Little-by-Little Excavation Creating a Large Structure

The Under Railway Road Tunnelling (URT) method makes it possible to bore a tunnel without stopping traffic where a railroad and road intersect

The shell of a tunnel is constructed with elements (square steel tubes) to complete the tunnel structure. Excavation and finishing work are then performed on the inner part of the shell all at once to complete the tunnel. This article describes an ideal tunnel construction method that ensures safety, short construction period, and high cost efficiency, and that does not interfere with traffic.

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Grade separated railroad/road crossing constructed using the URT method

Grade separated crossing

Railroad crossings that are closed longer than they are open during commuting hours, commonly known as the "crossings that never open," are becoming a social problem. In addition, since they are traversed by people, as well as a variety of vehicles such as bicycles, motorcycles and automobiles, a railroad crossing is highly likely to become the scene of an accident and could become a contributor to a traffic jam. With the aim of eliminating traffic jams and accidents attributed to railroad crossings, eliminating traffic jams right before intersections on arterial highways, and improving urban functions and usability, the introduction of grade separated crossings is being implemented. Such grade separated crossings are roughly divided into two groups by mode of crossing, namely, an overpass, where a road is elevated to pass above a railroad or another road, and an underpass, where the ground is excavated so that a road passes under a railroad or another road. In recent years, underpasses have been employed at a larger number of crossings, mainly because of consideration for the urban landscape. The construction of an underpass, where a road passes under another structure, means that a short tunnel must be constructed. Whereas a long tunnel is generally bored through with a shield machine, a short tunnel is bored in a completely different way. This article describes one of the construction methods for boring such short tunnels, known as the Under Railway Road Tunnelling (URT) method.

History and features

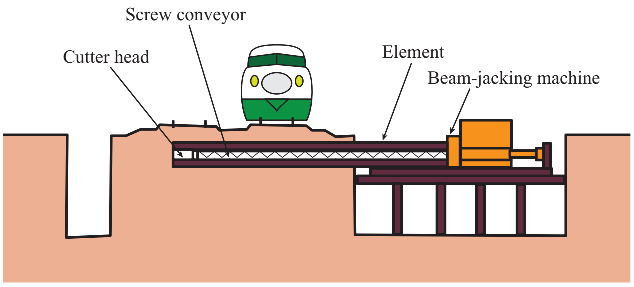
In the URT method, a pit is dug on each side of a railroad or a road straight down from the ground surface. One of these pits is called a starting shaft and the other an arrival shaft. From the side wall of the starting shaft, excavation and jacking is repeatedly performed using dozens of elements (hollow angular tubes made of steel) to form the circumference of a tunnel. After the elements have been connected with each other by a cable, concrete is poured into the elements and then hardened. Soil is then dug out to complete the tunnel. This method was developed in 1976 by the former Japanese National Railways, Ishikawajima-Harima Heavy Industries Co., Ltd., and Kyokuto Boeki Kaisha, Ltd.

Thereafter, the method has gone through various technological developments up until now, which include ① the development of an element head, i.e., a distal tip of an element equipped with a blade for excavation, ② the development of a joint for connecting one element with another, ③ improvements to the beam-jacking machine and elevating frame, ④ the development of techniques for handling obstacles, ⑤ the development of water cutoff techniques, and ⑥ the development of transverse prestressing of concrete materials. The URT method has the following features:

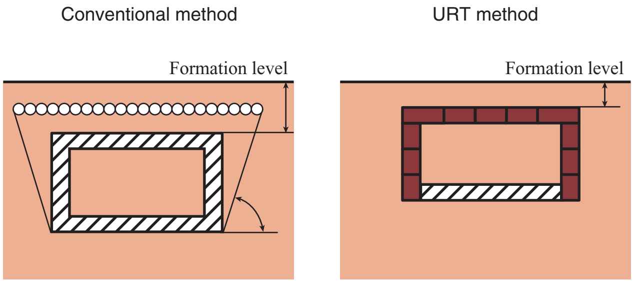
(1) The way in which small-section elements (square steel tubes) are advanced one after another renders the face area to be excavated more independent, enabling the impacts on the peripheral areas to be reduced; thus, construction work can be executed without interfering with train service or road traffic.

(2) Since the elements themselves are used as part of the tunnel, the depth of overburden over the finished structure (the thickness of soil covering the tunnel) can be reduced.

(3) Construction periods that affect live lines can be shortened to ease the burden attributed to speed reductions and nighttime work.



