

Challenges & Changes

TUNNELLING ACTIVITIES IN JAPAN 2004



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JAPAN TUNNELLING ASSOCIATION

Foreword



On behalf of the Japan Tunnelling Association, it is my great pleasure to present "Tunnelling Activities in Japan 2004".

The Japanese archipelago extends northeast to southwest over 3,000km. Seventy percent of the national land is mountainous. Many cities and villages are dispersed widely apart from one another, occupying limited plains along the coast. After a rapid progression of urbanization, 50% of the entire population is concentrated in three major metropolitan areas that account for only 10% of the entire land area. Under such geographic and demographic conditions, we are constantly confronted with the need to develop infrastructure and promote versatile utilization of limited national land through innovative technologies and management systems in order to ensure the mobility of people and goods and enhance regional linkages.

In the metropolitan areas, it is essential for us to develop technology to enhance the utilization of underground space to achieve sustainable development and improve the environment we live in. It is our continuing mission to foster new technology and disseminate knowledge through international cooperation and a variety of activities such as the implementation of joint studies with the International Tunnelling Association.

"Tunnelling activities in Japan 2004" introduces the eminent examples of tunnelling technologies and the utilization of underground space in Japan. It is our sincere hope that this booklet will serve as a useful resource to our readers.

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Hiroshi MITANI, Dr. Eng.
President
Japan Tunnelling Association

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Planned Shinkansen Lines

Outline of Planned Shinkansen Lines

The shinkansen lines bring economic and lifestyle benefits not only to the regions along which they run, but also to the residents of large cities, who are stimulated by the fulfillment of leisure activities created from the results of time saving, and who are brought a lifestyle of increased relaxation and refreshment. In addition to creating high speed safe travel, compared to other modes of transportation, they are more environment friendly and exceedingly energy efficient, and so there are high expectations for the promotion of future lines. Presently, three planned high-speed shinkansen lines, the Tohoku, Hokuriku and Kyushu lines, are in progress, based on the National Shinkansen Development Act of 1970.

Route Map



Tohoku Shinkansen

The Tohoku Shinkansen line, by extending the existing Tokyo – Morioka line, will run from Morioka to Shin-Aomori, and will connect to a Hokkaido Shinkansen line. Of this, the Morioka – Hachinohe line is already in operation, and the more northerly Hachinohe – Shin-Aomori is currently under construction (since 1998).

This section of line, which runs from Hachinohe via the newly constructed Shichinohe station, extends for approx. 82km to Shin-Aomori station jointly with the Oou Main Line. In addition to the construction of the 26.5 km long Hakkouda Tunnel, which started in August 1998, the Rokunohe Tunnel,



the Sanponihara Tunnel, Ushikagi Tunnel, Hosogoe Tunnel and others are also under construction. Once this section is complete, the travel time between Tokyo and Aomori will be reduced from the existing 3 hours 59 minutes by 40 minutes.

Hokuriku Shinkansen

The Hokuriku Shinkansen line runs from Tokyo via Takasaki and on to Osaka. Of this, the Takasaki – Nagano section is already operational, and the further inland Nagano – Toyama section and the Isurugi – Kanazawa sections are currently under construction.

The Nagano – Toyama section starts from Nagano station and runs through Iiyama station, which has been built adjacent to the Iiyama line Iiyama station, then to Joestu Station built next to the Shinestu Main line Wakinoda Station, on to Itoigawa station, which also lies on the Hokuriku Main line, then through the newly built Shin-Kurobe Station and on to Toyama station, a total extension of 170 km. Of the Nagano – Joestu section works, construction started with the Iiyama tunnel (total length 22.2 km) and others, and the Kousyasan tunnel and Takaoka tunnel are also under construction.

The Joestu – Toyama section construction started in March 1994, and includes the Shin-Oyashirazu and Asahi tunnels. In addition, for the Isurugi – Kanazawa section, 1km from the Hokuriku Main Line Isurugi station in the Kanazawa direction there is a new West Isurugi signal box where the line diverges, and the length of line from there to Kanazawa is 24km. The works for this section started in November 1992, and 47% of this line runs in tunnels of which Shin-kurikara tunnel and 8 others are all already completed.

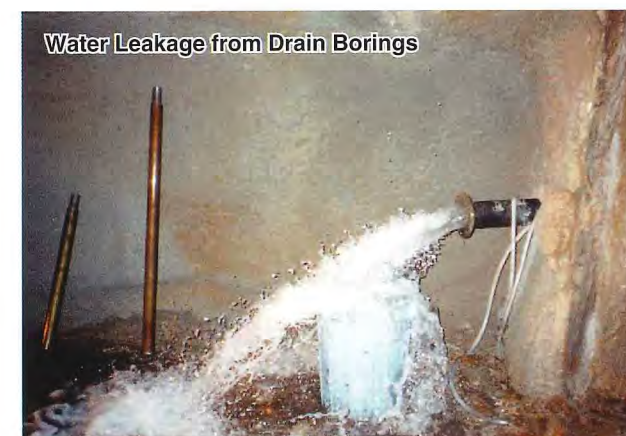
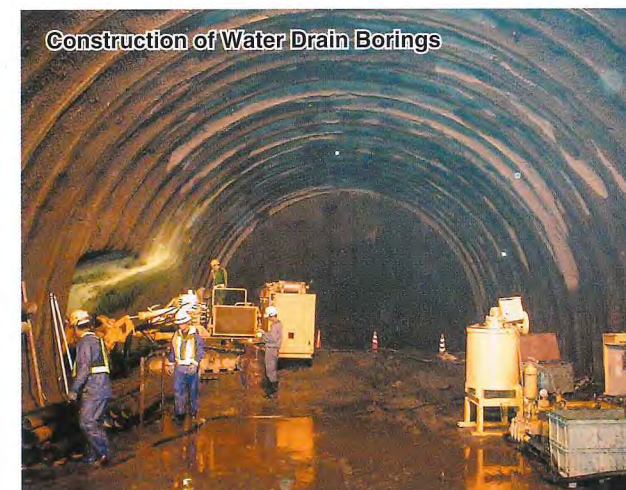
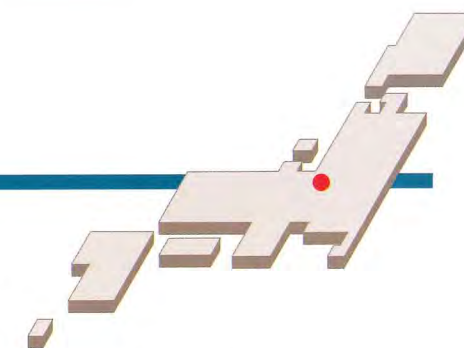
Kyushu Shinkansen – Kagoshima Route

The Kyushu Shinkansen Kagoshima route runs from Hakata to Nishikagoshima, and is a line 257km long. Of this, the Shin-Yatsushiro – Nishikagoshima section is 127 km long, running from Shin-Yatsushiro station, Shin-Minamata station, Izumi station, which is located adjacent to the existing station, through Sendai station to Nishikagoshima station. Of this section, the No. 3 Shibisan Tunnel (10.0 km) is the longest tunnel, and all other tunnel works, which run through the



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Sirasu plateau using water permeable sub-bases, are all complete.

The length of Hakata – Shin-Yatsushiro section, is long 130km which runs from the Sanyo Shinkansen line Hakata station to Shin-Yatsushiro. 10 tunnels are under construction.

They are Chikusi tunnel, Miike tunnel, Tamana tunnel and others.

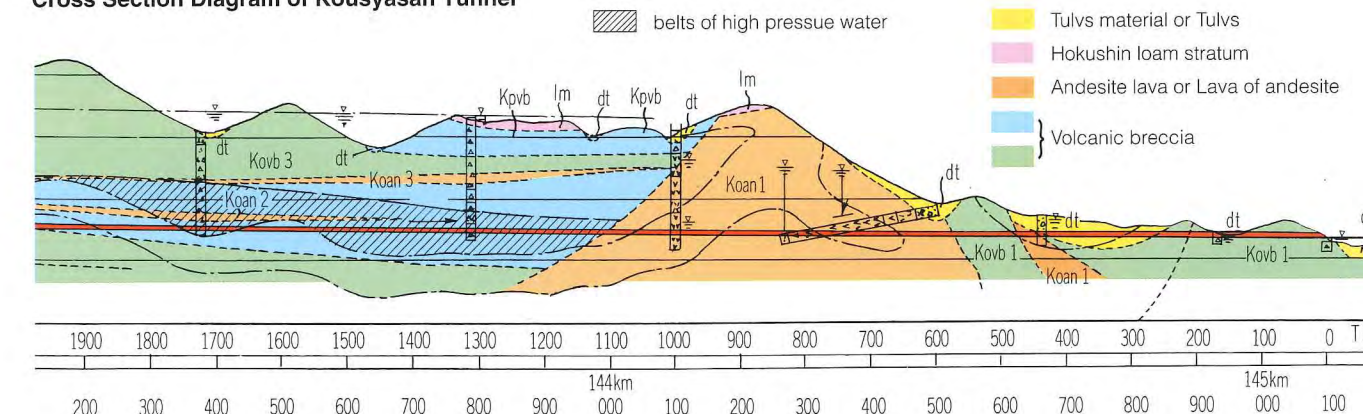
Kousyasan Tunnel of Hokuriku Shinkansen

The Kousyasan Tunnel of Hokuriku Shinkansen is a 4170m long tunnel which lies in the northern part of Nagano Prefecture. Works are progressing from both Nagano and Toyama portals, and as of July 2003, excavation of approx. 80% of the tunnel length was complete.

The ground conditions consist of volcanic breccia and tuff breccia in andesite rock. Close to the central section of tunnel, there are belts of high pressure water inflow strata, which were confirmed beforehand by boring surveys. Moreover, the stiffness of the ground is low, and has a permeability index of 10-2 cm/sec, and due to this very high permeability, there was concern of the possibility of the occurrence of collapses of the cutting face and crown during excavation due to the high water pressures. In order to stabilize the cutting face, water drain borings were carried out. From the Toyama portal over a distance of between 420 – 1698m of the progress of the cutting face, 61 drain borings were carried out, and over the total 9954m length, and average of 1 every 250 m, or a maximum of 1 over 300m borings were conducted, and a maximum of 3.2 tons/minute, or a total over the whole length of tunnel of 24 ton/minute of spring water flows were recorded. Due to the drain borings, the cutting face was stabilized, and excavation was achieved without severe troubles.

In addition, in the Nagano-side of the tunnel, the portal was planned on a gentle slope, and over a part of the length (approx. 80m), the cover was below 2m. As it is expected that the crown part of tunnel would be collapsed, the auxiliary methods will be performed using the backfilling method from the inside of tunnel to improve the ground and the embankment method on the ground surface to increase the cover. The ground improvement method using the cement-based solidifier will be adopted to reinforce the embankment to be constructed and the existing ground above the tunnel as one continuous body. At the current moment, the construction method for this section is planning.

Cross Section Diagram of Kousyasan Tunnel



Large Scale Underground Station in Urban Area (Akihabara)

Introduction (Overall Outline of the Tsukuba Express)

The Tsukuba Express is an inter-city express railway line stretching 58.3 km linking between Akihabara in Tokyo to Tsukuba in Ibaragi Prefecture.

This line is planned to eliminate congestion on the existing parallel Joban Line, and is being built by Japan Railway Construction, Transport and Technology Agency. It is scheduled that the railway will be operated by the No. 3 sector of the Metropolitan Intercity Railway Company. 24% of the total line length will run in tunnels, and of this 71% will be concentrated inside Tokyo. Within Tokyo, 7 stations are planned, of which 6 will be underground stations.

The terminus station "Tsukuba Express Akihabara Station" has been designed as 4 level underground station with approximate dimensions of width 22m, depth 37m and overall length 280m, and will connect with the JR Yamanote line, JR Keihin Tohoku Line and JR Sobu Lines. The station will all be built by open-cut tunnel, one part of which (length approx. 70m) will cross the JR Sobu line, and the East Japan Railway Company commissioned the Japan Railway Construction Transport and Technology Agency to construct this part. (perspective of underground station). The ground in this area, from the ground surface to a depth of around 25m consists of weak soil deposits (alluvial layer), and beneath this are mainly hard strata consisting of gravels and sands (diluvial layer).

