URUP (ULTRA RAPID UNDERPASS) METHOD
- TBM STARTING EXCAVATION FROM GROUND LEVEL WITHOUT SHAFT -

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KEYWORDS
underpass, no-shaft, environment.

INTRODUCTION

Many intersections in urban areas are chronically congested. Traffic congestion causes an economic loss and time consuming in passing intersections are having adverse effects on not only the local living environment but also on the global environment due to exhaust emissions from vehicles.
The new tunnel technology called URUP (Ultra Rapid UnderPass) method has been developed to solve those problems, and the method shortens construction period of an underpass and decreases noise, vibration and secondary traffic congestion by its innovative technology.
The characteristic of URUP method is a TBM (Tunnel Boring Machine) launching from a ground level, driving under thin overburden and arriving at the ground level again without launching/receiving shafts.
This paper introduces TBM tunneling technology named URUP and discusses the experimental construction undertaken in the development process. The paper also provides project reports on two of the public projects that implemented the URUP method.

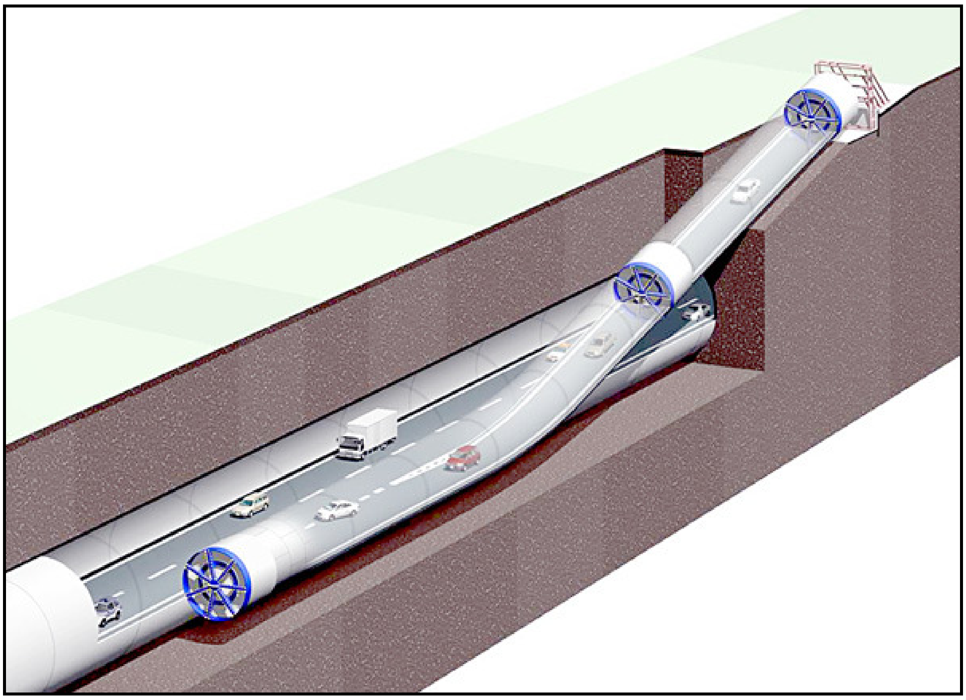

Figure 1. Concept of URUP

OVERVIEW

URUP method is a new TBM tunneling method originally developed for underpass construction by Obayashi Corporation.

The method makes a TBM launched at the ground level, driven under thin overburden and arrived at the ground level while safely maintaining the ground stability under zero to thin overburden conditions, and can eliminate the launch and retrieval vertical shafts by launching and holing. However, most of TBM tunnel projects are required to construct vertical shaft and/or open-cut pits on the entrance and/or end of the tunnel for the purpose of maintaining minimum tunnel coverage for ground stability.

Comparing with a conventional tunneling method, the URUP method can contribute to further advantages in both fast-track and environmental friendly construction (Figures 2).

