Construction of a Highway Tunnel Using Pneumatic Caissons

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ABSTRACT

The Kosoku-Ohmiya Route of the Metropolitan Expressway passes under the Shinkansen and Saikyo Lines of East Japan Railway Company through a tunnel near the entrance to the Saitama New Urban Center. The tunnel had to be constructed while minimizing the effect of tunneling on nearby facilities, including a regional air-conditioning center, abutments, piers, and other railway facilities. Also, any drop in groundwater level within the alternating beds of silt and sand had to be prevented. After identifying construction conditions, various countermeasures were discussed and planned, and six large pneumatic caissons were used for the construction, in which the P1 pier of the Saikyo Line above the tunnel was underpinned. The working chamber of a caisson is filled with compressed air at a pressure maintained nearly equal to the groundwater pressure outside the caisson. This paper reports the construction work.

1. INTRODUCTION

The Kosoku-Ohmiya Route of the Metropolitan Expressway connects the Saitama New Urban Center, performing some capital functions, direct to the city center of Tokyo. Near the entrance to the Center, the Kosoku-Ohmiya Route was designed to pass as a tunnel under the elevated tracks of the East Japan Railway Company's Tohoku, Yamagata, Akita, Nagano, and Joetsu Shinkansen Lines, which are major arteries in eastern Japan, and the Saikyo Line, which carries commuters to the Tokyo metropolitan area. Planning drawings of the tunnel construction are shown in Figures 1, 2, and 3.

2. CONSTRUCTION CONDITIONS

Construction conditions are as follows:
Structural safety of surrounding facilities, including abutments of Shinkansen Lines, bridge piers of the Saikyo Line, a regional air-conditioning center, and a central meat wholesale market of Saitama City, needs to be secured. And safety of railway lines in service (the Shinkansen, Saikyo, and Tohoku Lines) should be secured.