For the construction of this underground station, there are many nearby important structures, and it was necessary for the construction to protect and maintain these structures so as not to suffer deformation. The underpinning process and the development of a steel pipe column construction method that are employed for the underground station construction are reported here.

Underpinning Works

The JR Sobu Line runs on a steel viaduct, built in the 1930's. The foundations of this viaduct have reinforced concrete grouped piles, end bearing at a shallow depth of



GL-7.0m

To construct the underground station underneath the viaduct, and to maintain the safety of the trains, it was necessary to prevent displacement of the viaduct. Thus, before constructing the underground station the support for the viaduct needed to be replaced.

(1) When replacing the support of an existing structure above the construction of an underground structure, it is normal to replace the support for the foundations of the existing structure. However, for the reasons given below, for this project, the new viaduct was constructed and this was supported by the existing viaduct superstructure.

(1) the existing structure was at around 70 years old, quite aged.

(2) Directly above the underground station it is planned to build a new urban planning road, and the piers of the existing structure clashes with this.

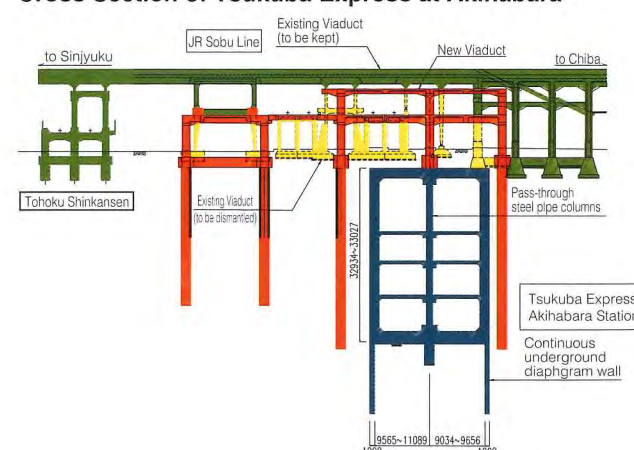
For the replacement works, temporary steelwork and hydraulic jacks were installed above the new viaduct, and the construction method would be carried out from this. Using this method, and considering the influence of the train load, and advantage was load adjustment during construction could be done. 16 hydraulic jacks were used, each with a lifting capacity of 100kN to 200 kN.

The replacement work was carried out in short periods during nighttime when there were no trains running (approx 3 hour periods), and the work was partially repetitive. Work was carried out while continually surveying and checking on the permissible vertical deflection of 6mm. This permissible deflection value was decided based on the JR Sobu Line track structure without ballast.

Development of Steel Pipe Column Construction Method

The construction of the new viaduct structure carried out prior to the replacement works uses steel pipe columns from the underground station continuing through to the viaduct columns. To do this, it was necessary to construct the foundation piles of the new viaduct simultaneously with the underground station steel pipe columns. The construction of the steel pipe columns (total length; approx 37m, dia.

Cross Section of Tsukuba Express at Akihabara



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1200mm), due to be built beneath the existing viaduct structure, created a height restriction for the construction. Thus, constructing deep 'Chicago Method' foundations using man power would lengthen the schedule. In addition, using the Chicago Method deep foundation method, as large deep holes would be built close to the existing load bearing structure, would necessitate strengthening methods such as chemical injection around the area of the holes, as a countermeasure to prevent displacement of the existing structure, which was feared would cause the construction cost to increase.

In order to solve these problems, for this project a new construction method of steel pipe columns was developed. The main construction sequence of this method is described



below (steel pipe column construction sequence)

- (1) Mechanical hole drilling (reverse circulation method)
- (2) Prior installation of casings (t = 9mm), with diameters larger than steel pipe columns, into slurry water
- (3) Pour concrete infill (as water barrier) into base and around casing perimeter, and drain out water inside casing.
- (4) After inside the casing has dried out, welded steel pipe columns are installed and the casing then withdrawn during excavation of the underground station.

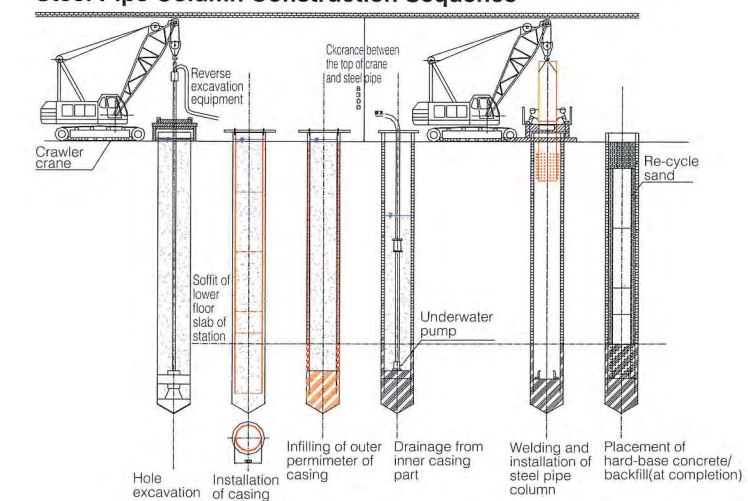
For this project, by the adoption of this new construction method, it was possible to shorten the construction schedule for the continuing steel pipe columns and also to construct safely while preventing deformation of the existing structure (new construction method photo)

Conclusion

It is expected that the adjacent works reported here could be expanded in future urban projects. From the experience of this construction report, it is thought the construction accuracy of underground station structures can be improved.



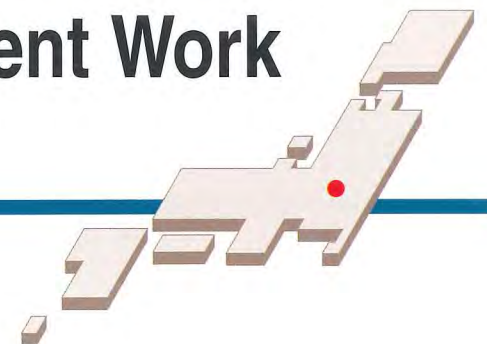
Steel Pipe Column Construction Sequence



Agatsuma Line Replacement Work on Yanba Tunnel

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In 1947, the Kanto region of Japan was affected by a large violent typhoon, and so to alleviate downstream flood damage and to ensure water supply to the metropolitan region, the Ministry of Land, Transport and Communication is promoting the construction of the Yanba Dam. From the planning of Yanba Dam, around 340 households including the Kawayu hot spring resort, National Roads and around 6km of the JR Agatsuma line were to become submerged.

The East Japan Railway Company received a commission from the Ministry of Land, Infrastructure and Transport to replace approx. 10.4km of the JR Agatsuma line. In this replacement works, there are 3 tunnels, 5 bridges, 1 viaduct and 1 station. Among these structures, the Yanba Tunnel is a new single line tunnel, whose length is 4,582m and leads from the start point of the replacement line to around mid-way of the replacement line where a substitution area of the Kawayu region is being newly developed.

At both tunnel portals of the Yanba tunnel are box culvert sections (L=219m), and the departure shaft and arrival shaft are NATM tunnels that are 239m long. The full face of the 4,124m central section is constructed by TBM. This is the first time in Japan that the complete cross section of a single line railway tunnel has been excavated in full face using the TBM method.

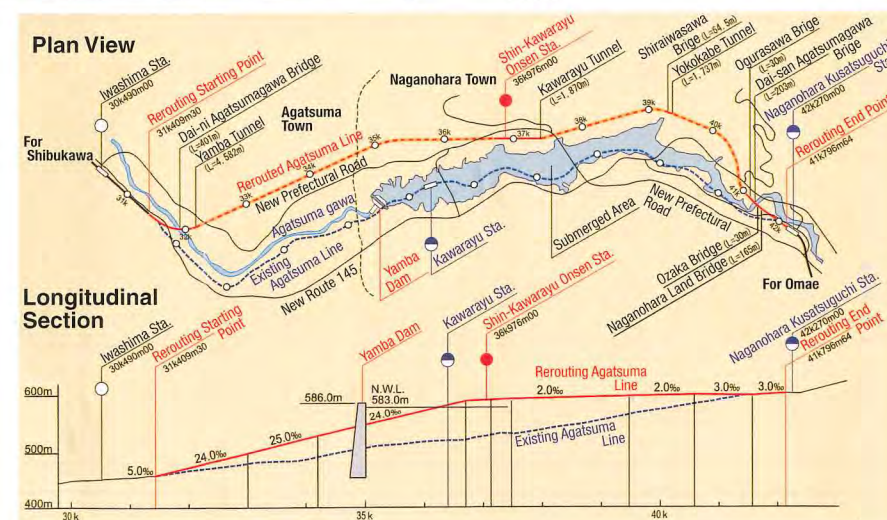
The TBM has an overall length of 17.83m, a weight of 350 t



and a machine diameter of 6.82m. The cutter head face plate has 48.17 inch roller cutters, and has a maximum turning speed of 6 revolutions per minute. The gripper reaction is 35,000 kN and the overall thrust force of the machine is 15,000 kN. Equipment for applying shotcrete and installing rock bolts mounted on the working platform which is attached to the rear of the TBM. Furthermore, when 8 rear wagons with the shotcrete plant and dust collector etc. are connected, the total length becomes 103.3m. In this TBM construction, as the excavated face becomes the completed cross section, the control of accuracy becomes more important than excavation speed, and a progress rate of 300m per month was planned.

Summarizing the ground conditions, from the start point there were mainly andesite type rocks, and near the end point plagioclase porphyry with a layer of andesite type rock in between. In the andesite type rocks section, it was confirmed that sills of porphyrite and andesite had intruded, and that these intrusions occurred almost in the same era of the penetration of the plagioclase porphyry. Furthermore, close to both portals, uncoagulated deposits of talus, mudflow deposits, terraces deposits, loam layers etc., cover the base rock. Although both tunnel portals pass through the uncoagulated layer, it was expected that apart from these parts the tunnel would pass through relatively sound rock, and around 60% of the tunnel length would have an unconfined compressive strength of over 130 N/mm². In addition, through seismic sounding surveys, 5 places of low velocity belts were found, indicating heavily fractured belts. As there is thus a possibility of encountering small scale deforming belts and crushed belts, before arriving at these places pre-boring investigations will be carried out, and careful construction confirming the rock condition will be made. The tunnel coverage varied from a minimum of 6m to a maximum of 350m.

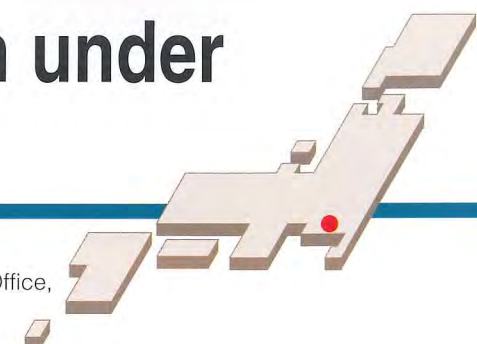
As for recent the construction progress, from January 2003 the TBM departure shaft was excavated 180m by mechanical excavation, and from September 2003 TBM excavation started. Tunnel breakthrough is expected in the spring of 2005.



Urban NATM Construction under Operating Railway Lines

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In Japan when excavating in weak ground in urban areas, while it is typical to use shield tunneling methods which cause small ground deformations, due to surrounding ground conditions and the progress of auxiliary methods for support work such as forepiling and the adjustability to changes in cross section, and for economics, it was decided overall to use urban NATM techniques. This project was the world's first case for excavating a tunnel by NATM techniques directly beneath an operating railway, with an overburden of 11-25m and a length of 850m.

The ground conditions consist of stable stiff silt and consolidated sand of Pliocene series. The tunnel crown passes through an approx. 5-8m thick uniform stiff silt layer. The grain sizes of the sand are fine and uniform, with large quantities of artesian underground water of 0.2 - 0.3 MPa.

Taking the required track and platform width, land widths, ground conditions and coverage into consideration, (a)Double bore NATM tunnel, (b)Twin 'binocular' NATM tunnels, (c)Triple bore NATM tunnel, (d)Double line single circular NATM tunnel were adopted. As there were many adjacent important structures, and as it was being built directly beneath tracks, settlement countermeasures were obligatory, and also effective usage of auxiliary methods and an overall management system was required. For the track settlement, the maximum limit of relative settlement was set at 7mm between two points at intervals of 10m based on the maintenance criteria and the construction control criteria set at 3.5mm.