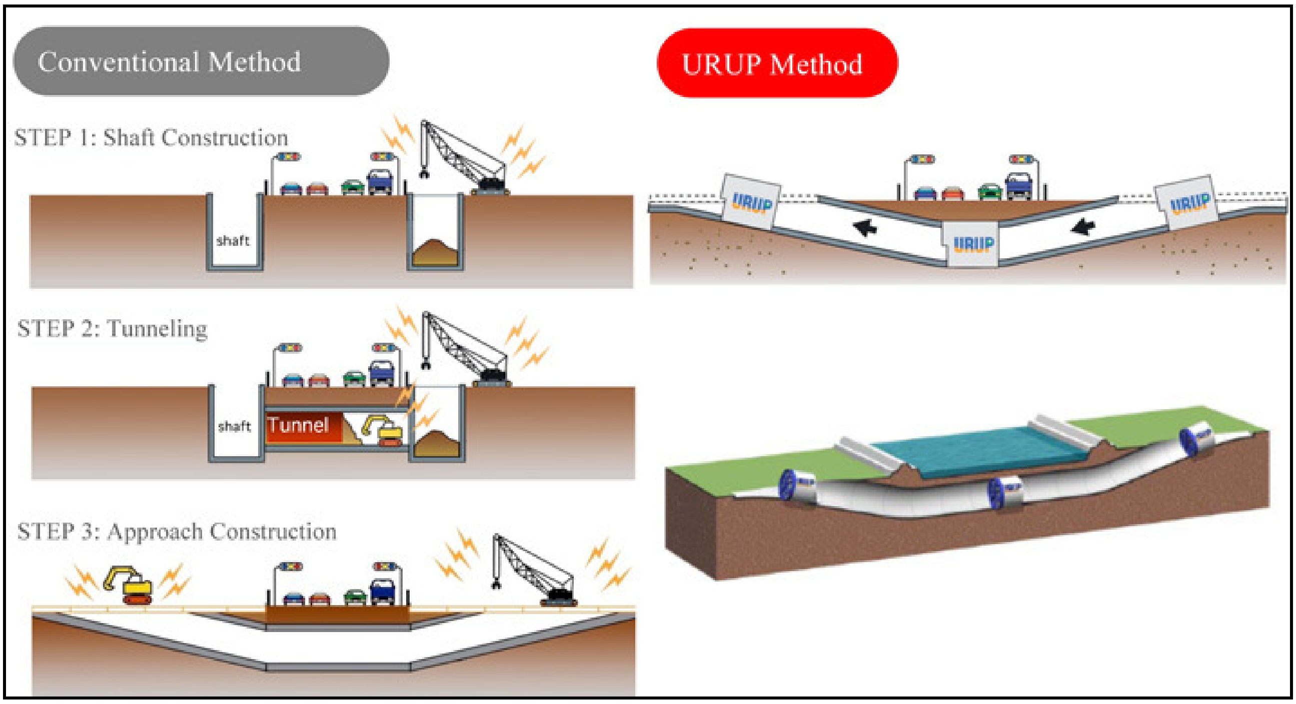

Figure 2. Comparison of conventional tunneling method vs. URUP tunneling method

Advantages of URUP

The notable advantages of the URUP method are summarized below.

(1) Schedule Acceleration

The eliminations of deep shafts and/or minimizing large-scaled open cut work can offer an accelerated schedule for construction.

(2) Minimizing Adverse Impacts to Existing Conditions

None or less open-cut construction requires a minimum impact to exiting traffic, surface structures, and nearby communities. Relocation of the existing utilities can also be minimized.

(3) Environmental and Ecological Friendly Construction

Less construction activity generates less noise and vibration. None or less open-cut construction can substantially reduce the volume and area of excavation required. Reduction of excavation volume will result in less carbon monoxide emission, providing a more environmentally friendly and ecologically efficient project.

DEMONSTRATION WORK

The feasibility of the URUP method was verified through the demonstration work. In the demonstration work, an EPB TBM (Figure 4) with the sizes of 2.15m in height and 4.8m in width was used to excavate over a distance of 100m. The tunnel alignment for the demonstration had a horizontal curve with a radius of 300m and a vertical curve with a radius of 100m as shown in Figure 3. The objectives of the demonstration were to verify the feasibility of "Departure and Arrival at the ground surface" and "excavation under a thin overburden layer."
The results of the demonstration work are summarized as follows:

Departure and Arrival of TBM at ground level

Visual observation at the launching phase was effective to maintain the stability of the cutting face by proper adjustment of the TBM face pressure and the admixture injection rate. The maximum ground displacement was within ±3 mm at the points (1 m laterally from the TBM) in the approach sections. The results indicate that the ground deformation was well minimized. The control of the TBM attitude during excavation was easily made as well as ordinary TBM driving by selective use of thrust jacks and articulation adjustment.