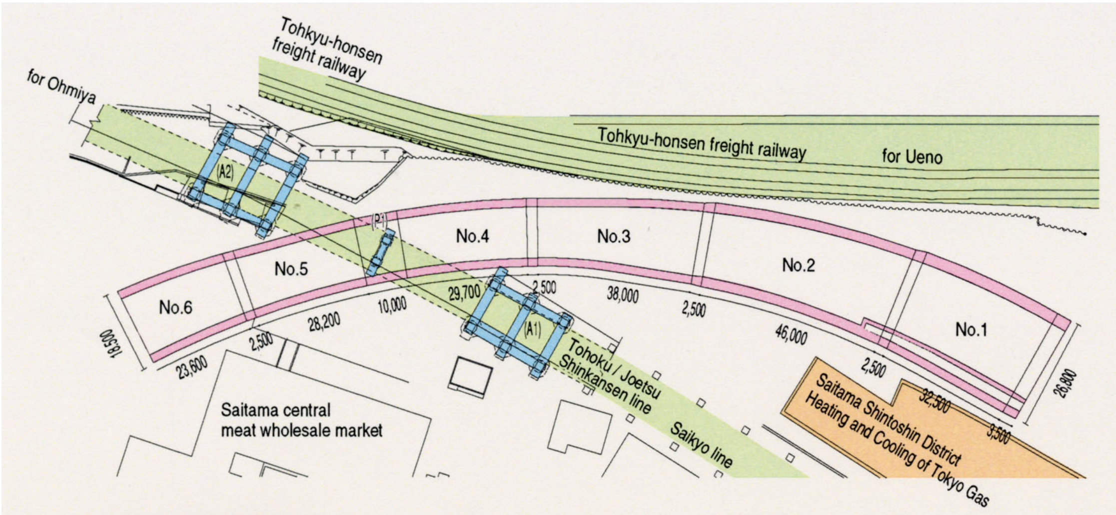

Figure 1 Plan

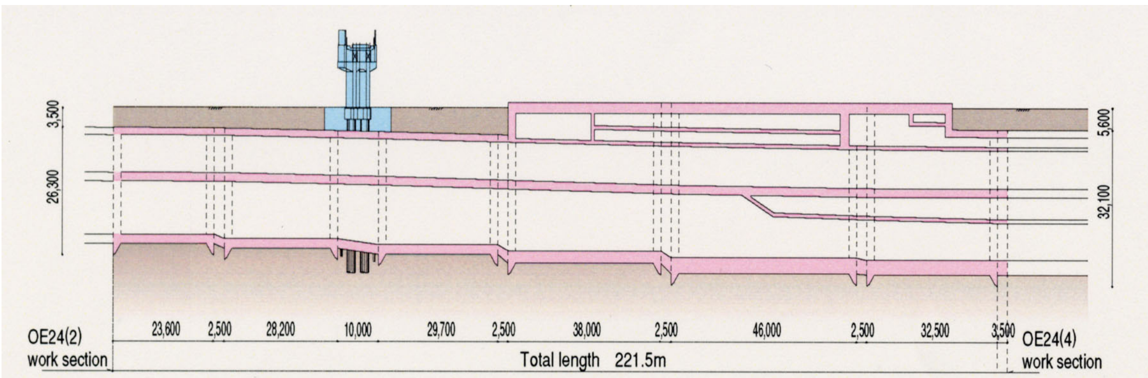

Figure 2 Profile

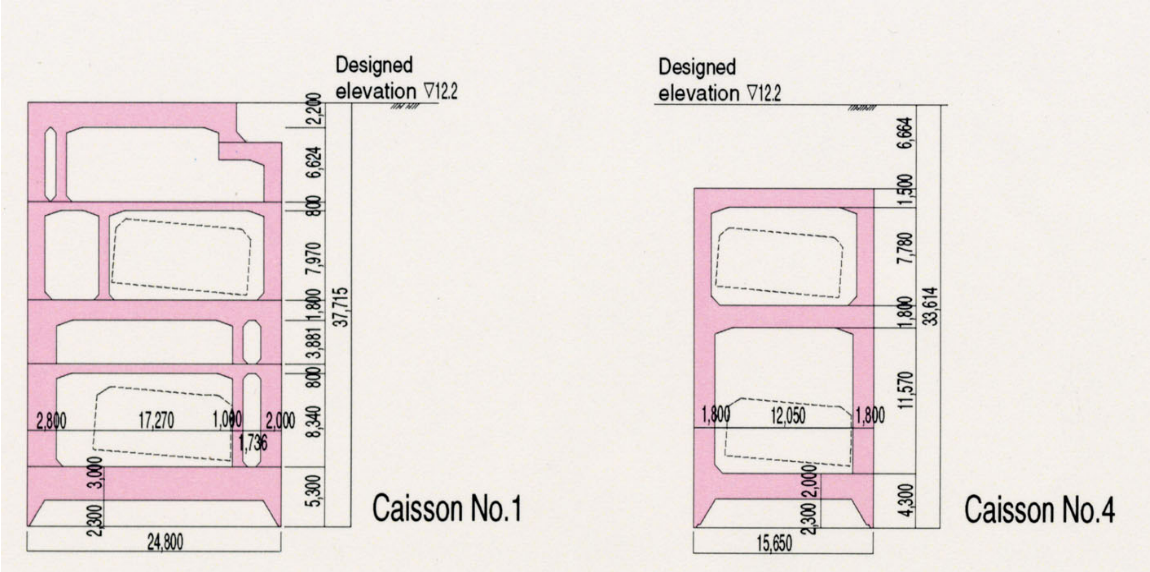

Figure 3 Cross section

The groundwater level should be maintained to prevent impacts on domestic wells. Construction needs to be carried out quickly in narrow work space. A pier of the Saikyo Line needs to be underpinned. The geology of the construction site consists of soft alluvium and the Kanto Loam Formation from the ground level to a depth of about 4.0 m, the Ohmiya Formation consisting of silty volcanic ash sand layers down to a depth of about 20 m, the Tokyo Formation consisting of mud layers with abundant fossil shells below the Ohmiya Formation, and gravelly soil layers below the Tokyo Formation. The groundwater level is at a depth of about 1.0 m below the ground level. Diluvial sand and other sand layers in and below the Ds2 unit are all confined. A geologic column is shown in Figure 4.