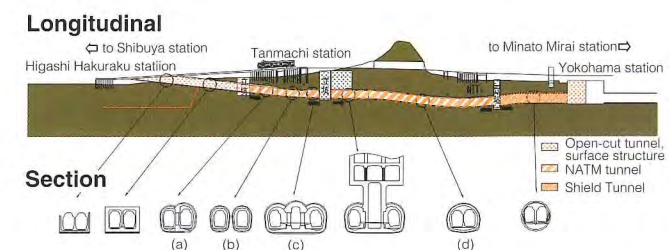
The new underground platform of Tanmachi station was built in the triple bore tunnel constructed by using the vertical shaft (30m x 20m) as the pilot base excavated directly underneath operating railway lines which were temporarily supported. In addition, in the top part of the tunnel, part of it was excavated by cut and cover method to form a 3 basement level station structure. A previous FEM analysis was used to study the basis of construction methods, and during construction, construction management and control measurements were closely carried out, and it was important for measurement data to be accurately judged and fed back into construction execution.

For ground settlement countermeasures, in order to restrain settlements from tunnel excavation which could cause

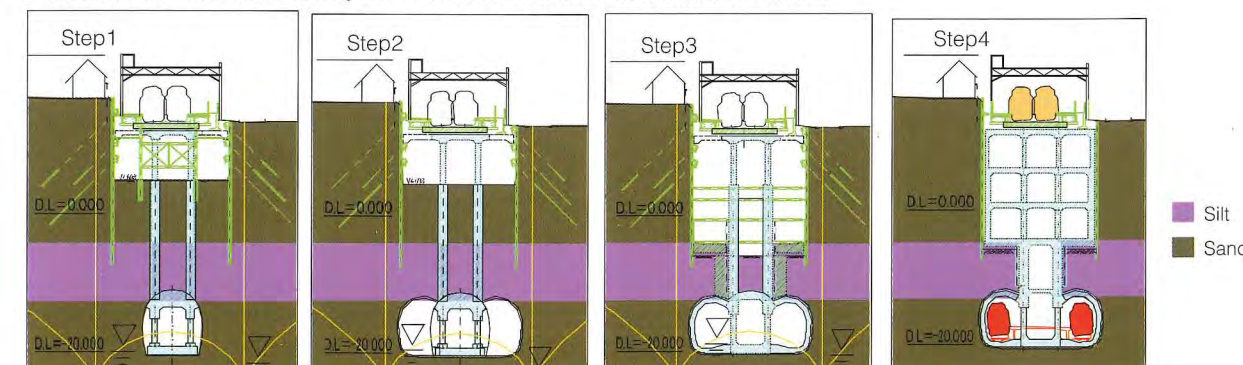
damage to the track and surrounding structures, various types of forepiling methods, face shotcrete, face bolts and various other forms of auxiliary methods were adopted.

Preliminary draining water tests within the area below the stiff silt layer were carried out, in order to confirm there was no influence to the ground surface. Then deep wells were employed for the sake of stabilizing the tunnel face in sand and alternate strata of sand and silt against artesian underground water.

Furthermore, automatic measuring systems were adopted, and meticulous survey control was carried out in order to accurately understand the influences of the tunnel construction. From the results of the measurements, convergence was limited to a maximum of 25mm and the maximum crown settlement to 20mm. The relative settlement of the track from the tunnel excavation was 3-4mm.



Construction Procedure of Triple Bore NATM Tunnel and Tanmachi Station



Railway Tunnel Constructed through Water-bearing Ground

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Introduction

The Keihanna New Line is a line stretching for 8.7km from Ikoma station of the Kintetsu Higashi Osaka Line to the Tomigaoka area in Nara City, and of which around 60% is composed of three tunnels. Opening is scheduled for 2005, and is now under wholehearted construction. With this line, the Kansai Cultural Science Research City and the surrounding residential area will be linked with the centre of Osaka and the Bay Area, and is expected to become a convenient and comfortable means of access between Osaka and Nara. Of the three tunnels, Kitayamato Tunnel is located between Kitayamato Station and Tomigaoka Station, and is a double-track railway tunnel with a total length of 1,100m.

Special Features of Kitayamato Tunnel

The special characteristics of Kitayamato Tunnel are that directly above the tunnel lies the extremely quiet Kitayamato residential area, numerous roads with buried lifeline utilities cross or run along the site, and directly below the residential land is non-compacted water-bearing ground with a thin average 17m coverage, and excavation was to be carried out by NATM. So, in addition to ensuring the safety of the works, the influence on the residential environment caused by the project and the new line operation was forecast, and in order to obtain the understanding of the local residents, actual experiments were carried out on train noise, and group experience tests on train noise and vibrations, so that suitable countermeasure methods could be incorporated into the works.

Conservation Countermeasures for the Surrounding Environment

As the Kitayamato Tunnel was subject to the above-mentioned conditions, it was important to reduce ground surface settlement, noise and vibration as much as possible to minimize the influence on the surrounding environment.

To reduce ground surface settlements, from the beginning long steel pipe injected type support as fore-shoring, base-part strengthening works and wing-rib support works with the aim of increasing the support strength of the shoring etc. were used combined with the design, and in addition to this, to prevent ground deterioration due to drilling water, aerated double pipe boring methods, preload shell methods to obtain early confirmed propagation of ground pressures toward support, early whole section closure methods, with the aim of ensuring tunnel stability and reducing following

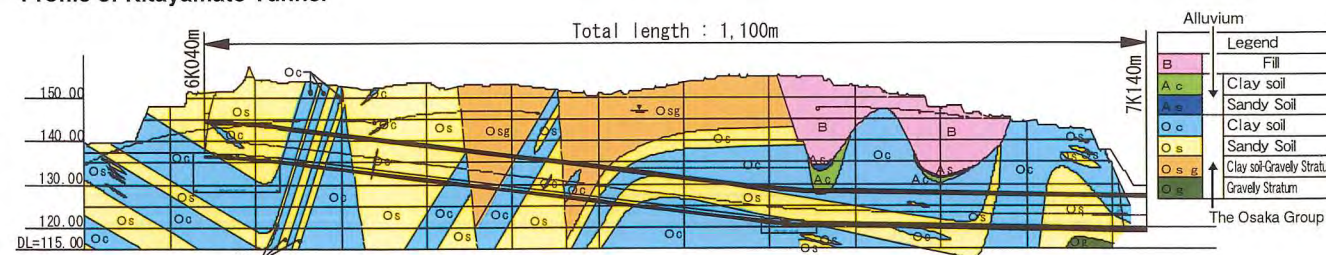
displacements etc., were introduced. Through the introduction of each of these methods and by thorough measurement control, ground surface settlement was reduced, and safe tunnel excavation could be carried out.

For the countermeasures against noise and vibration during construction, simulations were carried out by the arrangement of machines and equipment, and were implemented together with incorporating countermeasures beforehand and by making improvements to methods used on other past projects which had received numerous complaints.

Furthermore, regarding the influence of train vibrations after operations started, by making vibration measurements on existing tunnels and houses and carrying out base simulations, studies have been made on track structures to reduce the effect of train vibration propagation.



Profile of Kitayamato Tunnel



New Pre-Lining Support (PLS) Method on Yoshii Tunnel

Atsushi OIKAWA

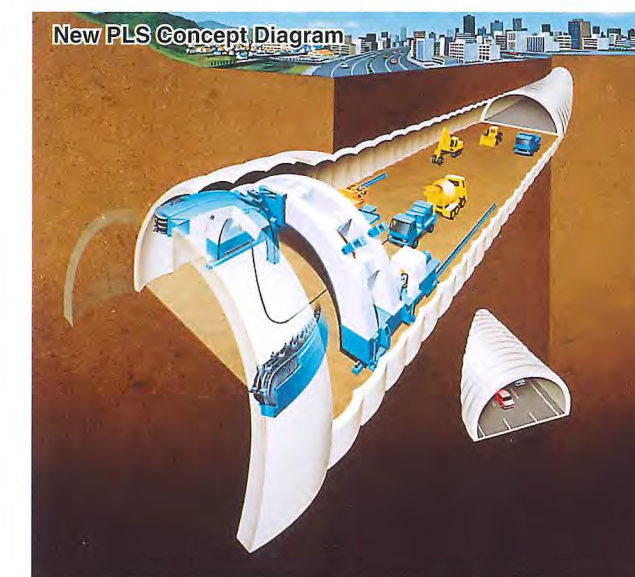
Project Manager,
Yokohama Construction Office,
Japan Highway Public Corporation

Project Outline

Yoshii Tunnel forms a part of the extension of the Yokohama-Yokosuka Road. It is situated in Yoshii Town of Yokosuka City, has a length of 346.5m, an excavated sectional area of 98m² and is 2-lane road tunnel.

This tunnel runs through built up land formed several years ago in a residential area and this backfill cover runs over almost half the tunnel length.

This backfill cover part is very loose (having an average N-value of 13) and has a thin overburden cover of only 7 -11m (approximately equal to 1D). A town road crosses over the route. This road possesses infrastructure gas pipes, water supply and sewage pipes underneath the pavement and also there is a steel tower only 7m away from the route, making very severe construction conditions.



New PLS Method

The PLS Method is one of the Pre-lining methods, where prior to excavation and ahead of the cutting face around the periphery of the tunnel, a concrete shell element is built in the form of an arch shell with a length of 3m and thickness of 40cm, with the tunnel excavation constructed afterwards (in 3m sections). The concrete shell element is formed so that the slit cutting is filled up immediately with concrete, therefore almost no ground loosening occurs in using this method. In addition, as the concrete shell has high stiffness it can also act as a support, so that the use of shot-crete or rock bolts are not necessary. This method only requires the construction of the concrete shell and excavation, and its special feature is this very simple cycle.

New Equipment for the PLS (Pre-Lining Support) and Concrete Shell

New equipment for the PLS (pre-lining support) method

uses a double-chain cutter (excavation depth 3.8m) attached to the arch frame to cut out the slit to form the shell, a concrete pressure pipe set in the back of the cutter and the end-form. The equipment used for the Yoshii Tunnel had a weight of approx. 115t and was able to excavate through the mudstone, which had a uniaxial strength of around 10 MPa.

As the concrete shell also acts as a support, there were requirements for confirming the absence of voids in the concrete filling (it was necessary to maintain the concrete slump and to adjust the support time), the self-standing ability of the concrete edge after passing the end form (it was necessary for the concrete to be self-supporting immediately after adding additives) and on confirming the required observed strength at early times during the tunnel excavation. To achieve this, three special additives were mixed into the concrete for each of these objectives.

Construction Situation

The Cycle time for the concrete shell concrete was on average around 12.5 hours, and tunnel excavation progress was maintained at around 40m to 60m per month. The results of settlement surveys of the ground surface were around a maximum of 20mm. In particular, the 20mm allowable settlement for the town road within the backfill cover was kept to within 15mm. Furthermore, the relative settlement of the steel tower foundations close to the tunnel was only 1.3mm, also within the allowable limits. This method can be said to be a suitable excavation method for use in unhardened ground and where it is required to reduce effects such as ground settlement towards adjacent areas.



Return Side Belt

Naka Ochiai Shield Tunnel on Metropolitan Expressway Central Circular Route

The Metropolitan Expressway Network

The Metropolitan Expressway is centered on the Tokyo area and is a transport network with an overall length of 264km, used each day by an average of 1.12 million vehicles and around 2 million passengers, thus serving as a very important support for the daily life and economic activity of the capital region. The Metropolitan Expressway Public Corporation is aiming to improve the service by expanding the network, and with society strongly seeking early service for improving the ring roads, this includes the preparation for the Central Circular Route which lies closest to the city center.

Outline Map of Project



Central Circular Route Shinjuku Line

The Metropolitan Expressway Central Circular Route (hereinafter called the Central Circular Route) has a total length of approx. 47km, and forms a ring road with an approximately 8km radius from the city center. The aims of the Central Circular Route are to mitigate traffic congestion by diverting and detouring through traffic that concentrates in the city center, to form a well balanced traffic network of ring and radial configuration. Furthermore, the improved effect of the city centre environment derived from the reduction of exhaust fumes due to the mitigation of traffic congestion is also expected, and early completion of the road is hoped for. Approx. 60% of the whole length, about 26km, has already been completed and is now open.