Excavation under a thin overburden layer

The face earth pressure in the demonstration work was controlled to keep it at the level of total overburden pressure. The final ground displacement was within ±10 mm. Use of lubricant was confirmed effective to minimize ground displacement as well as proper control of face earth pressure and backfill grouting pressure.

Knowledge gained from the demonstration work

The demonstration work verified not only the feasibility of the URUP method for underpass construction in rectangular shape but also indicated applicability of the method for other types of construction such as ramp tunnels in circular shape when proper face earth pressure, admixture injection rate and attitude control are provided.

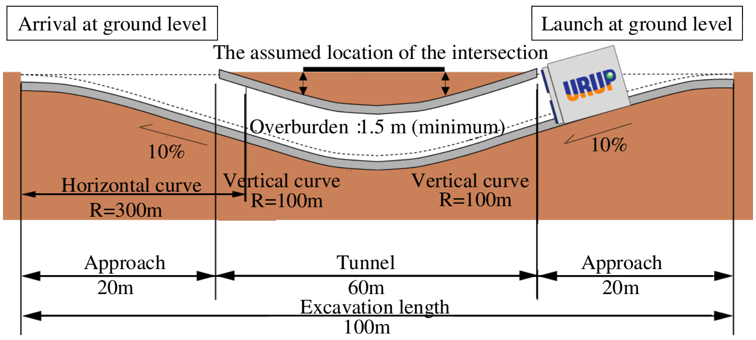

Figure 3. Alignment and profile in the demonstration

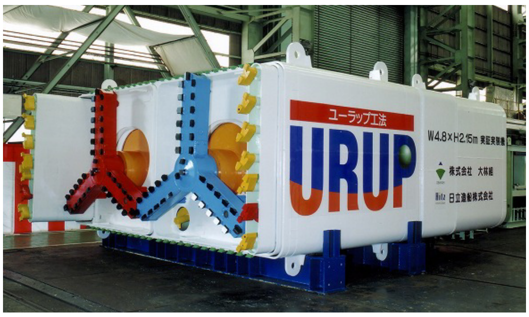

Figure 4. TBM for demonstration work

PROJECT NR.1 THE FIRST IMPLEMENTATION OF CIRCULAR URUP

The world's first URUP method using circular shaped TBM (hereafter called Circular URUP) was implemented for the underground approach highway tunnel in Japan.
The Oi Area Tunnel, a part of the Metropolitan Expressway Central Circular Shinagawa Route (hereafter called MECCSR), has constructed in the Tokyo metropolitan area. The entire MECCSR project includes 9.4 kilometers of 2-lane inbound and outbound roadway from Bay Shore Route Oi Junction to Shibuya Route 3, Ohashi Junction. The main purpose of this project is to mitigate long term traffic congestion in the metropolitan area, and to improve the living and global environment.
The Oi Area Tunnel Project includes the construction of the approach tunnel between Oi Junction

and Northern Oi ventilation shaft, in which two-lane roadways transit from viaduct to underground roadway.

The preliminary design envisioned building a cut and cover structure for the entire approach tunnel. The project contained challenging conditions from both technical and environmental standpoints, such as:

i) Excavation through soft cohesive ground.
ii) Minimum tunnel cover of 0 m, maximum tunnel cover of 25 m.
iii) The tunnel alignment passed under critical structures and utilities such as a power supply cable tunnel feeding power from a nearby power plant to the metropolitan area.
iv) Nearby residential area (including a high rise apartment building).

