URUP (Ultra Rapid Under Pass) Method
- The First Implementation in the World

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1 INTRODUCTION

The Central Circular Shinagawa Route of the Metropolitan Expressway is currently under construction in order to mitigate chronic traffic congestion in central Tokyo. The Central Circular Shinagawa Route planned by the Tokyo Metropolitan Government and Metropolitan Expressway Co., Ltd includes a 9.4-kilometer-long section from the Oi Junction of the Bay Shore Route to the Central Circular Shinjuku Route and the Ohashi Junction of Route 3 (Shibuya Route) of the Metropolitan Expressway (Figure 1).

In the project, the URUP (Ultra Rapid Under Pass) method has been adopted to Oi Area Tunnel located between a viaduct section at Oi Junction and a main tunnel section. The URUP (Ultra Rapid Under Pass) method has a new technology for the first time in the world that enables to launch from ground level and arrive to ground level. This paper reports on launching facility and tunneling control methods of the URUP and monitoring method on adjacent structures.

2 OVERVIEW OF THE URUP METHOD

The URUP is a newly developed shield tunneling method for construction of underpass without the departure/arrival shafts. The shield machine for URUP method can be launched from the ground level, drives under a thin overburden, and arrives at ground level as shown in Figure 2.

This method enables to construct the underpass in short construction schedule as compared with cut and cover tunnel method.
This new technology has already been verified in demonstration work carried out by using a rectangular shield machine. It was confirmed in the verification of the demonstration work that this technology was able to be applied to a circular shield machine as well.

3 OVERVIEW OF OI AREA TUNNEL CONSTRUCTION

3.1 DESCRIPTION OF WORK

As shown in Figure 3, the following structures are included at Oi Area.
1) Tunnel section by URUP method
2) Retaining wall/culvert section
3) Ventilation station
4) Bridge section

Table 1 shows construction data.

Table 1  Data on the Oi Area Tunnel construction project

<table>
<thead>
<tr>
<th>Name of project</th>
<th>Central Circular Shinagawa Route Oi Area Tunnel Construction Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction period</td>
<td>June 25, 2008 to June 30, 2011</td>
</tr>
<tr>
<td>Owner</td>
<td>Tokyo Metropolitan Government</td>
</tr>
<tr>
<td>Type of shield</td>
<td>Earth pressure balance shield</td>
</tr>
<tr>
<td>Outside diameter of shield</td>
<td>13.6m</td>
</tr>
<tr>
<td>Outside diameter of segmental lining</td>
<td>13.4m</td>
</tr>
<tr>
<td>Inside diameter of segmental lining</td>
<td>12.5m</td>
</tr>
<tr>
<td>Segmental lining ring width</td>
<td>1,700mm</td>
</tr>
<tr>
<td>Shield tunneling length</td>
<td>895m</td>
</tr>
<tr>
<td>(Oi-bound tunnel : 345m, Ohashi-bound tunnel : 550m)</td>
<td></td>
</tr>
<tr>
<td>Ventilation station</td>
<td>Pneumatic caisson method</td>
</tr>
<tr>
<td>Shape of structure in plan</td>
<td>39m*35m</td>
</tr>
<tr>
<td>Inside cross section</td>
<td>32m*28m</td>
</tr>
<tr>
<td>Excavation depth</td>
<td>44m</td>
</tr>
<tr>
<td>Retaining walls and culverts</td>
<td>Cut-and-cover method</td>
</tr>
<tr>
<td>Retaining wall length</td>
<td>265m (Oi : 205m, Ohashi : 60m)</td>
</tr>
<tr>
<td>Culvert length</td>
<td>80m</td>
</tr>
<tr>
<td>Bridge section</td>
<td>Two-span prestressed concrete bridge</td>
</tr>
<tr>
<td>Bridge length</td>
<td>60m</td>
</tr>
<tr>
<td>Piers</td>
<td>3</td>
</tr>
</tbody>
</table>

3.2 ADOPTION OF THE URUP METHOD

This tunnel project is a design–build contract in which bidders were requested to propose technical solutions for minimizing the length of the cut-and-cover tunnel section because of several technical problems of the construction as listed in Table 2. As a result of tender, the URUP method was adopted as the best solution which could substantially minimize the cut-and-cover tunnel work due to departure/arrival from at ground level with URUP.
3.3 EXPECTED ADVANTAGES OF THE URUP METHOD

(1) Reduction of cut-and-cover tunnel area
The URUP can reduce cut and cover tunnel area with the following advantages. 1) Large-scale temporary retaining walls are not required. 2) Quantity of utility diversion can be reduced.

(2) Minimization of impact on existing structures
The cut-and-cover tunnel method with deep temporary retaining wall might cause large deformation or settlement of the ground because there are soft ground layers. The URUP method with earth pressure balance shield machine can minimize the deformation or the settlement of the ground with properly controlled earth pressure at the face of the shield machine. Therefore, the URUP method will minimize impact on adjacent existing structures.

(3) Minimization of environmental impact
The URUP method can minimize the environmental impact with the following reasons. 1) The URUP method does not require departure/arrival shafts. Consequently noise and vibration can be reduced because heavy equipments for diaphragm wall and excavation for construction of the shafts are not necessary. 2) The URUP method can reduce amount of excavation as compared with cut and cover tunnel method.