The Central Circular Route Shinjuku Line (hereinafter called the Shinjuku Line) forms part of the western side of the Central Circular Route, has a length of 11km, is currently under construction and is due to be complete around 2006. The construction of the Shinjuku Line, with the aim of conserving a favourable urban environment and making efficient three-dimensional use of limited urban space, is adopting tunnel structures for almost the whole line, apart from junctions. Furthermore, in consideration of the influence of the residential and traffic environment during construction, around 70% of the tunnel length is adopting the shield method.

Outline of the Naka Ochiai Shield Tunnel

The Naka Ochiai shield tunnel extends approx. 2,020m

starting from the vertical departure shaft at Rikkyo Street in Toshima Ward as far as the Nakai Oedo Line subway station building in Shinjuku Ward, and is constructed by the earth pressure balance shield method. This shield has segments with an external diameter of 11.8m and the outer diameter of the machine is 12.02m, making it the largest diameter earth pressure balance shield in the world. With an earth coverage of between 9 -24m, and running underneath some major city center trunk roads as well as being constructed adjacent to important structures such as railway lines and bridge pier foundations, make the construction conditions extremely severe.

Reasons for Adopting the Earth Pressure Balance Shield Method

Normally, for large cross section shields with a diameter over 10m, due to the ease of preserving a stable cutting face, the slurry shield method is often adopted, but for the following reasons, the earth pressure balance shield was adopted for the Naka Ochiai Shield.

(1) The Naka Ochiai Shield runs under Yamate Dori, a major urban trunk road, and important structures such as railway lines and bridge pier foundations lie within a one diameter distance. Thus there is a concern that a sudden outburst of slurry from a slurry shield could influence the important structures.

(2) For this project, the start base for the shield is extremely restricted and as two shield tunnels would be built almost simultaneously, it was necessary to have two on-ground facilities for two shield machines. It would thus cause difficulties to install two shield facilities in the ground for slurry type shields.

(3) For the ground conditions in the excavated part of the tunnel, for the part up to 350m from the departure shaft, there are dense sand and gravel layers (hereinafter called the Mg layer) with N values from 12 to over 50, and an extremely dense layer (called the Tog layer) with N values over 50, and furthermore within the soil strata there are mainly silt with fine sand parts interspersed between clay layers (called the Toc layer). In both the Mg and Tog layers there are gravels with pebbles of around 100mm diameter size (with maximum boulder sizes expected up to 300mm diameter, and with a high water content, with a moderate permeability index of around the order of 10^{-3} . In addition, up to a distance of around 1,000m, the Tog layer is dominant, and the lower part of tunnel appears in a stiff clay layer with an N value of between 11 to over 50 (the Edc layer). Thereafter, as far as the arrival shaft, fine sands predominate with an N value between 12 to over 50, with a dense to extremely dense sand layer (the Eds layer) and the Edc layer existing in alternate layers.

Thus as the shield machine excavates through complex alternating soil strata including gravels, and as countermeasures against cutter bit abrasion had to be provided, and to preserve the stability of the cutting face, it was important to carry out the design taking into special account the ensuring of a good mixing ability of soil and

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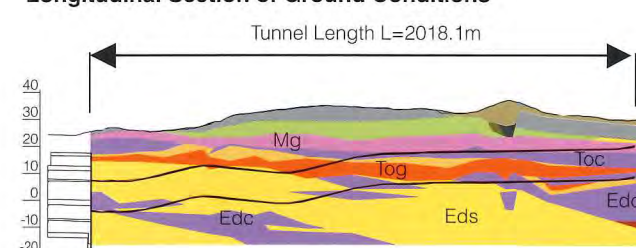
plastic workability of the soil inside the chamber. In addition, it was necessary to make studies on the system of gravel treatment.

Issues and Countermeasures on the Naka Ochiai Shield Tunnel

(1) Large section earth pressure balance shield

The earth pressure balance shield, carries out excavation by injecting and mix stirring additive materials into the excavated soil, improving its workability and water stopping properties, and stabilizing the cutting face by the internal chamber earth pressure acting against the ground. It is thus important to control the cutting face pressure, the amount of excavated soil and the plastic workability of the excavated soil. For the cutting face pressure and the amount of excavated soil, it is considered that using conventional control methods does not pose any problems even when using a large section earth pressure balance shield. However, for the plastic flow workability of the excavated soil, there is no established way that the plastic workability condition of the soil inside the chamber can be understood, which hinders the suitability of using the earth pressure balance shield for a large section shield. Therefore, it became important that studies be made on how to make the excavated soil inside the chamber to be plastically workable in a large section earth pressure balance shield. For this project, the following countermeasures were implemented in order to confirm the plastic workability of the excavated soil inside the chamber.

Longitudinal Section of Ground Conditions



- The number of additive injection holes were increased so that the additives could be more uniformly mixed.
- A high revolution speed agitator was installed inside the chamber to increase the stirring performance.
- A large diameter 2 stage screw conveyor was installed so that muck could be removed smoothly while preventing outbursts.

In addition, in order for excavation to progress smoothly, and because of the necessity to have equipment which could transport large quantities of excavated soil efficiently, it was required to select a method which could transport muck from the gravelly rock, and also preserve a soil stock volume in the narrow work space. Thus, for the excavated soil transport equipment, continuous horizontal and vertical belt conveyors were adopted, so that the soil could be continuously taken out

to the ground surface.

(2) Long distance excavation through sand and gravel ground, and cutting of NOMST (NOvel Material Shield-cuttable Tunnel wall system) walls, precast concrete elements which are reinforced by carbon fiber reinforced plastic, and earth retaining walls.

Normally, the cutter bit is made up of the shank and the tip, and it is obligatory to use a cutter tip with adequate durability. The cutter tip is made from a WC-Co type extra hardened metal alloy, and this steel alloy possesses special characteristics, such as are high abrasion resistance, high heat resistance, non-corroding and high stress strength etc., so that the right shape and hardness etc. are used under the various soil and construction conditions.



Large Variable Section Tunnel by MMST Method

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Takuo KINOSHITA

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Metropolitan Expressway Trans-Kawasaki Line Tunnel Section

The Metropolitan Expressway Trans-Kawasaki Line is an urban highway project currently under progress which is designed to improve connections between the center of Tokyo and other urban centers, and which runs through Kawasaki City, one such major urban center in the Tokyo metropolitan area.

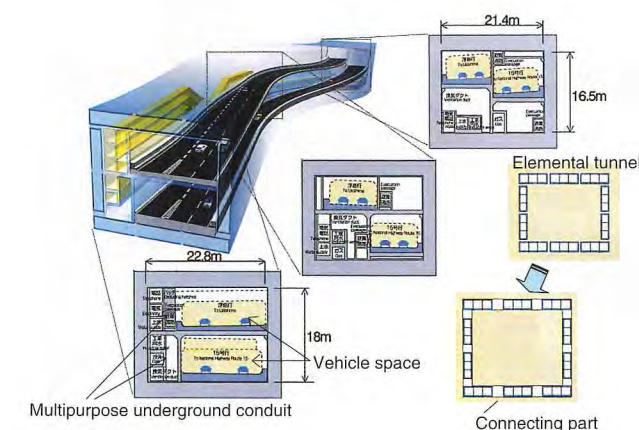
Along this route, there was a section of tunnel where there were many buried underground utilities and where land acquisition was extremely difficult. As it is close to a junction, the road alignment can not go very deep, and as the road has varying width, the carriageways have been arranged to lie one on top of each other, rather than left and right of each other. In addition, it was also a condition that it should serve a joint purpose as a multipurpose underground conduit for improving future urban infrastructure.

Therefore, as the tunnel has both a variable as well as a large cross section, with an extremely shallow overburden earth coverage, and where there was no spare width due to land restrictions, more usual non-open cut tunneling methods such as NATM and single circular section shield methods could not be adopted, leading to the development of the MMST method.

An outline of the development was introduced in the 1998 edition.

Tunnel Outline

Tunnel Length	: 540m
Tunnel Outer Dimensions	: Height 22.5 to 24.1m
	: Width 26.1 to 27.9m
Effective Internal Sectional Area	: 353 to 413 m ²
Earth Overburden Coverage	: 4.8 to 12.6m
Plan Radius	: Min. 1,000m
Longitudinal Slope	: Max. 2.5%



MMST Method

The Multi-Micro Shield Tunnel (MMST) method is the name given to the method for making tunnels where the outer perimeter wall structure, called an 'outer lattice', is first formed by excavation by numerous small rectangular shield

machines, of which adjacent sections are then linked together by reinforcing bars, and then filled up with concrete to form the overall large section rectangular tunnel, after which the soil within the internal section is then excavated.

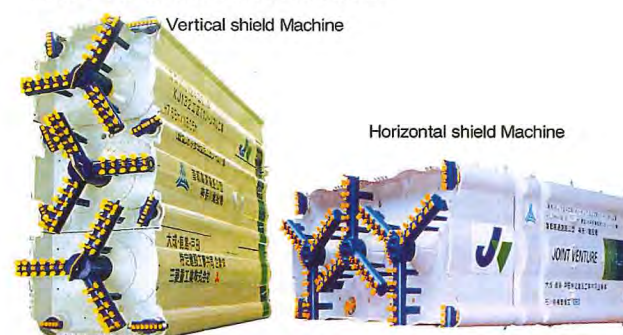
The special characteristic of this method is that the spacing of the elemental tunnel sections formed by the small scale rectangular shield machines can be controlled, so that the size of the tunnel can be varied. For this tunnel, the spacing was changed from 0.6m to 1.6m, thus increasing the inside section area by more than 15%.

As the excavation by the shield machines are of small scale, it is possible to carry out safe construction even where the overburden is small, and in addition the space for vertical shafts to move in equipment and materials can also be reduced. Furthermore, an overall safe environment can be made with regards to controlling noise during construction and for the influence on normal traffic.

While the construction of the 'outer lattice' tunnel structure is done by special methods, the following on excavation and construction of the internal structure can be done by using standard machines and methods.

Thus, the MMST method is a useful method which can be used in urban areas where there can be many restrictions.

MMST Elemental Shield Machine



Tunnel Design

From the results of tests on actual structural elements, the overall structure can be designed considering it as a reinforced concrete structure.

For the outer lattice structure, the concrete infill inside the steel shell parts forms a hybrid composite structure (SRC structure), and as the connecting parts between the steel shells are a reinforced concrete structure, the overall outer lattice structure is designed as reinforced concrete.

The connecting parts and the steel shells are connected by reinforcing bars, and by arranging the reinforcing bars on a bearing plate, the anchorage length could be shorter.

Progress Status of Tunnel Works

It is aimed to complete the main tunnel by 2006. The first elemental tunnel parts built by small scale shield machines started in July 2002, and completion of the elemental sections is scheduled for the spring of 2004.

Road Tunnel Construction by Pneumatic Caisson Method

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Introduction

The Omiya Express line of the Metropolitan Expressway, plays a role in the Capital Region of Japan, by linking the Centre of Tokyo with Saitama New Urban Center, and close to the entrance to Saitama New Urban Center, it is planned that this line will cross below, in the form of a tunnel, viaducts of the main transport artery of the Eastern Japan region, where the Tohoku, Yamagata, Akita, Nagano and Joetsu shinkansen high speed railway line and below the Saikyo Line, a major metropolitan rail commuter line. East Japan Railway Company thus received a commission from the Metropolitan Expressway Public Corporation to construct the crossing part of this project.

This work, including the underpass part, has a total length of 221.5m, a cross sectional shape of 19 to 27m wide and a height of around 26 to 38m, and is a tunnel with the eastward and westward lines basically constructed as a 2 storey structure.