Figure 5. Overview of Oi Area URUP tunnel

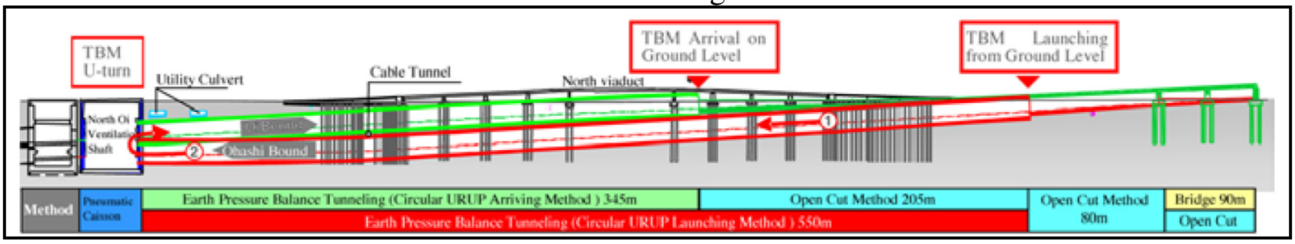

Figure 6. URUP Oi Area tunnel profile (first drive Ohashi-bound, second drive Oi-bound)

Construction Sequence

The construction sequence of the Oi Area Tunnel Project is described below:

i) The TBM drive for the Ohashi-bound tunnel launches from ground level (URUP method launching) and arrives at Northern Oi ventilation shaft which will be built prior to the TBM arrival.
ii) The TBM is turned around in the ventilation shaft and lifted up to the elevation for the second driven Oi-bound tunnel.
iii) The TBM drive for the Oi-bound tunnel re-launches from the ventilation shaft. The second driven TBM is planned to arrive at the ground level (URUP method arrival) (Figure 6).

Table 1. Project data (Oi Area tunnel)

Project Owner	Tokyo Metropolitan Government
Project Duration	June 25, 2008 to January 31, 2012
Tunneling Method	Earth Pressure Balance method (URUP method)
TBM Data	Excavation Diameter: 13.6 m Tunnel Length: Total 886 m Ohashi-bound (1st drive): 550 m Oi-bound (2nd drive): 336 m
Lining Data	Outside Diameter: 13.4 m Inside Diameter: 12.5 m Segment Width: 1,700 mm
Other Structures	Ventilation Station (TBM receiving / U-turn shaft) constructed by Pneumatic Caisson method 39 m × 35 m × 44 m (depth)

Technical Challenges in URUP Application

Prior to URUP application, the following technical challenges were identified and solutions for these challenges were discussed.

i) Potential ground deformation caused by TBM drive within the area of zero to thin overburden.
ii) Up lift buoyancy forces to the tunnel lining due to zero to thin overburden.
iii) Segmental lining instability from unbalanced earth and water pressure.

Solutions

i) As learned from the URUP verification project, the support face pressure was strictly managed to maintain the target support pressure with particular focus on the earth pressure measured at the crown of the tunnel.
In the approach section, target pressure was calculated using at-rest horizontal earth pressure + hydrostatic ground water pressure. By visually observing and adjusting the muck flow conditions in the chamber with proper ground conditioners, the TBM was safely launched utilizing the circular URUP method without causing noticeable ground deformation (Figures 7 and 8).
ii) During the TBM excavation phase, a temporary embankment was built over the ultra thin cover launching area in order to resist the uplift buoyancy acting on the tunnel lining.
Once all the permanent structure components are built inside the segmental lining, the total tunnel structure section will have sufficient dead weight to resist the uplift buoyancy. The temporary embankment can be removed after this phase.
iii) A half buried circular tunnel lining inevitably undergoes unbalanced external pressure because of the lack of the vertical earth pressure on the tunnel arch. In order to resist the unbalanced forces that potentially cause oval deformation, temporary steel struts are being installed inside the tunnel lining during the TBM drive (Figure 9). Once the TBM excavation completes, these temporary steel struts will be replaced with two tiers of permanent concrete beam struts.