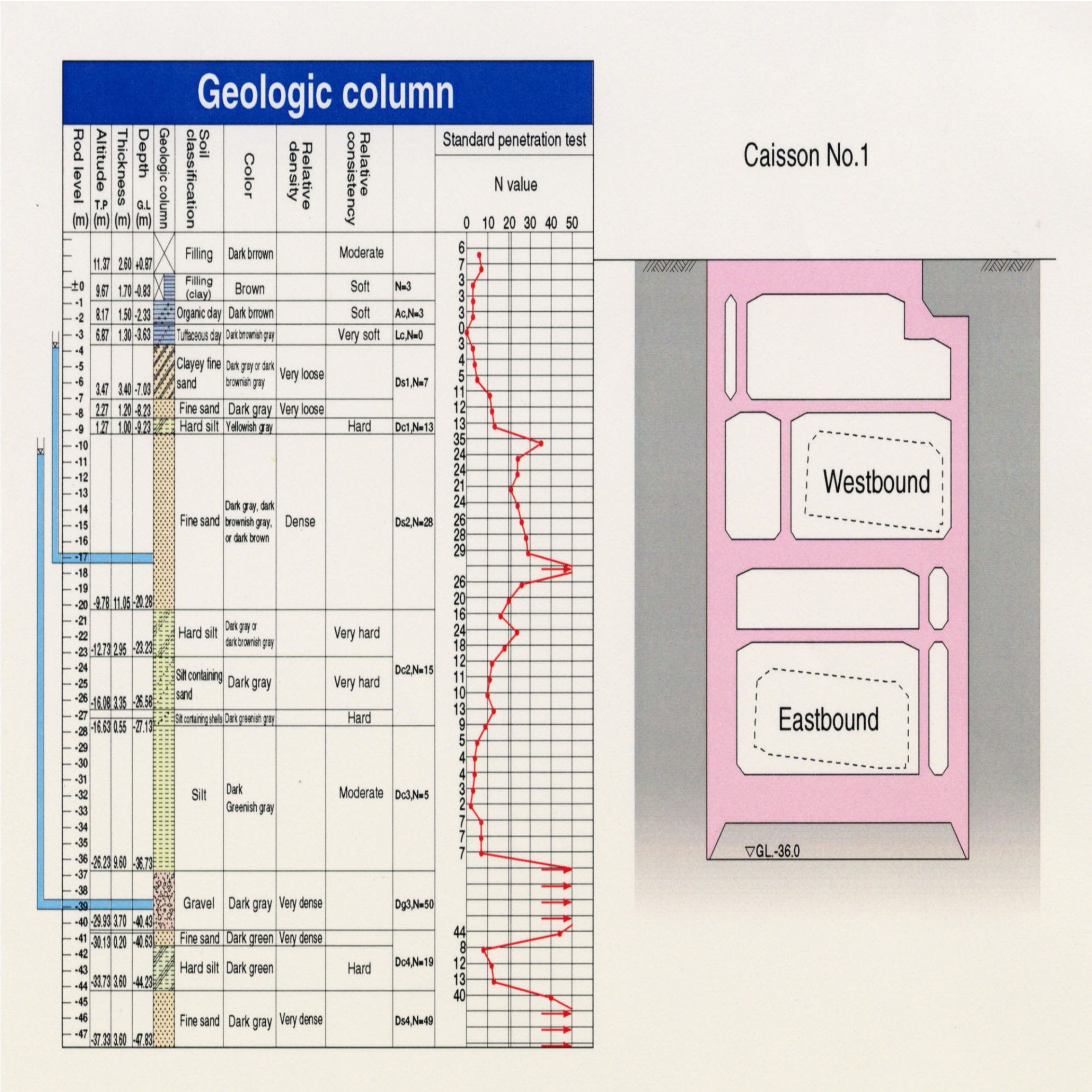

Figure 4 Geologic column

3. SELECTION OF CONSTRUCTION METHOD AND CONSTRUCTION DETAILS

The pneumatic caisson method was selected after comparison with the cut-and-cover method because of ensured safety of facilities and railway lines in the vicinity (smaller possibilities of displacement), superiority in controlling impacts on groundwater level, lower cost, and shorter construction period. The following measures were planned and carried out for the construction using pneumatic caissons.

Six caissons were employed to construct a tunnel over a total length of 221.5 m. The plan spect ratios of the caissons were designed to 3:1 or less for the sake of cost efficiency and the precision of caisson settlement (see Figure 1). The gap between caissons was designed to 2.5 m to allow machine excavation of caisson jointing areas. The gap was set to 10.0 m at the P1 pier, which was underpinned, in consideration of the crossing angle of the new tunnel and the pier (see Figure 1).