URT method allowing construction to be executed without closing the construction site to all traffic



Thin overburden

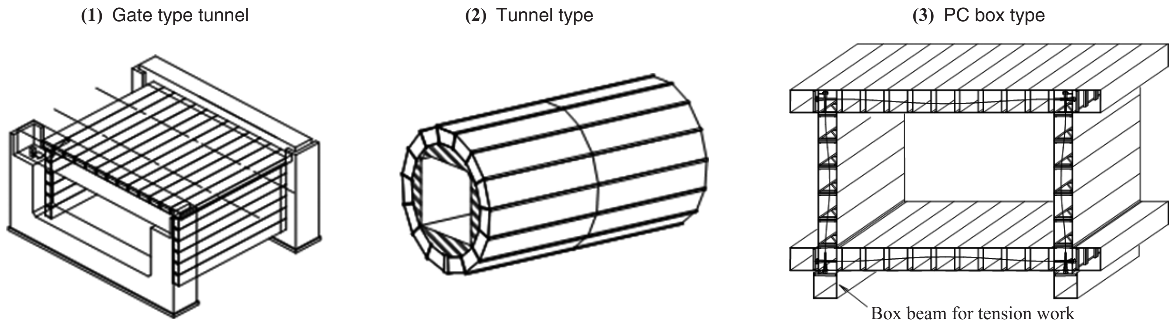
Structural types

Basically, the URT method has three structural types.

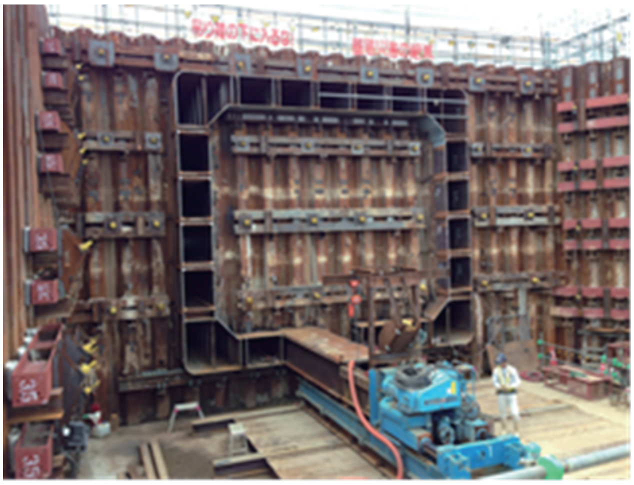
(1) Gate type tunnel

This type of tunnel has a structure consisting of ceiling box beams intended to bear the loads of trains or automobiles, both ends of which are connected to main girders parallel to the railroad track or road, and side-wall elements intended to bear lateral earth pressure, both ends of which are supported by an abutment.

This type has advantages, including ① reduced impact on the relevant track and ② the ability to reduce the depth of overburden. The bridge sections on the Hokuriku Main Line of Japan Railways (JR), and over bridges on JR's



Structural types of the URT method



URT work without box beams for tension work in progress

URT work without box beams for tension work at completion

Joban Line and Tohoku Main Line are examples of sites where a Gate type tunnel is employed.

(2) Tunnel type

The tunnel type is designed so that elements arranged to form an arched or cylindrical structure bear the train load and earth pressure.

Although the depth of overburden is larger than that of a Gate type tunnel, the tunnel type has advantages including the following: ① the approach in which an arched structure is formed by advancing elements and pouring concrete into them simplifies the type of works, allowing the construction period to be shortened; ② since elements can be connected with each other on site by welding while they are advanced, a longer tunnel can be constructed (the longest length previously achieved: 80.5 m). The tunnel type has been employed for a viaduct bridge (where a railroad passes above a road) on JR's Kansai Main Line, the ordinary road passing under Suzuka Circuit (Suzuka City, Mie Prefecture), and a connection road between buildings.

(3) Prestressed concrete (PC) box type

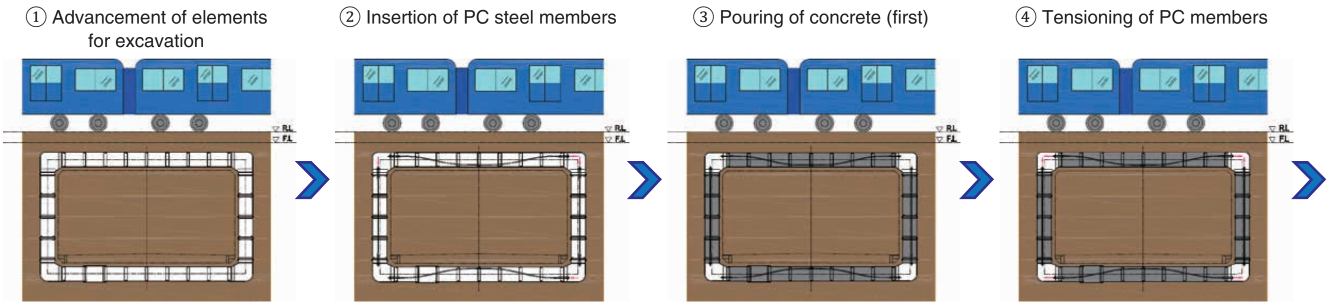
The box type is a box culvert constructed by arranging elements to form a box shape, inserting a PC cable perpendicularly to the elements, pouring concrete into them, and then introducing tensioning force (prestress). Truss elements are used in side walls to integrate poured concrete with the framework. Although works must be executed in a small space, the PC box type has advantages, including ① reduced impact on the tracks, ② the ability to reduce the depth of overburden, and ③ the ability to provide a longer overall tunnel length.

