Development of a Geosynthetic-reinforced Soil Integrated Bridge with Prestressed-concrete T-shaped Girders

PCT 桁を用いた GRS 一体橋の開発

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Keywords: geosynthetic-reinforced soil, integrated bridge, prestressed concrete girder
DOI: 10.11474/JPCI.NR.2022.171

1. Introduction

A geosynthetic-reinforced soil (GRS) integrated bridge is a new type of bridge proposed in order to improve two weaknesses of existing bridges consisting of abutments and simply supported girders on bearings. The first weakness is potential abutment damage induced, represented by differential embankment settlement at the backfill. This is improved by using GRS abutments, which are widely used as the standard abutment type in Shinkansen bridges. The other weakness is the presence of bearing itself. Bearings are costly in terms of installation, maintenance, and repair, and they tend to be weak points under seismic loading and may cause unseating of the supported span. In the road sector, integrated bridges with no bearings have been developed to solve these problems. A GRS integrated bridge is proposed and developed to improve the two aforementioned weaknesses by combining the ideas of GRS abutments and an integrated bridge (**Fig. 1**).

In 2012, a prototype made of reinforced concrete was constructed for the Hokkaido Shinkansen, and in 2014 a prototype made of steel-framed reinforced concrete was constructed for the Sanriku Railway to replace the three simply supported girder bridges that were collapsed by the tsunami of the Great East Japan Earthquake. In addition, a GRS integrated bridge with prestressed concrete (PC) girders was developed for the Nishi-Kyushu Shinkansen to pass over a highway (**Fig. 2**).

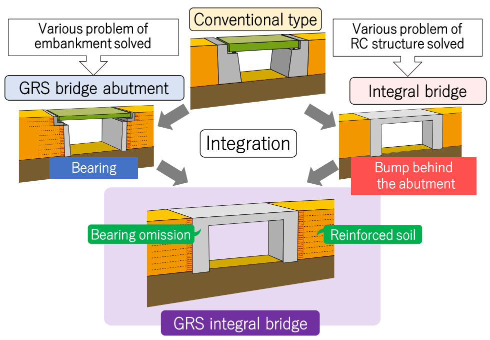

Fig. 1 GRS integrated bridge

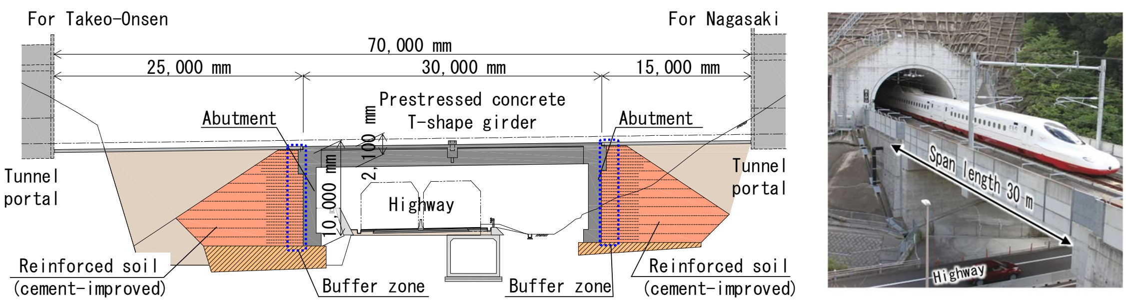

Fig. 2 General view of the GRS integrated bridge with PC girders (Genshu over-road bridge)

2. Structural Characteristics

(1) Construction Process

Fig. 3 shows the construction process of the GRS integrated bridge with PC girders. First, GRS is constructed (i), and after the subsidence of the GRS by deformation of the soil and after sufficient convergence of the supporting ground, the walls facing the GRS are constructed (ii). Second, PC girders manufactured in a yard on site are placed on the abutments (iii). Finally, the joints between the PC girders and the abutments, the spaces between the girders, and an overhanging slab are constructed (iv).

