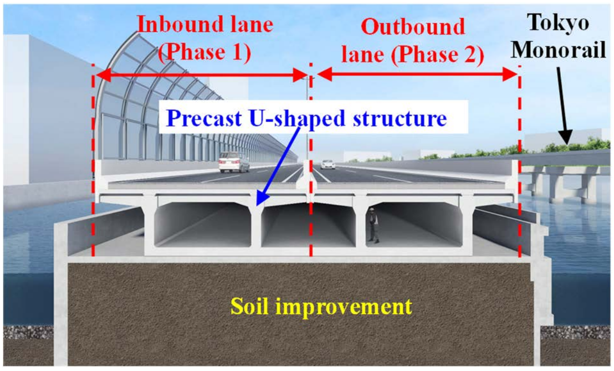

Fig. 2 Conceptual illustration of the renewed section on completion

3. Overview of the Box Culvert Structure

The box culvert structure is a box structure consisting of a U-shaped segment with ribs and a prestressed concrete (PC) composite deck slab (PC panels + cast-in-place slab) (**Fig. 3**). This application of bridge superstructure technology to a box culvert is unprecedented in Japan. In order to proceed with the construction of the box structure while keeping the existing route in service, the box structure was divided into independent inbound/outbound lane segments that would later be joined in place by their top and bottom slabs to create a complete full-size inbound and outbound structure (three-box structure). The segment was designed as a U-shaped segment with ribs and no deck slab to reduce its self-weight. PC panels were used as permanent formwork for cast-in-place concrete deck slab. Taking transportation and installation into account, segments with a length of 1.5 m and weighing approximately 22 t were designed and manufactured using the short-line match casting method.

For the Samui Reclamation Area, which is approximately 450 m long, 27 box culvert blocks were used, with each block comprising 11 segments (1 block = 16.5 m).

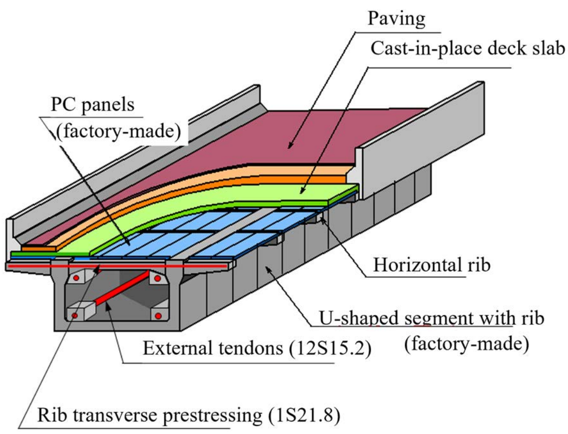

Fig. 3 Overview of the box structure

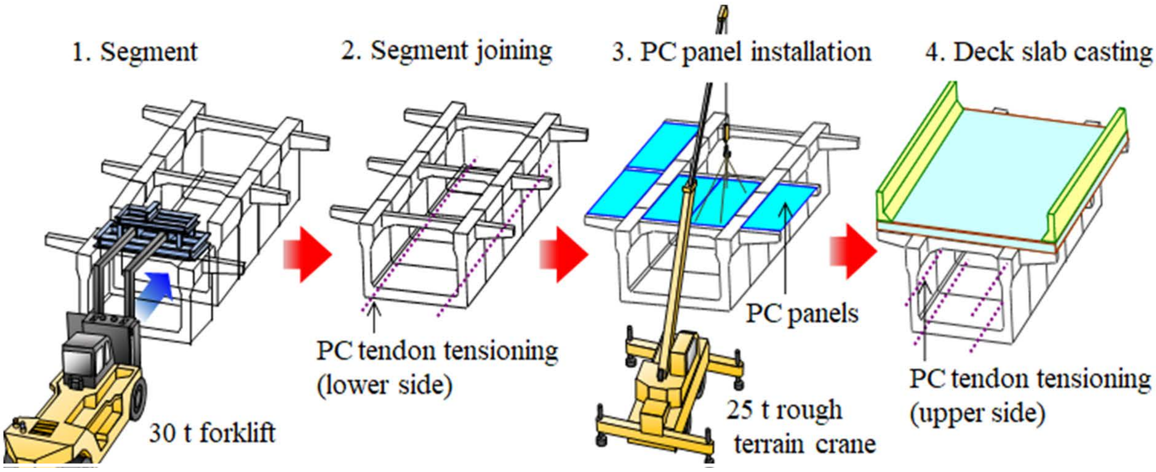

Fig. 4 Box culvert construction processes

Fig. 5 Segment installation

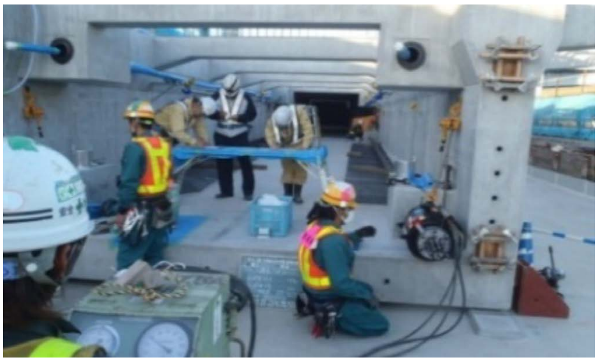

Fig. 6 External PC tendons tensioning (lower side)

