Japan's first full tunneling construction of glasses-shaped twin tunnel without Advancing drift by drill and blast method in residential areas

― Itsutsugaoka tunnel project on Route 475 named Tokai Ring Expressway ―

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1.Construction outline

The Itsutsugaoka tunnel consists of twin tunnels (two two-lane tunnels) on the Tokai Ring Expressway. The Expressway, a free-access controlled highway, forms a loop connecting Toyota, Seto, Gifu, Ogaki, Yokkaichi and other cities in Aichi, Gifu and Mie prefectures in a zone 30 to 40 km from Nagoya City, and combines with the Tomei, Meishin, Chuo, Tokai-Hokuriku and Second-Tomei/Meishin Expressways to constitute a wide-area network. The Tokai Ring Expressway also provides a key access to the main site of EXPO 2005 AICHI JAPAN. The location of the tunnel is shown in Fig. 1. Fig. 2 shows a typical cross section of the tunnel. The construction of Japan's first twin tunnels using no drift was started in March 2002 and completed in July 2004. This tunnel is one of urban tunnels constructed near built-up residential areas (Photo 1).

Project: Construction of the Itsutsugaoka Tunnel on the Tokai Ring Expressway in 2001

Owner: Meishi National Highway Office, Chubu Regional Development Bureau, Ministry of Land Infrastructure and Transport

Contractor: Hazama-Okumura joint venture for specified construction work

Construction site: Matsudaira Shiga-cho, Toyota City, Aichi Prefecture

Construction period: March 19, 2002 through July 30, 2004

Construction details: NATM (tunnel type: twin tunnels)
Length: 321 m in either direction

Geology: Ryoke belt Inagawa granite and decomposed granite soils of the Cretaceous Period of the Mesozoic era
Fresh granite soils with an unconfined compressive strength of 80 MPa to 150 MPa

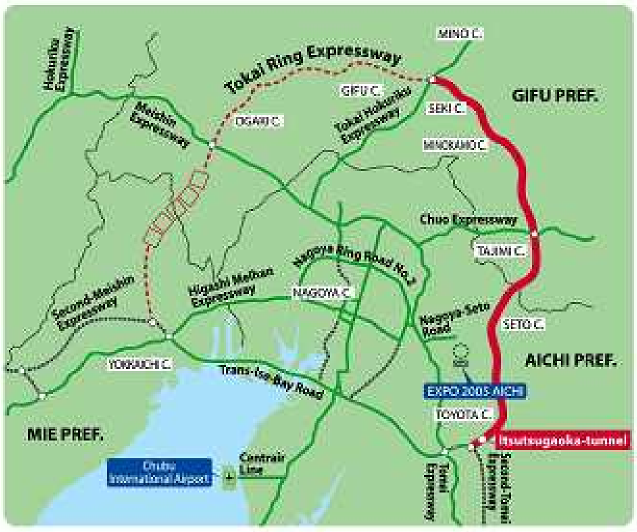

Fig. 1: Location of Itsutsugaoka Tunnel

2.Design and construction of drift-less twin tunnels

The Itsutsugaoka Tunnel has large excavated cross sections: approximately 107 m^2 in the leading tunnel and 100 m^2 in the following tunnel. The planned tunneling site is adjacent to a large housing complex accommodating 10,000 residents. The minimum and maximum earth covers are 1 m and 28 m, respectively.