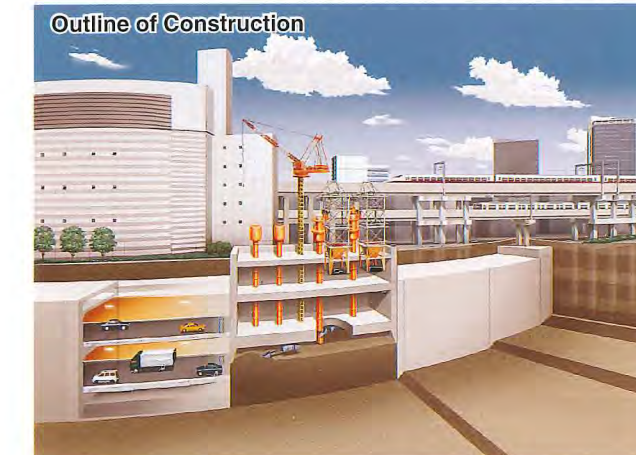
Construction Conditions

The construction conditions are as follows:

- (1) To ensure the structural safety of the various adjacent facilities (the shinkansen high speed railway abutments, the Saikyo Line piers, the heating and cooling district centre, the Saitama central meat wholesale market)
- (2) To preserve the safe operation of the railway lines (Shinkansen, Saikyo Line, Tohoku Main Line)
- (3) To maintain the ground water level and not affect the public water wells.
- (4) The necessity to carry out fast construction in the narrow work site
- (5) The necessity to carry out underpinning of the Saikyo Line Bridge piers
- (6) The artesian pressure of the ground water in the gravel layer directly beneath the tunnel structure

Selection of Method and Execution

From the results of comparison studies between open cut excavation and the pneumatic caisson method, from the certainty of ensuring the safety of the various adjacent facilities, the superiority of influencing the underground water

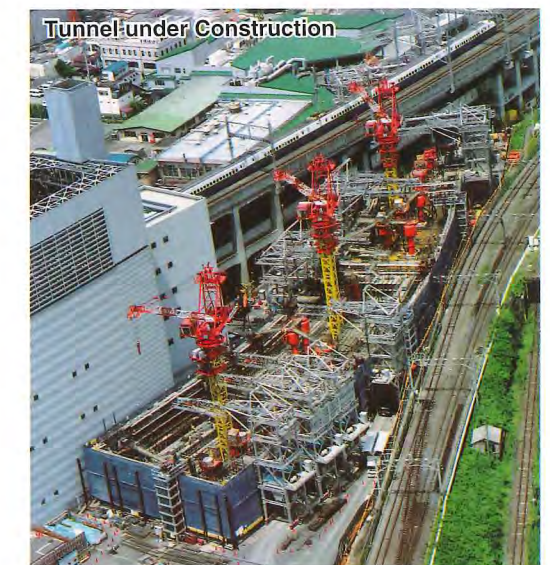


level, and from cost and schedule aspects, the pneumatic caisson method was adopted.

By drafting the following countermeasures relating to the pneumatic caisson method, construction was carried out.

- (1) To build the total 221.5m long structure, it was divided into 6 caissons, with a gap of 2.5 to 10m between each of the caissons.
- (2) To prevent the air penetration flow through phenomena occurring due to constructing 6 caisson simultaneously, the internal pressure in the work chambers was controlled by high accuracy automatic pressure adjustment devices, so that the sinking speed could be adjusted to prevent differences occurring in the depth of the caissons.
- (3) To ensure the safety of the various adjacent facilities, a protection wall was built between the tunnel structure and the facilities, and by carrying out real-time monitoring of the displacements of the facilities by using a total station displacement measuring system. Any yawning caused during the sinking of the caissons was restrained by adopting a jacking insertion system, which controlled the influence on the surrounding land.
- (4) To alleviate the works being carried out under high pressures, worker-less excavation was carried out using remote control from the ground surface, thus improving the labour conditions.
- (5) After the sinking of the caissons, a slab was built above the caissons between the piers of the Saikyo line to carry out underpinning
- (6) Postscript

For this project, the 6 caissons were built and sunk in March 2002, and in October underpinning work for the piers was completed. Currently, completion is targeted for October 2003, with work concentrating on the connection works between the caissons. This report shows how the pneumatic caisson construction method has been developed as a technique for creating underground space such as underground tunnels.



Large Section Tunnel in Unsound Ground

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Osaka Prefectural Road Public Corporation

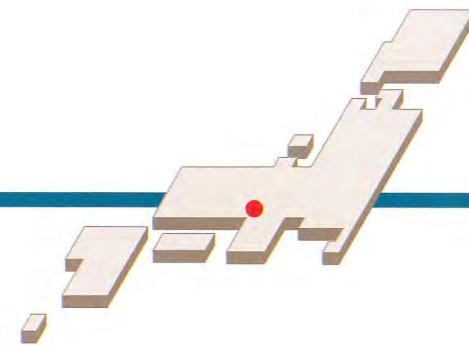
The Minoh Toll Road forms part of the National Road Route 423 Bypass, which runs in a northerly direction from the center of Osaka and then further north to connect with the future New Meishin Expressway, forming part of a large regional network. Of this, the Mountain Tunnel part, is a road tunnel which runs for 5.6km in a north-south direction through the Hokusetsu Mountain range (height 200 to 600m), and is currently under construction.

The south portal of this tunnel is under severe ground conditions. The Osaka group unconsolidated ground range which is composed of sands, clays and gravels, and the unsound ground of the strongly fractured shales of the Tanba belt make severe ground conditions, and due to the necessity for the exit and entrance ramps of the road to merge within the tunnel, the maximum excavated cross section exceeds 300m², making a challenge for constructing a very large section road tunnel, the likes of which have not been seen before in Japan.

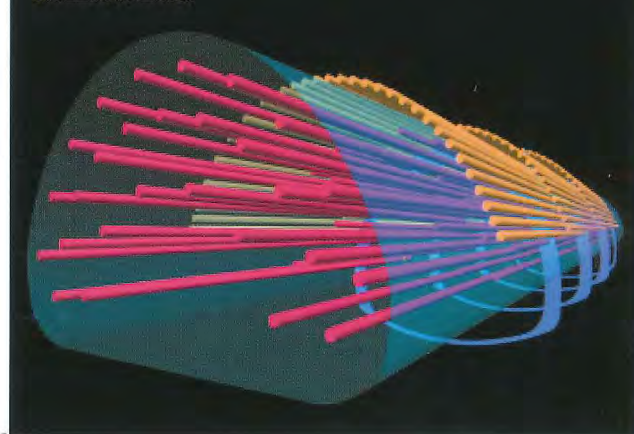
Prior to the construction of the main tunnel, a parallel working drift (excavated section 41m², length 347m) was started, but the cutting face in the heavily fractured shales was not self-standing, and the extrusion or failure of the face caused large deformations to occur. Thus, it was foreseen that difficult circumstances would be encountered during construction.

In addition to the aforementioned unsound ground conditions, within the 40m overburden coverage the large section tunnel (in this part the tunnel's effective excavated section gradually increases from 97 to 227m²) passes directly underneath a welfare facility building, and so it was necessary to tightly control the influence of the tunnel excavation. In response to this problem, long face-piling (FIT method) and long steel fore-piling (Trevi tube method) etc. were adopted, thus restraining the ground ahead of the face by forming "cores" of the ground and so minimizing the influence to the surroundings.

For constructing the very large section tunnel at the south portal, by feeding back the work experience gained from the working drift and also during sequential progress of main tunnel construction, the design and construction method were



Auxiliary Works ; Red Indicates Long Face Reinforcement



reevaluated and detailed studies were made on the tunnel construction one by one.

From these results, for the very large section tunnel part, a multiple side drift method was initially planned. Then, in addition to this method, a top heading bench cut method and a side drift method were evaluated for comparison, and finally the side drift method was adopted for use.

For the part where the maximum cross section of over 300m² occurs in the Osaka group unconsolidated ground range, the pipe roof method (812.8mm dia.), and for parts where the cross section was slightly smaller (215 to 262m²), top heading bench cut method with long fore-piling and long face reinforcement was adopted.

In October 2003, the left and right side drifts passed through the south portal, and side wall concrete work started. The main excavation part of the 313m² very large cross section will be actually executed and as the survey and measurements data obtained is fed back to the actual construction and excavation carefully undertaken, breakthrough of the upper face is aimed for the spring of 2004.

Long Fore-piling Method



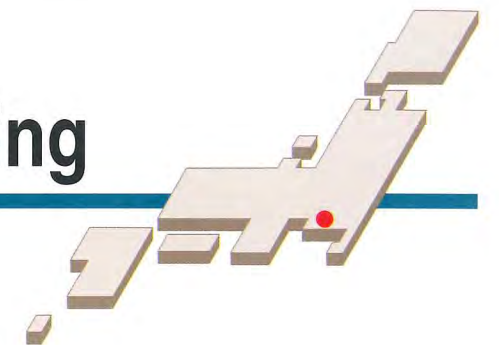
Overall View of Side Drift Heading Method



Underground Reservoir Inclined Shaft by Pipe-Jacking

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The Ventilation Facilities Structural Works of the Imaigawa Underground Reservoir Construction Project had the excavation works for an inclined ventilation shaft connecting the main underground reservoir by a shield tunnel to above ground to a depth of 87m down to the main underground regulation pond. The shaft, with an inner diameter of 2,000mm, was built using a slurry shield, with an inclination angle of 75.6 degrees, and under high artesian pressure conditions of up to 0.66MPa at the connection point.

The geology from the surface, consist of surface soil, loam, diluvium, consolidated silt and fine sands. The thickest layer and the bedrock in the ground is the hard silt, which has an unconfined compressive strength of 2.7 N/mm². The fine sands are in layers 1cm to 2.4m thick, and are interspersed in many locations with the hard silt, and at the connection point of the shield tunnel is around 50cm thick. The permeability coefficient of the sand layer is between 1.1×10^{-3} to 9.6×10^{-3} cm/sec.

The excavation method used for the inclined shaft for this project was the pipe-jacking method by slurry shield, which can deal with the high underground water pressures when constructing the very deep shaft. The inclined shaft connects with the free area on the ground as an access shaft to the deep substructure.

In order to adopt the pipe-jacking method for a near-vertical inclined shaft, which is normally used for the excavation of horizontal tunnels, many devices were required which are described below:

(1) The slurry shield machine used for excavation:

- Maintain high water impermeability by a sealing performance up to 1.0 MPa
- All-directional spherical articulation device to control the

excavation direction

- Upon reaching arrival, the driving device of the shield machine to be divided into two parts, to allow for later dismantling and removal through inside the pipe-shaft and thus shorten the schedule and improve safety

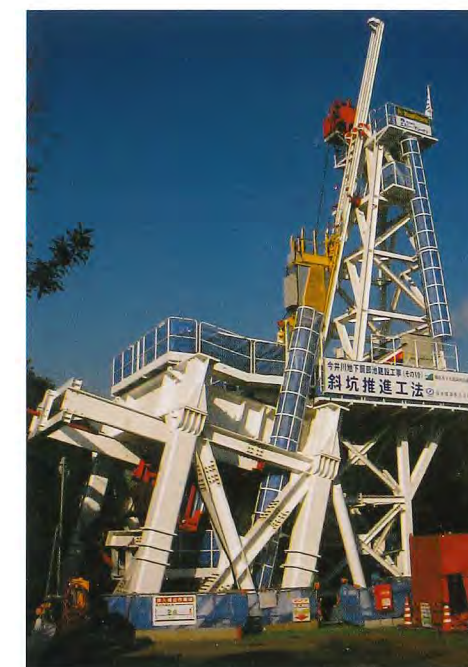
(2) Temporary equipment on the ground:

- sliding type pipe jacks
- fixing equipment by power casing jacks to prevent pipe uplift due to buoyancy
- Ground anchor in order to ensure adequate reactions to the two above-mentioned devices
- Work elevators for use inside the pipe-shaft

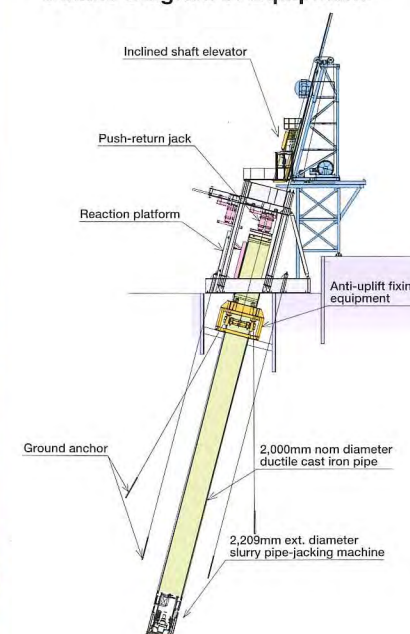
The pipe used was ductile pipe, built in lengths of 5m, and connected together by bolts.