Fig. 7 Backfilling mortar into the gap under the bottom slab and levelling concrete

Fig. 8 Laying of PC panels

Fig. 9 Cast-in-place concrete deck slab

Four external PC tendons (12S15.2) were used to prestress the whole block in the longitudinal direction, thereby enhancing integration as a single structure and improving longitudinal seismic performance. Structural joints were installed between the blocks to allow the section to move in the event of an earthquake[3].

4. Overview of Box Culvert Construction

Figs. 4-9 shows the box culvert construction processes and photos. Once the 11 segments had been aligned in place, the longitudinal external PC tendons (lower side) were tensioned to unify the segments into a single unit.

Segments were supported by multiple pedestals with laminated plates of Teflon and steel of 1 mm thickness on top of them to minimize friction with the contact surface. After tensioning the external PC tendons, the gap between the bottom slab and leveling concrete was backfilled with mortar in the same way as for a regular box culvert to integrate the boxes with the foundation. Deck slab construction involved laying PC panels followed by rebar assembly/formwork and concrete casting for the cast-in-place deck slab. The external PC tendons (upper side) were then tensioned to complete the construction of the single box culvert block[4]. **Figs. 10** and **11** show overviews of the completed box culvert.

5. Conclusions

Aggressive use of precast members to streamline construction enabled on-site processes to be shortened by reducing the amount of rebar/formwork and other on-site construction works, resulting in more efficient, labor-saving construction. Construction of a block composed of 11 box culvert segments and tensioning of the lower tendons took 4 days, with backfilling and top slab construction took another 2 days. This represents a time saving of 3 months for a lane of the whole section compared with the conventional cast-in-place methods that would have required a construction period of 340 days.

The box structure comprising U-shaped segments with ribs was originally inspired by the Furukawa Viaduct construction on the new Meishin Expressway[1] [2]. This article will hopefully help to promote the use of precast members in civil engineering structures other than bridges.

References

[1] Ikeda, H., Kasuga, A., Mizuguchi, K., Muroda, K.: *Design and Construction of Furukawa Viaduct (volume one)*, Bridge and foundation engineering, Vol. 35 No. 2, Kensetutosyo, Tokyo, pp. 2-9, Feb. 2001 (in Japanese).

[2] Ikeda, H., Kasuga, A., Mizuguchi, K., Muroda, K.: *Design and Construction of Furukawa Viaduct (volume two)*, Bridge and foundation engineering, Vol. 35 No. 3, Kensetutosyo, Tokyo, pp. 11-16, Mar. 2001 (in Japanese).

[3] Taniguchi, H., Kojima, N., Onishi, T., Tomiyama, S., Kudo, T.: *Tokyo Metropolitan Expressway Route No. 1 Haneda Line renovation: overview of Samezu Reclamation Area box construction*, Japan Society of Civil Engineers 74th Annual Meeting pp. VI-335, Sep. 2019 (in Japanese).

[4] Taniguchi, H., Kojima, N., Onishi T., Tomiyama, S.: *Tokyo Metropolitan Expressway Route No. 1 Haneda Line Renewal Report on Samezu Reclamation Area box design and construction*, Japan Prestressed Concrete Institute 28th Symposium on Developments in Prestressed Concrete pp. 637-640, Nov. 2019 (in Japanese).

[5] Taniguchi, H., Tomiyama, S., Kojima, N., Takashi, O.: *Precast Segmental Construction of Box Culvert on Renewal Project of Expressway*, Proceedings of fib Symposium pp. 1669-1676, 2020.

Fig. 10 Inside the box culvert

Fig. 11 Outside the box culvert

概　要

首都高速 1 号羽田線は，1963年の供用から50年が経過した延長約1.7km の区間である。部分的な補修を行っているが，損傷が顕在化しており2015年 8 月より大規模更新工事が進められている。

上記延長のうち約450m を占める鮫洲埋立部は，既存の盛土構造を地盤改良により安定した基礎地盤に改良し，その上に橋梁上部工技術をボックス構造に適用したこれまでにない函体構造を構築する計画とした。

鮫洲埋立部函体工では，リブ付き U 型セグメントと PC 合成床版（PC 板＋場所打ち床版）から成るプレキャスト U 型ボックス構造により急速施工を実現している。