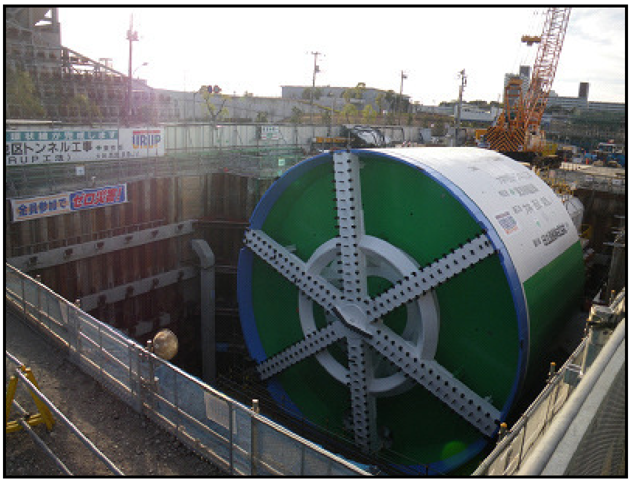

Figure 7. TBM before launching

Figure 8. TBM launching

Progress Update

In March 2010, the EPB TBM was successfully launched from the ground surface utilizing the URUP method. After successful excavation through the area of zero to thin overburden, the TBM passed under the existing power cable tunnel by the clearance of ±400 mm. The observed settlement of the structure directly above the tunnel drive was 10 mm. After the first Ohashi-bound tunnel

drive, the TBM arrived at the Northern Oi ventilation shaft by the conventional arrival method in November 2010.
The TBM was then turned 180 degrees and lifted up inside the shaft. The second drive re-launched in January 2011, the TBM passed above the existing power cable tunnel again by the same clearance of ±400 mm. The settlement of the same observed point was 5 mm. Thereafter continuously excavating safely, and finally the TBM emerged from the ground utilizing the URUP arrival method in May 2011. (Figure 10)

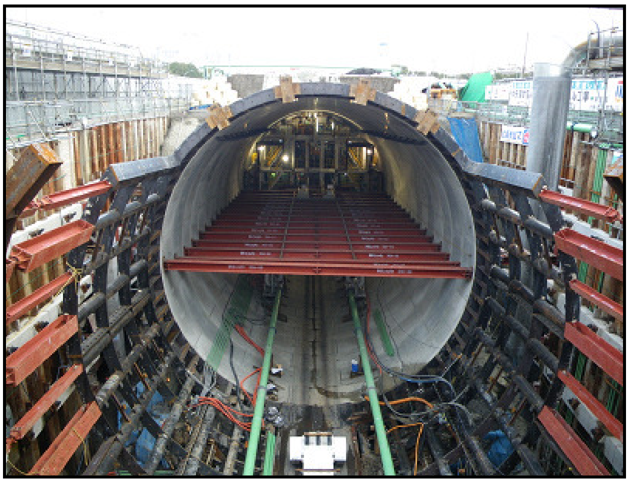

Figure 9. Temporary strut installing

Figure 10. TBM arrival

PROJECT NR.2 URUP APPLICATION TO GAS LINE TUNNEL
The URUP method was applied to another case in Japan. The Tahara 2nd Trunk Line Mikawa Bay Crossing Shield Tunnel Project involves installation of a new gas conduit underneath the seabed of Mikawa Bay (Table 2).
The original plan, as shown in Figure 11, had positioned deep vertical shafts on both ends of the tunnel for use in launching and receiving the shield tunnel drive. Installations of the conduit inside the vertical shafts and inside the tunnel were planned after completing the tunnel excavation in the original scheme. In this project, application of the URUP method contributed to substantial schedule acceleration and cost reductions as explained hereafter.

Tunnel Alignment

i) By selecting the URUP method, a 15.0% downhill launching, and a 14.0% uphill arrival were applied to the entrance and end of the tunnel alignment.
ii) Although the tunneling length was increased by 150 m in this proposal, the overall conduit length was reduced by 30 m because of the eliminations of the vertical shafts.

Launching and Arrival

i) Surface launching and surface arrival eliminated the necessity to excavate two 25m deep vertical shafts (support of excavation, ground modification, and open cut excavation).
ii) Surface launching and surface arrival do not require break-in and break-out through a soft eye under high earth pressure. As a result, ground modification behind the soft eye was not required.
iii) Surface launching allowed the lineup of the TBM and all its trailing gears on the surface. The TBM was able to start productive excavation with full equipment set up from day one.