During construction, excavation was carried out by a shield machine suspended from a platform at a shallow depth location, so that there would be no effect from buoyancy due to the ground water, and the shield machine would not enter into the ground. Furthermore, at depths where buoyancy from dead weight would become large, and also to prevent uplift from buoyancy within the pipe when the jacks were released, the power casing jacks were fixed to the pipe. The construction was completed within a short period, and reached the main shield tunnel with a high level of accuracy.

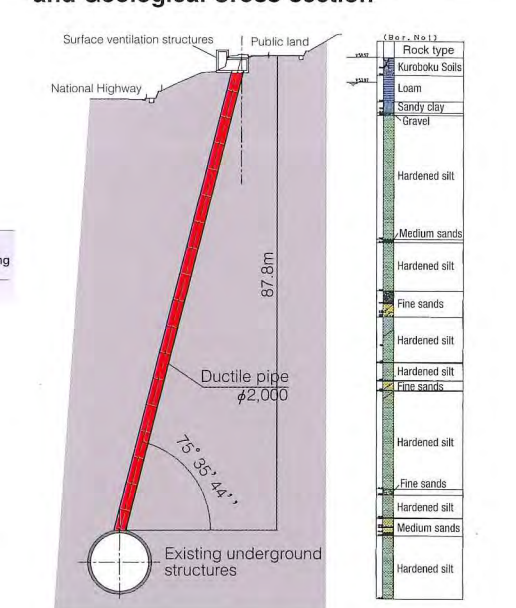
The inclined shaft excavation method used for this project, as both of the costs and construction schedule are favourable compared to constructing a shaft and then excavating a horizontal tunnel from the base of the shaft, could also be used for constructing connecting shafts for ventilation purposes, and also for small scale elevator shafts and the like.



Outline Diagram of Equipment



Cross-section through Ventilation Hole and Geological Cross-section



Connecting Neighbouring Dams for Effective Water Use

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Ministry of Land, Infrastructure and Transport

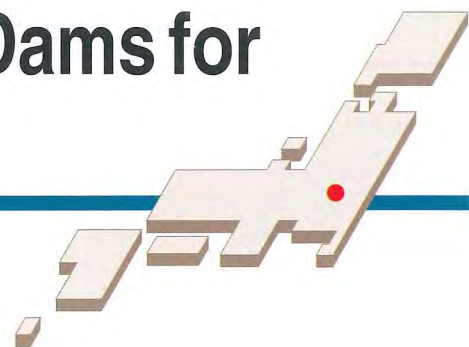
The Kinugawa River is a large tributary of the Tonegawa River, which has an overall length of 177km, and a catchment area of 1,784km². In the upper reaches of the basin, are the Kawamata Dam and Kawaji Dam in the Kinugawa River itself, and the Ikari Dam in the Oga River tributary, which as well as controlling flooding, store water for irrigation and urban use, and also are used for power generation, thus supporting economic life in the region. Of these, the Ikari Dam and Kawaji Dams, separated by a close distance of only 1,100m, lie in very rare geographical conditions seldom seen in the whole of Japan.

The Ikari Dam has an annual inflow volume of 330 million m³, which although larger than the Kawaji Dam, the effective storage of water is 32 million m³, is not enough to meet the water resource demands. On the other side, the Kawaji Dam has a smaller annual inflow volume of 120 million m³, but an effective storage volume of 76 million m³, or 1.6 times, and once the stored water level drops, needs time to recover.

By connecting these two existing dams, which have large differences in inflow volume and storage, with a water tunnel, the aim of this project is to make the water flow more efficient. When Ikari Dam is full and cannot store any more water, the water tunnel is able to transport a maximum flow of 20m³/s if there is spare capacity, to Kawaji Dam. In addition, when the flow volume in the lower basin of Ikari Dam is not enough, storage water in Kawaji Dam supplied from Ikari Dam is returned to Ikari Dam with a maximum flow of around 1m³/s, thus improving the flow condition, and by preserving a steady flow, making the river flow more scenic.

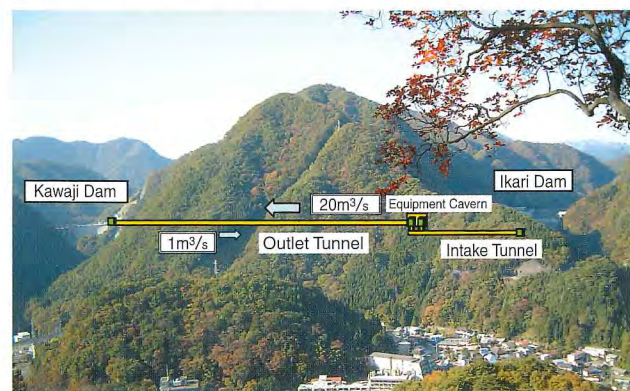
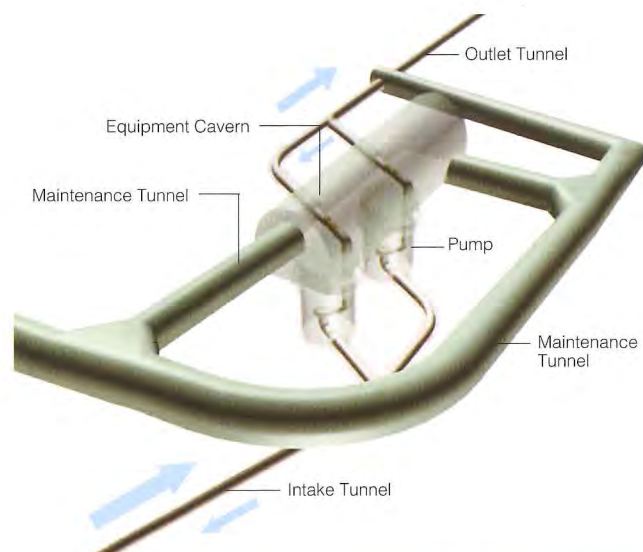
This project involves the construction of a bullet shaped underground cavern (width 17m, height 15.6m, length 59m), with two shaft at its bottom (diameter 13m, depth 20m), an intake tunnel connecting Ikari Lake with the cavern (width 3.8m, height 4m, length 221m), an outlet tunnel connecting Kawaji Lake with the cavern (width 3.8m, height 4m, length 846m), a tunnel around the cavern for maintenance (width 7.8m, height 6m, length 368m) and a ventilation cable tunnel (width 6m, height 5.8m, length 41m). Thus there are 6 types of tunnels with varying cross sections (approx.1,575m length) constructed by NATM techniques.

From the start of the project, there were many tasks to be attended to. approx. 1,000m away from the portal of the maintenance tunnel on the opposite shore of Ikari Lake, as



Kumataka hawks, an endangered species, were nesting there, a sound-proofing house was installed at the tunnel portal to reduce noise. The outlet tunnel crossed the path of the operating railway tunnel with a difference in elevation of 37m. So as not to cause any damage to the concrete lining of the railway tunnel during excavation of the outlet tunnel by blasting, surveys and measurements were carried out, and by suitable controlled blasting, the adjacent construction part excavation was completed.

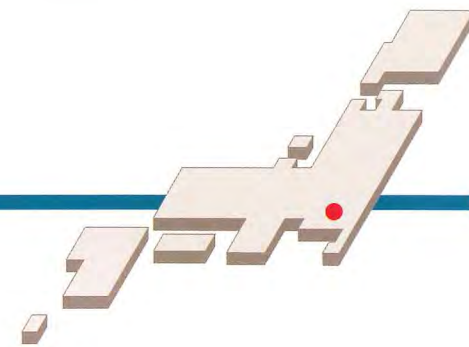
The ground conditions at the site consisted mainly of a highly permeable tuff breccia and the underground water level around the cavern was governed by the water level of Ikari Dam. As the shaft at the bottom of the cavern and the intake tunnel lied below the underground water level, grouting to improve water tightness was carried out in advance, and excavation work carried out after the rock permeability had been improved. For the excavation works, the maintenance tunnel started in March 2001, and excavation for the intake tunnel was completed in July 2003.



The Metropolitan Area Outer Discharge Channel

Minoru SANDOU

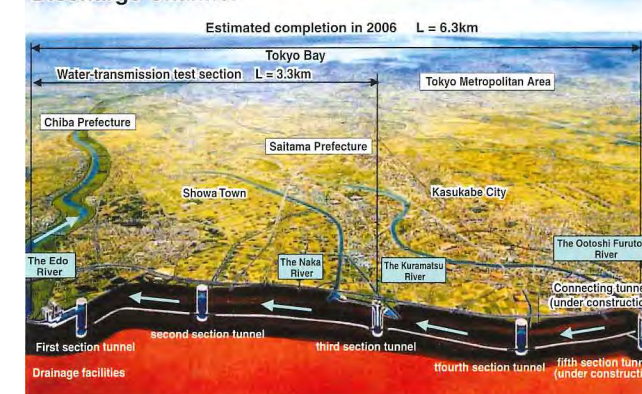
Chief of Diversion Channel Section,
Edogawa River Work Office,
Kanto Regional Development Bureau,
Ministry of Land, Infrastructure and Transport



Introduction

The Naka River originates at Hannyu City in Saitama Prefecture, and then runs through eastern Saitama Prefecture and through the Edogawa Ward in Tokyo before flowing into Tokyo Bay. It is a First Class River with a total length of 81km and a catchment area of around 1,000 km². Its basin area is bounded by the Ara River, the Tone River and the Edo River, all major rivers. It is shaped almost like a saucer, with average slope of only 1/4,000. Due to this flat slope the water can't flow easily and in heavy rain the water overflows affecting a large area over a long period, and flood control has been an ongoing problem for a long time. The Metropolitan Area Outer Discharge Channel pumps the flood water of medium and smaller rivers from the middle reaches area of the Naka River into the Edo River by way of the underground River. Thus it acts as a flood control measure by greatly reducing flood related damage in the Naka River basin area.

Total Image Illustration of the Metropolitan Area Outer Discharge Channel



Outline of the Metropolitan Area Outer Discharge Channel

The Metropolitan Area Outer Discharge Channel is a tunnel which is buried at 50m depth below National Road Route 16 between Kasukabe city and Showa town in Saitama Prefecture, having an internal diameter of 10.6m and a length of 6.3km, and collects the floodwaters of the Ootoshi Furutone River (85m³/s), the Kurumatsu River (100 m³/s), the Naka River (25 m³/s) etc., finally draining into the Edo river with a maximum flow of 200m³/s (50m³/s x 4 pump sets). With the generally completed 3.3km long section (From No. 3 shaft to the Edo River, drainage scale 100 m³/s) water flow tests have begun.

Tunnel Characteristics

The tunnel depth was set to allow for construction by the shield method in ground where deformation could be kept to an absolute minimum, which was mainly in stable diluvial ground typically at 50m depth. Due to the large depth (50m below ground) and the large diameter (internal tunnel diameter of 10.6m), the closed type slurry shield was adopted. For this project, new technologies were adopted in order to try to reduce costs, for example, the inner-lined

structure was left out. Thus, we have developed the new segment structures which can withstand internal water pressure with water-tightness.

Flood Prevention Results of Water Flow Tests

From June 2002, water flow tests were started, and despite the arrival of Typhoon No. 6 in July, bringing heaviest rainfalls recorded in recent years of 141mm, through the operation of the Metropolitan Area Outer Discharge Channel regulating approx. 4,560,000 m³ of flood water, flood damage was prevented. By September 1, 2003 there were 9 occasions of flood water flows into the Channel, thus resulting in an overall flood water regulation of 13,000,000 m³. Through operational tests, its large flood prevention effects have been achieved in this area.

Conclusion

10 years have passed since the Metropolitan Area Outer Discharge Channel Project has started in March 1993, and during these time the project has progressed smoothly on the whole, and by the end of March 2003 approx. 90% of the project was completed. According to the local residents comments on the water flow tests compared with before, the water in the rivers and other water courses have run markedly quicker, and overflow from the rivers have not occurred. To have further effect, we are speeding up the project to complete by March 2007.



