World's First Application of Underground Large Diameter Tunnel Widening Technology Using Enlargement Shield Tunneling Machine

Kazuhito UCHIUMI ▸ Deputy Manager, Design Division, Kanagawa Construction Bureau, Metropolitan Expressway Company Limited
E-mail: k.uchiumi63@shutoko.jp

Metropolitan Expressway Route K7, Yokohama North Line, is an expressway which links the port area and the inland area of Yokohama City over a total length of approximately 8.2 km. It was opened for traffic in March 2017. In order to minimize the number of houses to be removed and to preserve the environment in the surrounding area, Yokohama North Line was designed and built as a tunnel structure under the residential area covering approximately 70% of the total length equating to around 5.9 km, out of which around 5.5 km was built as two parallel tunnels of an external diameter ϕ 12.3 m using two large diameter earth pressure balanced TBMs.
After completing the construction of the above parallel tunnels, tunnel junctions connecting four ramps were further constructed to Yokohama North Line at the mid-point of its route where the tunnel cross-section was enlarged by a trench less construction method without using the conventional cut and cover method. This was the first project in the world in which the tunnel widening under the residential area was attempted and achieved.

1. Summary of the underground tunnel enlargement technology

The surface area, where the tunnel widening was implemented, was densely packed with houses, and the overburden was of great depth ranging from 28 m to 54 m. This made construction works using the open cut method difficult, so it was decided to use the trench less method that enlarges the structure from the segmentally lined tunnel. Although the geology was relatively good, and consisted mainly of Kazusa layers, there was a possibility of triggering quicksand and consolidation settlement in case groundwater flooded from aquifers interlaid in Kazusa layers. That is why we employed new technologies, to widen the tunnel underground in the most reliable and safe manner from the viewpoint of reducing impact on the surrounding environment, i.e. a combination of two approaches; one was a new type of TBM (Enlargement Shield Tunneling Machine/ ESTM) designed to widen the tunnel diameter and the other is a conventional pipe roofing technique (Large Diameter Pipe Roofing/LDPR). The construction steps are summarized as below.

① In order to split the underground enlargement section (a total length of 150m – 220m) into multiple blocks, a groundwater cut-off wall was built by injecting chemical grout at the starting, intermediate and terminal points of the section for enlargement.
② At the starting point of the section for enlargement, the main tunnel was widened from ϕ 12.3m to ϕ 18.3m in outer diameter using Enlargement Shield Tunneling Machine (ESTM), and as a result the launching base for Large Diameter Pipe Roofing (LDPR) was built.
③ A large-diameter pipe (ϕ 1200 mm) was installed from the pipe-roof launching base in the direction of the tunnel axis one by one to form LDPR (27 pipes per block).
④ Chemical grout was injected from inside of each pipe into the ground between the pipes of LDPR to improve the ground to the extent excavation works can be carried out inside LDPR.
⑤ The steel segments of the main tunnel were cut and removed at a width of 4m – 8m in the direction of the tunnel axis, and the ground inside LDPR was excavated.
⑥ After excavation, the concrete structure constituting part of the bifurcation junctions was built.
⑦ The above steps of cutting, excavating, and constructing the bifurcation structure were repeated until the tunnel enlargement was fully completed.

2. Advantages and effects of the technology

① The newly developed Enlargement Shield Tunneling Machine (ESTM) makes it possible to widen the diameter of the main tunnel running under the residential area at great depths, without resorting to the cut and cover method.
② During construction, the tunnel enlargement section was covered by LDPR with extremely high rigidity. LDPR in the excavated sections was supported at all times by the concrete structure and the ground in the still-to-be excavated sections, so stable construction was possible.
③ Possible to minimize the excavation volume in accordance with variations in tunnel cross section profile at the junctions flexibly.
④ No weak point in water-tightness as the tunnel bifurcation had an autonomous elliptical structure on completion without having structural joints between the steel segments and the RC structure.

3. Summary

Through this project, we were able to develop and establish new technologies for the underground tunnel enlargement, proven to be very beneficial for project safety, minimizing the ground settlement resulting from tunnel widening excavation, and reducing impact on the surrounding environment and residential buildings. We could also construct the tunnel bifurcation junctions safely by having protection of pipe roofing that prevented collapse of the ground at the tunnel crown.

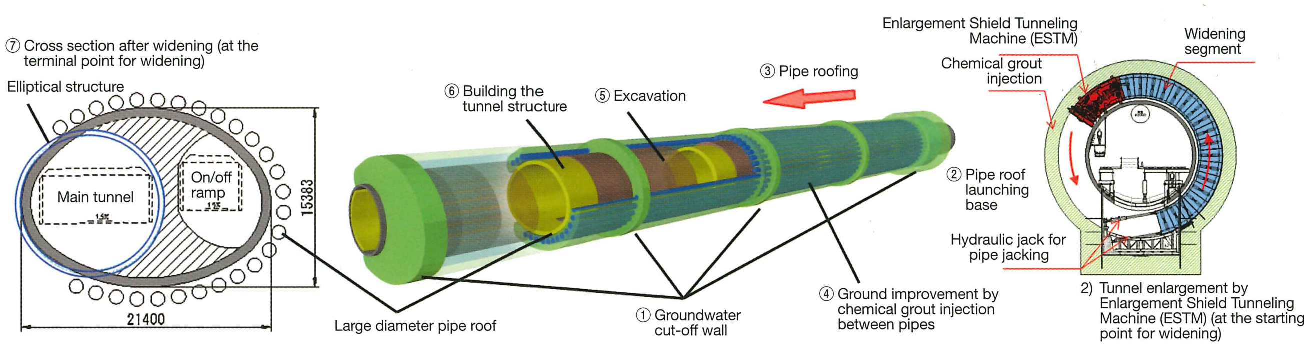

Fig. A new underground large diameter tunnel widening technology that combines Enlargement Shield Tunneling Machine (ESTM) and Large Diameter Pipe Roofing (LDPR)