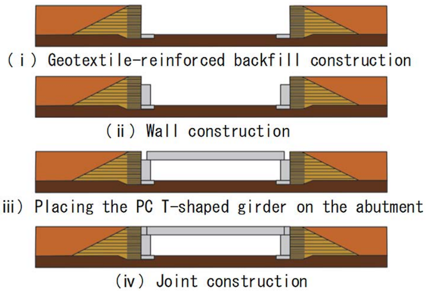

Fig. 3 Construction process of the GRS integrated bridge

(2) Long-term Behavior

Creep deformation and drying shrinkage of the PC girders affect the cross-sectional forces on the girders and abutments. Therefore, the precast PC girders were temporarily placed on the abutments for 1 month and then joined after their creep deformation and drying shrinkage had progressed. As a result, the bending moment under permanent action after the creep deformation was almost the same as that of the simply supported girders. In addition, a non-cemented (gravelly) layer was placed on a partial area of the cement-improved embankment behind the abutment to buffer the deformation of the girders (**Fig. 4**).

Estimates of the design response of the structures were verified using concrete strain gauges; stress gauges for rebar, geotextile, and PC cables; and thermometers installed during construction. Concrete strains at the center of the span on the bottom of girder are fairly consistent with the analysis and the measured value as shown in **Fig. 5**.

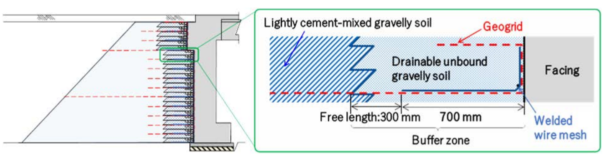

Fig. 4 Buffer zone of the GRS integrated bridge

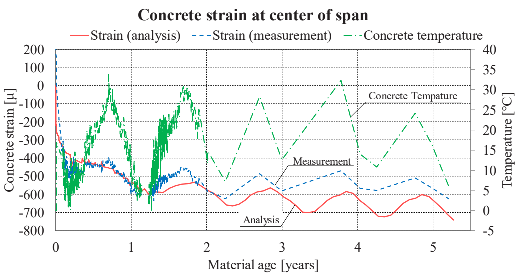

Fig. 5 Concrete strain at the center of the span

(3) Connections between Girders and Abutments

The onsite connection points between the precast girders and abutments must resist shear and torsion during an earthquake. Therefore, as shown in **Fig. 6**, the flanges of the T-shaped girders were notched, the upper reinforcing bars of the PC girders were sufficiently fixed to the joints, and reinforcing bars were also placed on the sides of the T-shaped girder web.

These connections were verified by load tests using a 1/3 scale model. In addition, PC cables bend more compared with simply supported girders, and thus PC cables were placed in a straight manner on the upper sides of the girders to resist the negative bending moment resulting from the rigid connections between the girders and abutments. **Fig. 7** shows the layout of the PC cables at the girder ends [1].

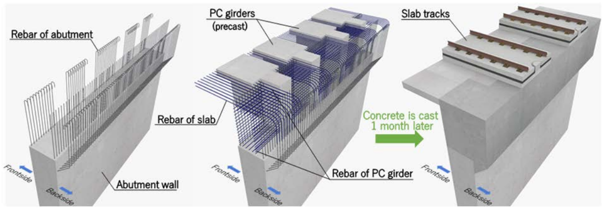

Fig. 6 Connection sectors

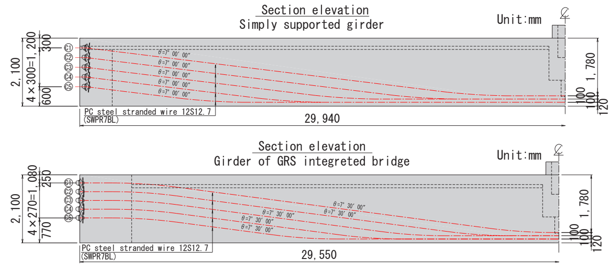

Fig. 7 PC cables

3. Conclusion

Longer-span GRS integrated bridges are possible by through the use of PC girders. The following measures were taken to address the two weaknesses of conventional bridges consisting of abutments and simply supported girders on bearings.

- A buffer zone was provided at the back of the abutments to prevent deformation of the girders.
- The precast girders were temporarily placed for one month before being rigidly connected with abutments in order to let creep deformation and drying shrinkage to proceed.
- The details of the girder–abutment joints were designed to resist shear and torsion during earthquakes based on the results of 1/3 scale model tests.
- The layout of PC cables was arranged to resist negative bending moments.

Reference

[1] Todoroki, S., Okamoto, M., Nishioka, H., Tamai, S., Yonezawa, T., and Ishii, H.: *Design Method for GRS Integral Bridge with the Use of PCT Girder*, Quarterly Report of RTRI, RTRI Tokyo, Vol. 63, Issue 2, pp. 108–114, May. 2022.