Compact Shield Method to Restore Sewer Line

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Introduction

The Compact Shield Method, is a method developed for the Tokyo Metropolitan Government's sewer restoration works, to smoothen project progress as also to reduce cost, shorten the construction schedule, reduce the environmental burden and to improve maintenance management efficiency.

Construction Record

This project is carried out for the structural restoration of the main branch line close to the Asakusa Shrine in Tokyo, in Taito-ku close to Misuji 2-chome and Torigoe 2-chome. The project scale has an internal diameter of 2000mm, length of 1,280m, overburden cover of 5-6m, and with 2 curves (R = 30m). The results of the construction were that the construction period, project cost, environmental burden etc were all greatly reduced.

Special Features of the Compact Shield Method

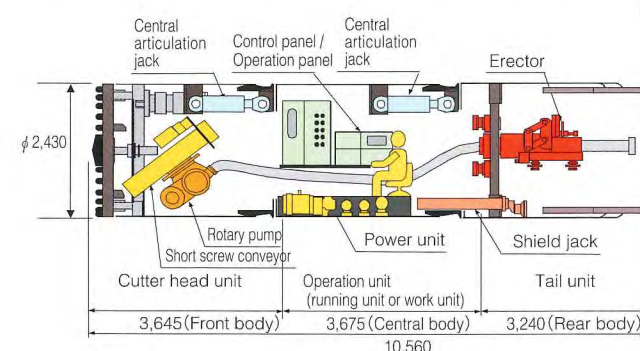
(1) Integrated secondary lining type segment

Until now, after the primary lining, the secondary lining was constructed using in-situ concrete. The functions of the secondary lining to prevent corrosion, act as waterproofing and to smooth the internal surface of the tunnel are kept, but this method uses one-piece integral segments with the same anti-corrosion qualities instead of the in-situ concrete, placed on the inside of the primary lining segments. Accordingly, the schedule for the secondary lining works could be deleted, and the overall schedule greatly reduced. Furthermore, as the thickness of the secondary lining was reduced from 250mm to an integral anti-corrosion layer of only 50mm, the external diameter of the segments was reduced and the excavated cross section reduced by 25%, and the concrete volume reduced to 58% of the previous value.

(2) 4-division 3-hinge lining structure

Compared to the standard segment for shield works (Japan Sewers Association), the number of divisions was reduced, and a statically determinate 4-division 3-hinge segment was adopted, which forms a safe and stable tunnel structure. In addition, due to the structural connection device, the segment erection time is reduced. Furthermore, as the invert ditch is integrated with the segment in a single form, walking is made easier, and also making automatised inspection and repair possible, forming an easy to maintain structure.

(3) Shield comprising the front part, the middle part and the



rear part and containing some parts the back-up carriages inside it.

By preserving enough work space behind the shield machine, following-on equipment work was accommodated in the shield machine. Furthermore, as divided into 3-parts, the structure allows for easy starting and withdrawal. As a result, the size of the departure and arrival shafts was reduced by 30%, and multiple re-use of the shield machine also became possible.

(4) Tire-mounted Transportation wagon

Until now, materials and excavated soil were transported using battery locomotives on rails and sleepers. This time, the invert ditch formed in the secondary lining integral segment acts as a guide for a self-steering tire-mounted transportation system. As using this method, the invert becomes the walk path, walking becomes both easier and safer.

This method was in May 2003 given technically innovative appraisal by the Japan Society of Civil Engineers, and was awarded a Technical Development Prize.



High Speed Shield for Power Cable Tunnel

Kazuto TASHIRO

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Chuo Transmission & Substation Construction,
Kysyuu Electric Power Company, Incorporated

Recently, for the construction of power cable tunnels by the shield method in urban areas, it has become an issue to carry out high speed construction because of increasing tunnel distances from the shaft, and from the view-point of saving cost and shortening the construction schedule. From this background, the construction of the shield tunnel works (length 1,934m, internal diameter 3.0m, excavated external diameter 3.61m) of the 2.8km long 220kV Kurume Branch Line in Fukuoka Prefecture, the F-NAVI Shield Method, as introduced in Tunnelling Activities in Japan 2002, was applied. Using RC segments and a sliding steel wagon muck removal method, a progress rate of over 500m per month was achieved.

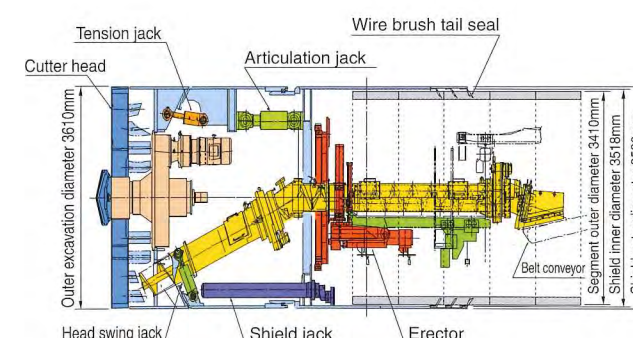
The F-NAVI Shield Method, as described below, is able to carry out high speed construction by controlling the direction of excavation during simultaneous advance. Simultaneous advance is where the tunnel excavation work and segment erection work are done at the same time. Furthermore, in the F-NAVI shield machine, the articulated joint structure connecting the main body and front body parts features a semi-spherical shape bearing surface, allowing the front body to move freely in both horizontal and vertical directions, so the excavation direction can be controlled irrespective of the selection of the shield jacks operation.

In this way, the front body guides the shield machine in the correct position, and from this meaning it has been given the name of Front-NAVigate (or F-Navi Shield Method).

This shield machine consists of a main body and front body and has tension jacks to connect the two parts, articulation jacks to perform the position control (the head swivel of the front body) and shield jacks.

For the shield construction of this project, it was planned there would be no changing of the cutter bit over a length of approx. 2 km. Also, if the excavation speed was reduced from the design velocity of 25mm/minute, the moving distance of the cutter bits would lengthen, and there would be a danger that the excavation progress performance would be lost due to bit abrasion. Thus, by reducing the high thrust force at the start of simultaneous advance as starting excavation progress movement (excavation speed 3mm/minute), the following items were carried out:

- Test Construction of reduced thrust force (excessive overcutting volume, sliding materials etc).



- Carrying out F-NAVI simultaneous advance using manual operation by increasing the number and capacity of the jacks.
- Software to completely automatic operation by increasing the number of shield jacks during simultaneous advance.

From the results, using manual operation of the F-NAVI simultaneous excavation from February 2001 and then carrying out completely automatic simultaneous advance from March 2001, and using sliding steel muck wagons and RC segments, we were able to confirm the main construction by F-NAVI simultaneous advance. In addition, a maximum monthly advance rate of 526m was recorded.

The factors for the success of this high speed construction method are:

- Reduction of assembly time of RC segments by using one-touch connection method.
- High accuracy of the direction control using the head swivel mechanism and positional control system of the F-NAVI shield machine.
- Application of sound proofing of the temporary spoil stock yard allowing construction during day and night.
- The ability of the following-on rear equipment to achieve the assumed 500m monthly progress.

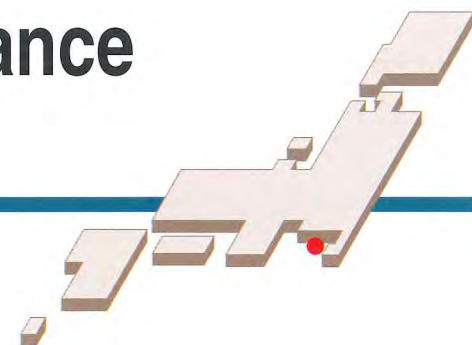
By using this high speed shield method, we were able to reduce the tunnelling schedule by two months, and open the electrical transmission facilities for operation by June 2003



Construction of Long-Distance Undersea Shield Tunnel

Shinichi SHIRAI

Group Manager,
Tunnelling Management Group,
Higashi Ohgishima Power Plant,
TEPCO (Tokyo Electric Power Company)



Introduction

In order to provide an efficient fuel supply to each existing LNG power plant around Tokyo Bay, TEPCO is constructing a gas pipeline which will stretch 20km connecting the Higashi Ohgishima LNG base in Kawasaki to the Futtsu LNG base in Chiba Prefecture. Of this, the part crossing Tokyo Bay will be built as a shield tunnel with an internal diameter of 3.0m and length 18km, and inside which a single 700mm diameter gas line will be installed inside. Two slurry shield machines working under maximum water pressures of 0.66 MPa will each excavate 9.0km and meet up and connect underneath Tokyo Bay. The project schedule is 37 months to completion, lasting from April 2003 to April 2006.

Design

(1) Tunnel Alignment

The tunnel alignment was selected based on ensuring the tunnel safety in the event of an earthquake, and to reduce the construction risk from encountering methane gas and gravel deposits, and avoided the soft weak soils (Yurakucho layer) and instead passed through relatively stable soils (Nanagochi layer and diluvial layers).

(2) Segments

In order to reduce erection time, segment joints were built as one-touch type connections. In addition, for the part passing through the undersea diluvial layers on the Futtsu side, where the section forces created in the segment ring are governed by axial forces, the segments are simply butt jointed against each other, without physically connecting

them together. (ref: QB segment)

Construction Planning

(1) Countermeasures against abrasion of cutter bit

The cutter bits are planned to be non-replaced throughout the 9km long excavation distance, and are planned to have an increased lifetime through research of their shape and arrangement layout, control of the cutter rotation speed and the employment of a back-up bit.

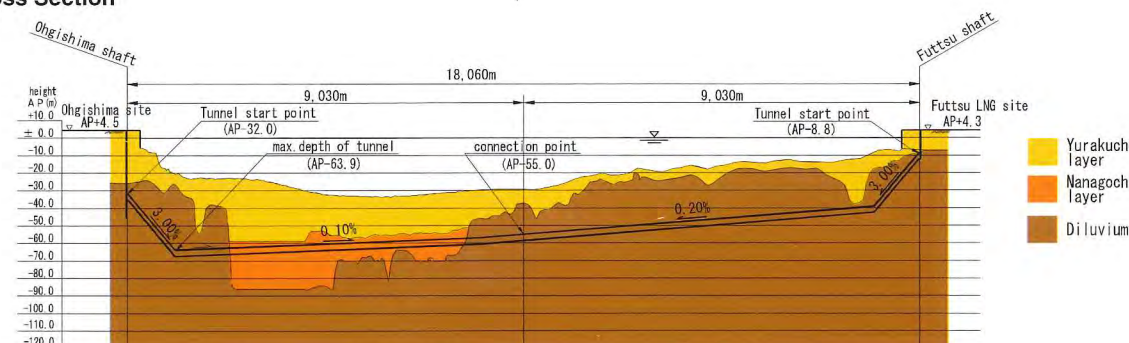
(2) Method of simultaneous excavation and segment erection
To maintain high-speed excavation, simultaneous excavation with segment erection was adopted. The monthly progress is planned as approx. 500m, and the daily progress as approx. 25m.

(3) Mechanical underground connection

The mechanical underground connection method which is economical and requires a short construction period is being employed for this project. The sequence is, firstly, horizontal borings from inside the arrived machine are to be made to grasp the relative position of the other approaching machine, and then the excavation of the later approaching machine corrected accordingly. Next, the internal body of the arrived machine will go back, the front of the internal body of the approaching machine would thrust inside the hood of the arrived machine. After water-sealing is executed with a tube seal device attached to the hood of the arrived machine, slurry will be removed from inside the chamber, then disassembled, and connection works carried out.