4 PLANNING OF URUP FOR OI AREA TUNNEL

4.1 TUNNEL CONSTRUCTION SEQUENCE
The followings are construction sequence for Oi Area Tunnel by URUP method.
1) The URUP shield machine launches from ground level, and arrives to Oi-Kita Ventilation Station for construction of Ohashi-bound tunnel.
2) The URUP shield machine turns around in the ventilation station and to be elevated to the re-launching position of construction of Oi-bound tunnel.
3) The URUP shield machine re-launches from the Ventilation station and arrives to ground level for the construction of Oi-bound tunnel.
Figure 4 illustrates the tunnel construction sequence

<table>
<thead>
<tr>
<th>Construction conditions</th>
<th>Technical problems</th>
</tr>
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</table>
| -The soil to be tunneled through is composed of soft cohesive soil.  
- The maximum overburden depth is about 25 m.  
- There are structures such as large-scale water outlets of a thermal power plant and power cable tunnels. | - Deformation of retaining wall caused by deep excavation work  
- Influence on existing structures  
- Need for large-scale temporary relocation of underground pipes |

Table 2  Construction condition and technical problem

![Figure 4  Tunnel construction procedure](image)
For the construction sequence, the followings are important technical items in the planning of the URUP method in Oi Area tunnel.

a) Temporary equipments for launching
b) Lining support structures at the launching/arrival points
c) Appropriate face pressure control to prevent the deformation of surrounding ground
d) Monitoring method of adjacent existing structures

The details of each item are reported below.

4.2 TEMPORARY EQUIPMENTS FOR LAUNCHING

In conventional shield tunneling, the shield machine is launched from a vertical shaft where the shield machine has earth pressure and underground water pressure according to overburden depth (at least 1D or more: D=outer diameter of the tunnel). Therefore, the launch seals shall be provided to prevent underground water with soil ingress into the shaft, and temporary lining segments and heavy reaction truss shall be installed to sustain the thrust force from the shield machine for its launching.

On the other hand, the shield machine of URUP method can be launched from a shallow pit on the ground. Consequently, earth pressure and underground water pressure on the shield machine are small. Therefore the entrance packing, temporary lining segments and heavy reaction truss are not required. Only simple reaction truss with small amount of steel pipes or H-beams will be used for launching of the shield machine in URUP method.

The launching thrust force of the shield machine for URUP method in Oi Area Tunnel is 25% of the total capacity of thrust force. As shown in Figure 5, the simple reaction truss with steel pipes and H-beams will be provided at the lower half of the shield machine.

![Figure 5](image-url) Overview of the launching at ground level
4.3 LINING SUPPORT STRUCTURES AT THE LAUNCHING/ARRIVAL POINTS

As shown in Figure 6, the lining segments without vertical pressure at launching/arrival level or small vertical pressure at shallow tunnel sections have different section force and deformations as compared with the lining segments with overburden in general case. In order to minimize such section force and deformation of the lining segments, temporary and permanent support structures shall be installed as shown in Figure 7. The temporary steel members shall be installed horizontally in the tunnel cross section during the tunnel driving. The permanent structural beams shall be installed in the upper and lower parts of the tunnel cross section after the completion of shield tunneling, and then, the temporary steel members shall be removed.

4.4 FACE PRESSURE CONTROL

When the shield machine of URUP is launched at the ground level, the upper part of the face of the shield machine is still aboveground. As the shield machine is being advanced into the ground, accordingly the chamber will be filled with excavated soil as shown in Figure 8. For the launching at ground level or driving under a thin overburden layer by the shield machine of URUP, stabilization of the face is important to minimize deformation of ground. Insufficient or excess earth pressure in the chamber will affect the face stabilization. Therefore, the pressure in the chamber shall be monitored properly and maintained/controlled appropriately. In the shield tunneling for the Oi Area Tunnel, the pressure in the chamber to be maintained to equal to or greater than assumed pressure, i.e. static earth pressure plus...
underground water pressure. In order to monitor the pressure in the chamber, earth pressure cells shall be installed in the chamber. Earth pressure in the chamber shall be controlled on the condition that the earth pressure at the highest location in the chamber monitored by the cell shall be kept to more than the above-mentioned assumed pressure.

In ground-level launching, the plastic flow of excavated soil in the chamber can be directly observed visually. Therefore, proper quantity of additive and plasticity of the soil can be controlled with the visual monitoring the conditions of excavated soil in order to ensure safe and successful shield tunneling of URUP.

4.5 MONITORING METHOD OF ADJACENT EXISTING STRUCTURES

As shown in Figure 9, existing structures adjacent to the shield tunnels include footings and foundation piles of the existing road bridge. In order to examine the impact of shield tunneling on these adjacent structures, advance analyses have been conducted to check on the movement of and stresses in each structure. The analytical results indicate that there will be no adverse effects on the adjacent structures. Trial measurement will be conducted in the first 100-meter section where there is no adjacent structure. Settlement of the ground surface above the tunnels will be measured to verify the effects of the above-mentioned face pressure control. The measurement results will be fed back to the analyses in order to minimize the impact of shield tunneling on adjacent structures. During shield tunneling in the vicinity of existing structures, the movement of the structures and the surrounding ground will be measured in real time.

The results will be able to be reflected in the tunneling control in order to ensure successful and safe tunneling work. Furthermore, the results of the advance analyses shall be compared with the measurement results, and then, the advance analyses can be verified for future study.

5 CONCLUSION

The URUP method, which has been originally developed to construct the underpass in a short period of time, was adopted in Oi Area Tunnel project. Adoption of the URUP method solved a number of technical issues in the cut and cover tunnel method which was planned originally. The erection of the shield machine has already begun in November, 2009, and the driving is expected to start from the end of February, 2010.

Safe and successful shield tunneling work with the URUP method shall be executed in accordance with the construction plan and the control methods reported in this paper. The progress and results of the shield tunneling work with URUP method at Oi Area Tunnel Project will be reported in near future.