When multiple caissons are placed in sand or gravel layers under a continuous air-impermeable layer, inflow of air occurs from the working chamber of a caisson under higher pressure (at a greater depth) into the working chamber of another caisson under lower pressure (at a smaller depth). An oxygen deficiency accident may be caused if there is an air-permeable layer deficient in oxygen. The control of air pressure in the working chamber of the caisson receiving air inflow may also become difficult. To prevent air inflow from a caisson into another while settling multiple caissons in alternating beds of silt and sand, air pressure in the caisson working chamber was controlled by high-precision, automatic pressure adjusters. The construction schedule was arranged so that the cutting edges of a first group of caissons (Nos. 1 to 3) and those of a later group of caissons (Nos. 4 to 6) do not exist simultaneously in sand layers Ds1 and Ds2. The rate of settlement was controlled to prevent any difference in depth between caissons within each group.

Retaining walls were built between the tunnel and surrounding facilities to secure the safety of the facilities.

Displacements in the surrounding facilities were measured using a total station instrument and real-time measurement control was carried out. The instrument, which has the capability of both an electro-optical distance meter and a theodolite, allows three-dimensional measurement. External control from a personal computer and automatic target tracking are possible.
We used a system that pressures caissons into the ground while suppressing rocking during their settlement was adopted to minimize the impact of the construction on the surrounding ground. Control of caisson rocking is possible because settlement force (dead weight of caisson) can be biased instantaneously. Ten jacks, each having a maximum capability of 3000 kN, were installed. Ground anchors were used to provide reaction force. Figure 5 shows the pressuring system. The pressuring system contributed to achieving sufficient settlement precisions when asymmetric (curved) caissons were used or when the beds on which caissons were settled had N values of 2 to 7 (diluvial silt layer; Dc3).

Pneumatic excavation was applied to caisson joining areas to cope with confined groundwater. To improve working conditions under high pressure, unmanned excavation was remote-controlled from the ground surface. The situation of the working chamber and all information required for settlement control were shown on a surveillance monitor in the control room.

After the caissons were settled, a support slab was constructed on the caissons on both sides of a pier of the Saikyo Line; this involved the existing pier footing. The structures were bound together with steel wire for prestressed concrete so that the loads of trains and the structures are directly supported by the underpinning caissons. Figure 6 shows the scheme of the underpinning.

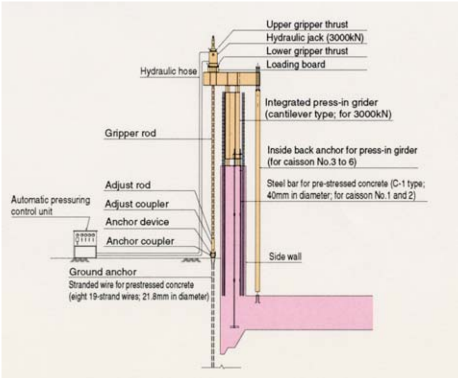

Figure 5 Pressuring system

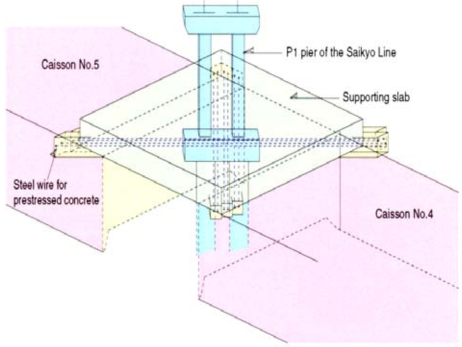

Figure 6 Scheme of underpinning

4. CLOSING REMARKS

In this project, six caissons were assembled and settled in March 2002, the underpinning of a pier was completed in October 2002, and the jointing of the caissons was completed in October 2003. This paper reports that the pneumatic caisson method has been improved as a means to create underground space including tunnels.

REFERENCE

Kunio Kobayashi, Akira Seto, Toshihiko Suganoya, and Mitsuru Shimoma: Crossing under the Shinkansen and Saikyo Lines using caissons, Tunneling & Underground Structures, Vol. 34, No. 4, 2003.