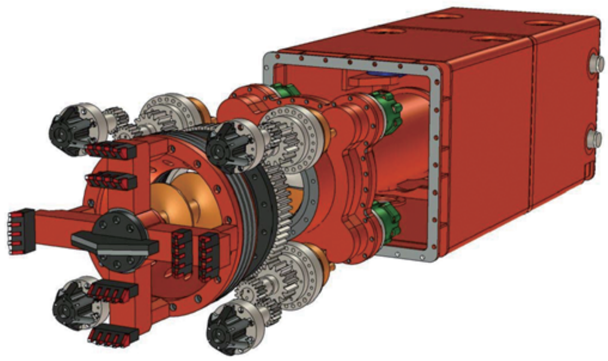
The PC box type has been employed at sites such as a viaduct bridge on JR Tokaido Main Line, an over line bridge on a station's premises on JR Sobu Main Line, a pedestrian road under an expressway, and a roadway between buildings.

Type without box beams for tension work

The original PC box type needed to have box beams for tension work in their corners to perform tension work on two intersecting PC steel members, but these box beams were not needed for a tunnel to fulfill its functions. We thought that the box beams for tension work could be omitted by using corner elements as workspace for tensioning PC members and that this would lead to improved economic efficiency. In 2003, we therefore conducted a load test on the corners using a full-scale model, confirming that the test results were comparable to the results of an experiment conducted on the traditional type having a structure with intersecting PC steel members. Following this, we completed a demonstration in 2011.

The viaduct bridge situated between Shimamoto station and

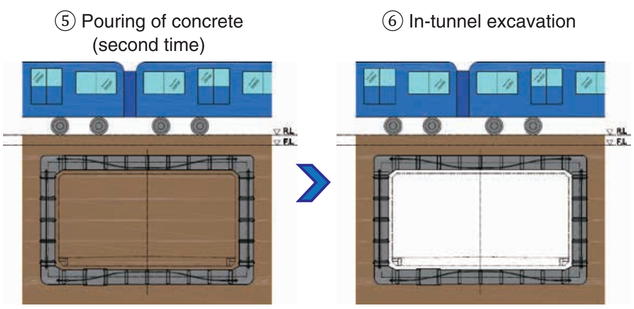




New type of excavating machine

New type of excavating machine (in an element)

Takatsuki station on JR's Tokaido Main Line, which was constructed for works associated with the construction of an accessway to the Second Meishin Expressway, forms a grade separated crossing with JR's Tokaido Main Line. The overall length of the bridge is 22.0 m. Since the depth of overburden was only about 800 mm, the type without box beams for tension work was adopted to reduce the number of elements that needed to be advanced, in order to reduce the impact of the element-advancing work on the tracks. Due to the extremely soft silty sand in the area, it was a challenge to properly control the accuracy of element advancement, but the work was completed with the desired accuracy achieved.



URT work sequence for the PC box type

Improvements of excavating machinery

Previously, one drive unit was shared between an excavating cutter and a screw conveyor for earth removal. This drive unit could only rotate in one direction and rolling remained to be addressed.

(1) An improvement was made to provide the cutter with a drive unit independent of the earth-removing mechanism (screw conveyor), in order for the cutter to have a structure allowing it to rotate in both the forward and backward directions, making it possible to address rolling.

(2) Excavation efficiency was improved by deploying a sub-cutter at the four corners. Whereas the ratio of excavated area achieved by a single-cutter head was 70%, the same ratio achieved by a five-axis cutter head was improved to 90%.

During the experimental construction that was implemented to verify workability, trial construction was executed using an 800 mm overburden, resulting in no marked upheaval or subsidence. In addition, the trial work demonstrated that an advancement speed of 50 mm per minute was achieved in diluvial clay soil with an N-value of about 10 (the advancement speed actually achieved by the conventional URT method was about 30 mm per minute).

The Future of the URT method

Since 1978, we have executed URT works at 139 sites (including three under construction). In addition, the type without box beams for tension work has been put into practical use (two sites in service and one site under construction), thanks to which we are able to reduce the area of shafts and the number of elements that need to be advanced. In order to increase the width of the type without box beams for tension work in the future, a large tensioning force must be introduced, for which an appropriate PC configuration and PC-tensioning material remain to be selected. However, we have confirmed improved speed of mechanical excavation and become able to shorten construction periods.

Since the URT method allows for advancement toward an in-service structure (that is, advancement that can be performed without the need for an arrival shaft), we consider it applicable to underground passageways, for example. With the advice of our customers and contractors, we will continue to commit ourselves to several tasks, including the development of techniques for accelerating advancement, improving safety and reliability, and improving the water cutoff performance between elements. We will also review our efforts as appropriate to make improvements.

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