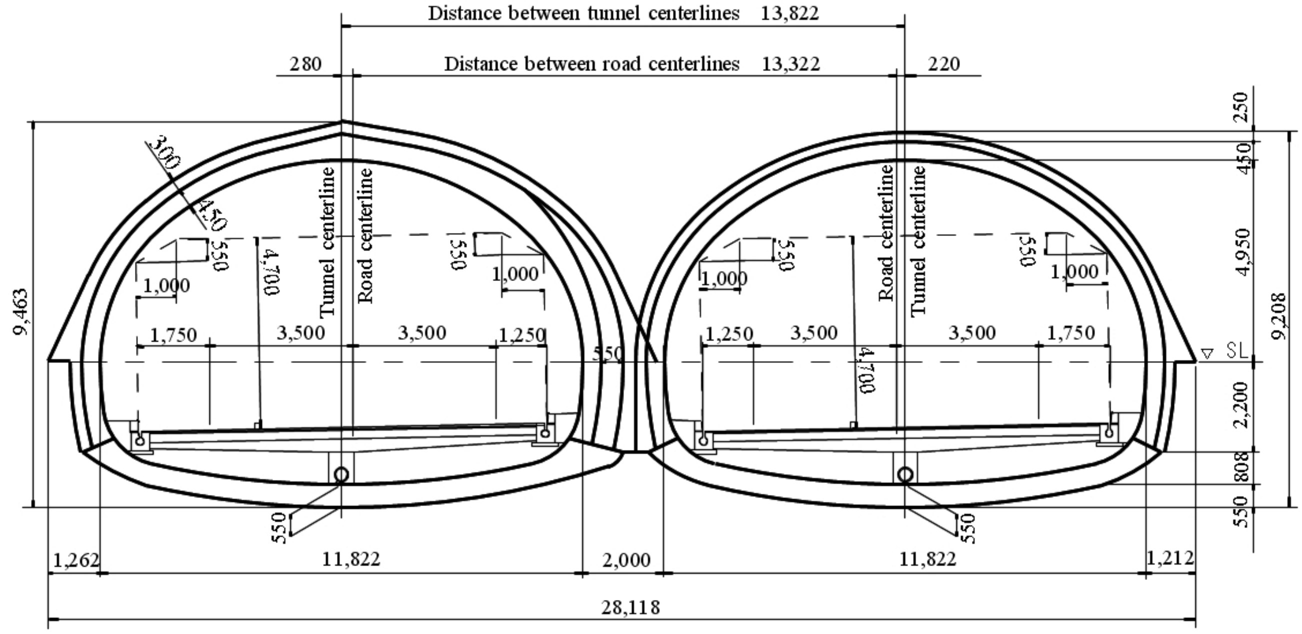

Fig. 2: Typical cross section

Photo 1: Itsutsugaoka Tunnel and surrounding area

Photo 2: Portal at the time of tunnel construction

The geology consisted of sandy layers and very hard granite soil layers with a high unconfined compressive strength of 150 MPa and was subjected to unsymmetrical loading. To construct twin tunnels without using drifts under such conditions, high-standard steel support (H-250 x 250: SS540), high-strength shotcrete (36 N/mm^2) and steel fiber reinforced shotcrete were adopted in support design. Forepoling was also adopted in sections of the tunnel alignment with a thin earth cover to ensure the stability of tunnel crown. This made stable tunnel excavation possible (Fig. 3 and Photo 2).

Tunnel support members were designed based on the results of two-dimensional elastic FEM analysis of simulated tunnel construction steps. Constructing twin tunnels has been considered difficult because tunnel support was subjected to complex changes in load during excavation such as increases or changes of earth loads attributable to the excavation of two tunnels. An increasing number of twin tunnels have, however, been constructed recently because more tunnels need to be constructed in built-up areas and because the preservation

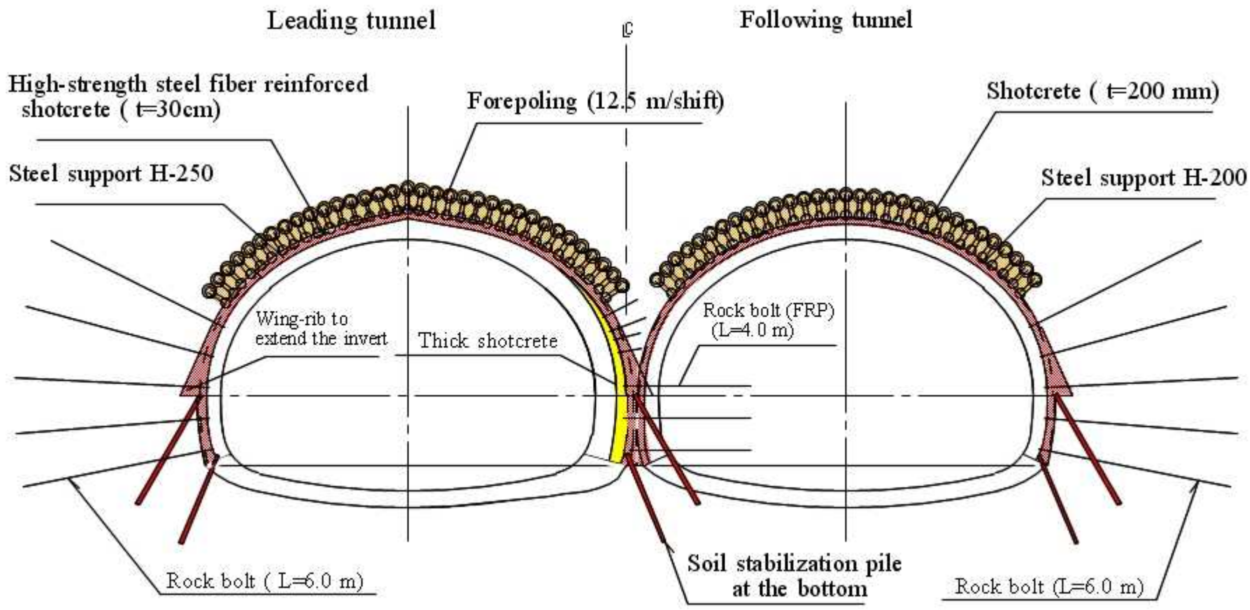

Fig. 3: Tunnel supports of glasses-shaped twin tunnel withoutAdvancing

of the environment and cultural properties is required.