Table 2. Project data (Tahara 2nd Trunk Line Mikawa Bay Crossing Shield Tunnel Project)

Project Owner	CHUBU GAS Co.,Ltd.
Project Duration	June 28, 2010 to November 30, 2011
Tunneling Method	Earth Pressure Balance Method (URUP method)
TBM Data	Excavation Diameter: 2.13 m Tunnel Length: Total 1,086.7 m
Lining Data	Outside Diameter: 1.956 m Inside Diameter: 1.800 m Segment Width: 750 mm

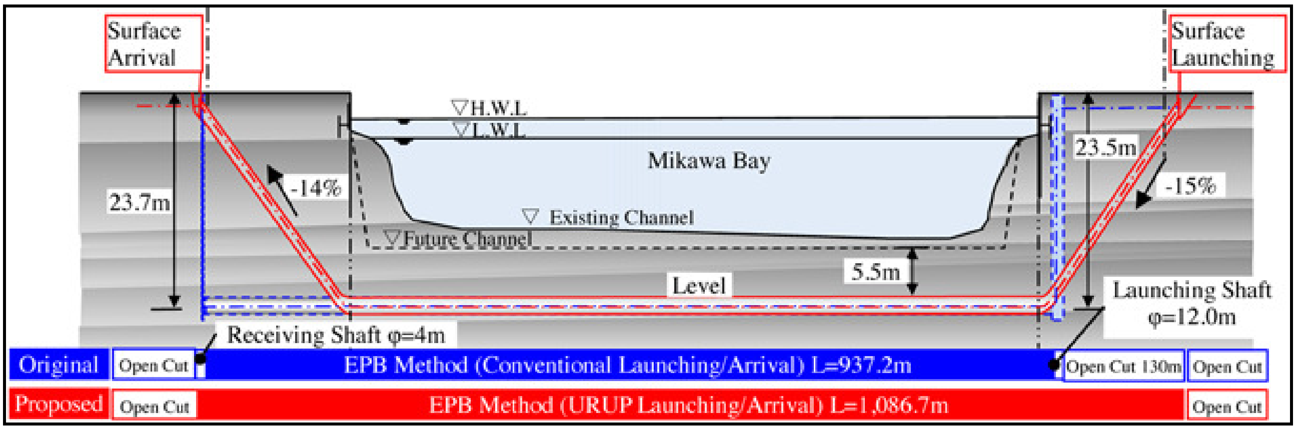

Figure 11. Comparison of original design and proposed design

Conduit Installation

i) The maximum length of the gas conduit sections was no longer restricted by the width and/or the length of the vertical shaft. Therefore, ramp access allowed by the URUP method provided an efficient and safe transportation path compared to that in conventional vertical access.

ii) Installation of vertical conduit was no longer required.

Schedule

i) Eliminations of vertical shafts construction contributed to a time saving of 5½ months.

ii) Efficient ramp access and elimination of vertical conduit installations were accounted for a further time saving.

Figure 12. TBM launching

Figure 13. TBM trailing gears

Progress Update

On September 1, 2010, the TBM began cutting the launching slope face (Figure 12). As shown in Figure 13, the URUP launching configuration enabled connection of all the TBM trailing gears from the beginning, and minimized the time for set up or re-configuration of equipment required by the conventional process. In order to minimize the reach of the URUP method (to reduce the length of ultra thin excavation), a maximum grade of 15% was introduced. The selection of 15% grade was based on the successful record of conduit installation in this slope in the past. A rack and pinion railway system was utilized for the locomotives to overcome this steep slope, and has been providing safe transportation and access for the project.

The World's first ever Circular shaped TBM surface arrival was achieved safely in January 2011. (Figure 14)

Figure 14. TBM arrival

CONCLUSIONS

The new tunneling technology URUP method developed to shorten construction period and decreases noise, vibration and secondary traffic congestion for environmental friendly was validated through the public construction projects using a circular TBM, and was further studied from these projects. The proposed new technology and the reports from the successful application of the URUP provide substantial benefit and flexibility to the planning of future tunnels as recent urban construction is facing greater technical challenges while the society is demanding a minimum impact to the local and global environment.

ACKNOWLEDGEMENTS

The authors would like to thank the Tokyo Metropolitan Government and Chubu Gas Company Ltd. for their support in publishing this paper. Any opinions, findings and conclusions expressed in this paper are those of the authors and do not necessarily reflect the views of the Tokyo Metropolitan Government or Chubu Gas Company Ltd.

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