Twin tunnels have generally been constructed by the multiple-drift excavation system. The method involves the excavation of drifts of small cross section at the center and along the sidewalls and concrete placement at the foot before the excavation of top heading of large cross section. It therefore requires complicated work procedures and long period of time. In this project, twin tunnels were excavated using no drifts throughout for the first time in Japan. Measures were taken to control ground surface settlement and the deformation of support of the leading tunnel because great loads concentrated on the center pillars. To minimize the load of loosened ground during tunnel excavation, lining concrete was placed after the excavation of two tunnels. Then, the safety of tunneling was enhanced, risk of construction delay was minimized and the quality of lining was improved.

3.Blasting very close to housing area

A large housing complex accommodating 10,000 residents exists above the Itsutsugaoka Tunnel. The tunnel was excavated 23 m away from a building at the minimum. In a section close to the housing complex, hard granite soil layers with a high unconfined compressive strength of 80 MPa to 150 MPa had to be excavated by the drill-and-blast method around the clock. In the twin tunnels, the following tunnel was excavated after the construction of support for the leading tunnel. It was therefore necessary to prevent the excavation of the following tunnel from destroying the support of the leading tunnel. Thus, a strictly controlled blasting technique was required.

The leading tunnel was excavated by a controlled blasting method that was found to have no impact on the adjacent large housing complex in pilot excavation by drill and blast. While excavating the following tunnel, the velocity of vibration of shotcrete, a type of support of the adjacent leading tunnel, induced by the excavation was measured using vibration velocity transducers each time blast was made. The following tunnel was excavated by controlled blasting to prevent the deformation of the support of the leading tunnel. Controlled blasting of the following tunnel basically involved single-hole, single-stage blast using electronic delay detonators. The amount of explosives used was controlled during the excavation by blasting. Even with controlled blasting, the deformation of the support of the leading tunnel was expected in sections 1.5 m away from the leading tunnel wall. Mechanical excavation was therefore adopted in the sections using large chisels (Fig. 4).

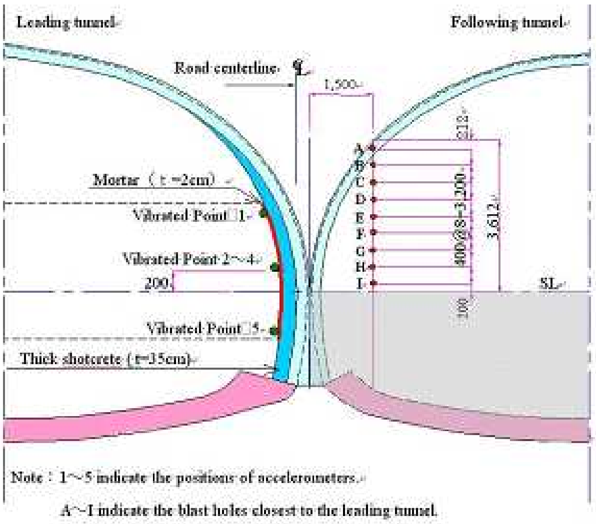

Fig. 4: Measurement points of velocity of blast-induced vibration

Photo 3: Portal of Itsutsugaoka Tunnel

4.Result of construction

In the Itsutsugaoka Tunnel, the twin tunnels with no drifts were highly affected by topographic and geological conditions. The leading tunnel in particular was found to be subjected to complex deformation and stresses on the support in each excavation step. The stress in each support member was below the allowable level. Thus, the size of each member of the driftless twin tunnels proved valid.

The following tunnel was constructed by drill and blast while reflecting the measurements of velocity of blast-induced vibration in the following blast patterns. As a result, excavation could be completed without deforming the support members of the leading tunnel (Photo 3). Thus, adopting controlled blasting for the excavation of the following tunnel based on the measurements of velocity of blast-induced vibration was found to enable blasting very close to an adjacent tunnel as in this project.

The driftless twin tunnels construction method adopted in the project proved to be superior to the multiple-drift excavation system conventionally used for twin tunnels, in terms of construction cost and period.

5.Closing remark

In the Itsutsugaoka Tunnel project, twin tunnels could be constructed without any drifts by 24-hour drill and blast in very hard granite soil layers in the vicinity of urban housing areas. The achievement will make great contributions to the enhancement of stability and quality of twin tunnels to be constructed by the drill-and-blast method in the future and to the preservation of the environment during tunneling. The twin tunnels could be constructed without using any drifts by the drill-and-blast method under severe excavation conditions while maintaining the natural and housing environments where land acquisition was extremely difficult. The drill-and-blast method is now applicable to the construction of twin tunnels in an increasing number of cases.