Route Cross Section



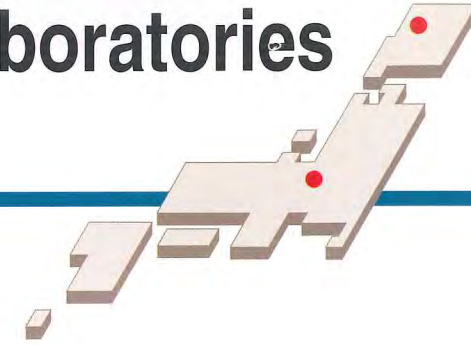
Underground Research Laboratories for R&D on HLW

Toshinori SATO

Tono Geoscience Center,
Japan Nuclear Cycle Development Institute

Nobuaki SHIRATO

Horonobe Geoscience Center,
Japan Nuclear Cycle Development Institute



The Japan Nuclear Cycle Development Institute is carrying out research and development projects. This includes the construction of deep underground research facilities in Mizunami, Gifu Prefecture and in Horonobe Town, Hokkaido. This project is part of the research and development of technology for geological disposal of high level radioactive waste, with the aim of preparing the base for engineering technology of deep underground application and developing the technology of investigations, analysis and technical evaluations of the deep underground environment. Over around 20 years, progress will be made in 3 phases; the research phase of forecasting investigations from the ground surface-based investigation phase (Phase I), the research phase with excavating exploration shafts construction phase (Phase II), and the research phase of using the exploration shafts operation phase (Phase III), and currently we are at the moment where phase I and II overlap. As of July 2003, a portal of the shaft is being constructed at Mizunami, and at Horonobe, the land development works have started.

The purpose of this plan is to confirm the technical reliability of geological disposal methods which were indicated by the Second Progress Report.

Plan for Underground Laboratory (Mizunami City, Gifu Prefecture)

The various features of the research shaft currently planned are as below:

- Main shaft: Internal diameter 6.5m, depth around 1,000m
- Ventilation shaft: Internal diameter 4.5m, depth around 1,000m
- Intermediate and maximum depth stages: hood shape, internal diameter 3.8m, overall length approx. 800m (Intermediate stage installed at 500m depth, and maximum depth stage at 1,000m depth).
- Reserve stages: hood shape, internal diameter 3m, length approx. 35m (installed at every 100m depth)

For the excavation of the vertical shaft, and in order to reduce the construction period as much as possible, an irregular short step method will be adopted, i.e., for pouring the lining concrete after every second blasting. For the horizontal shaft, excavation will mainly be carried out by NATM, with plans to introduce a TBM for a part for research purposes.

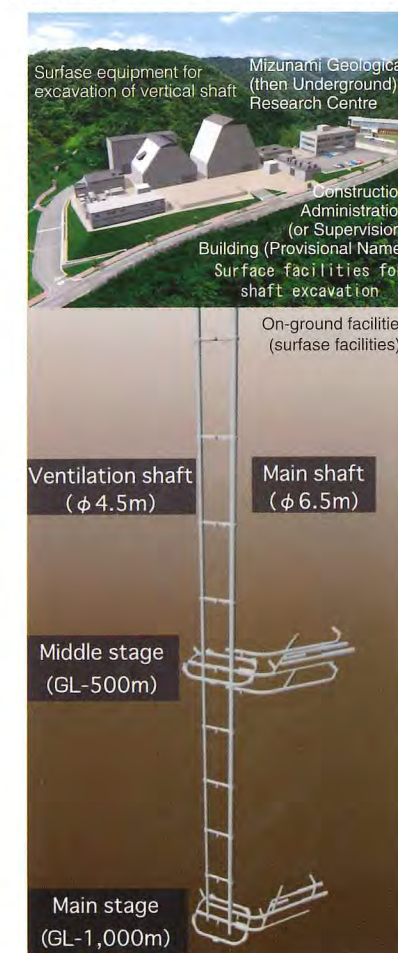
Plan for Horonobe Underground Facility (Horonobe Town, Hokkaido)

The various features of the research shaft currently planned are as below:

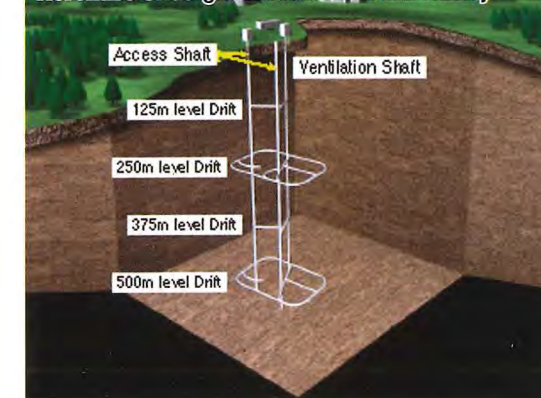
- Access shafts: Internal diameter 6.5m, depth around 500m.
- Ventilation shaft: Internal diameter 4.5m, depth around 500m.
- 250m level Drift, 500m level Drift: three-centered circular horseshoe shape, internal width 4m, overall length approx. 1,600m.
- 125m level Drift, 375m level Drift: three-centered circular horseshoe shape, internal width 4m, overall length approx. 200m.

For the excavation method of the vertical shafts, short step methods using either mechanical excavation or blasting methods are planned, and for the excavation of the drifts, NATM excavation by mechanical excavation methods (free cross section excavation machine) is planned.

Mizunami Underground Research Laboratory



Horonobe Underground Research Laboratory



Underground Liquefied Petroleum Gas Stock Base

Takeshi OTAKE

Project Director,
Stockpile Management Department,
Japan National Oil Corporation

Introduction

Storage methods for LPG, whether at normal temperature and high pressure, or at low temperature and normal pressure, are done in liquid form, and depending on the form of storage, are divided into above ground, on-ground and underground types.

Currently, Japan National Stock bases are being constructed at Nanao in Ishikawa Prefecture, Fukushima in Nagasaki Prefecture, Kamisu in Ibaraki Prefecture, Namikata in Ehime Prefecture and Kurashiki in Okayama Prefecture, and of these 5, the Namikata base and the Kurashiki base will become Japan's first large scale water sealed underground rock cavern storage tanks. Water seal type storage system stocks propane or butane gas in liquid form under pressure for long periods in a stable condition, within the excavated cavern utilizing the dynamic water head potential of underground water in the surrounding rock.

Outline of Namikata Base Features

(1) Topography

The Namikata base is located at the tip of the Takanawa peninsula facing the Seto Inland Sea in the northern part of Ehime Prefecture. The surrounding mountain ridge has a maximum elevation of 135m, and an average elevation of 50 ~ 70m, with widespread narrow valleys, forming a hilly land topography with few flat surfaces such as terraces. The shoreline is rugged with sea cliffs and many bare rock exposures.

(2) Ground conditions

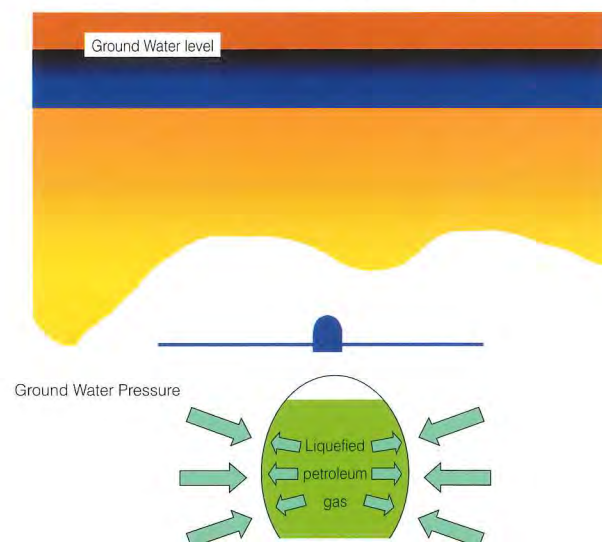
Belonging to the South West Japan Inner belt, granite formed in the Mesozoic Cretaceous period exists on the site. A large part of the land area consists of Namikata granite type, and around Cape Karatsu on the northern coast there is Takanawa granite. The Namikata granite is classified according to the level of weathering; weathered, partially weathered and non-weathered fresh bedrock. The non-weathered fresh bedrock has apart from some parts good

physical properties, and low permeability (average permeability index : 5×10^{-7} cm/s), and is a fairly consistent rock.

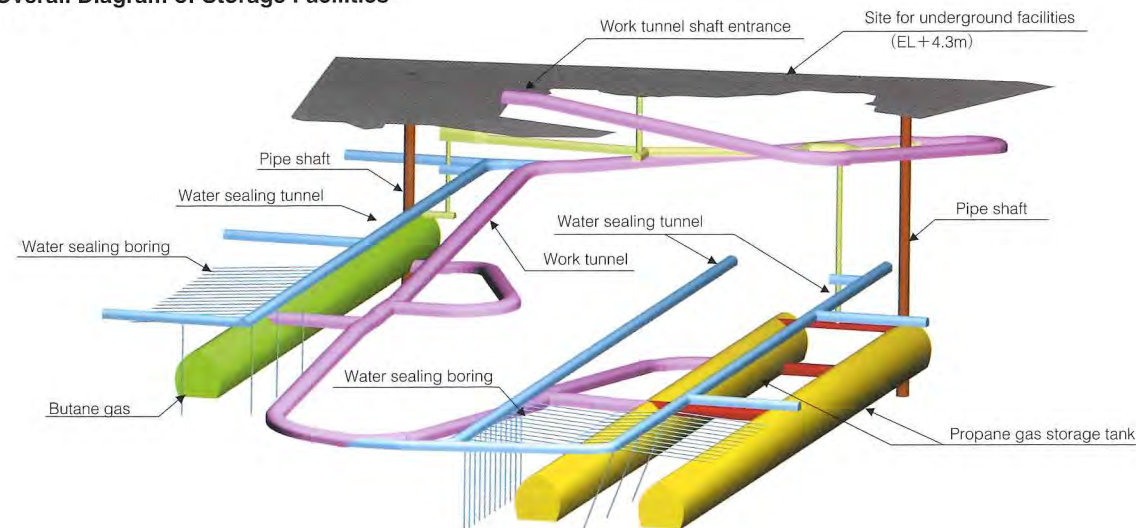
Plan Outline of Namikata Base Facilities

The Namikata base is equipped with 150,000 tons class storage of butane and 300,000 ton class storage of propane. The cavern tank section is planned as an egg shape, with water sealing tunnels and water sealing borings provided at the top part of the storage. These tunnels and borings are used to provide water in the rock, for the purpose of stabilizing the ground water pressure. In addition, the above-ground facilities area is being developed using land reclamation along the shore.

Concept of Water Sealed Underground Rock Cavern Storage



Overall Diagram of Storage Facilities



Innovations in Technology

Simultaneous Segment Erection/ Shield Driving System

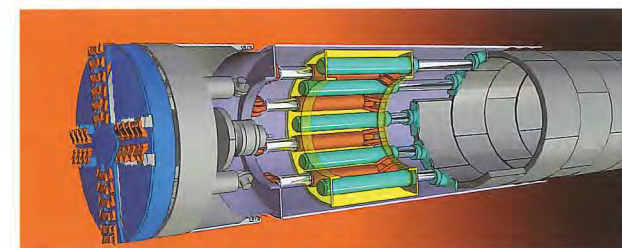
Recently, due to social needs for cost reduction, longer routes and shortened schedules are being expected for shield tunneling. The double jack simultaneous excavation shield method, compared to conventional shield machines, allows for the simultaneous difficult erection of segments together with tunnel excavation, speeding up the construction schedule and thus making it possible to shorten the construction schedule.

The machine developed for this system is equipped with a drum that can slide inside the machine. The drum has two types of jack; one is specifically used for excavation and is fitted on the front side of the drum, and connects the drum to the main body of the machine. The other is mainly used for segment erection and is fitted on the rear side of the drum. Equipped with these two types of jacks, excavation work and segment erection can be performed concurrently, thus making it possible to shorten the construction period.

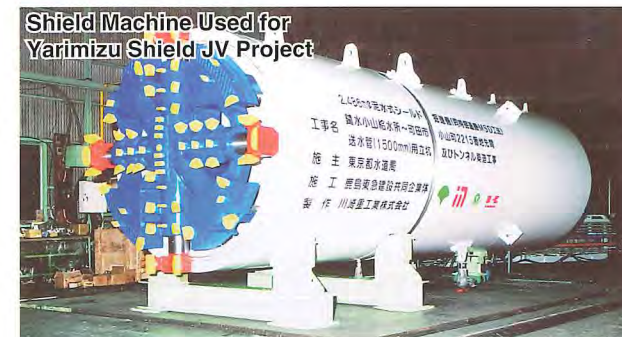
For the sequence of excavation and erection, by pushing forward with the excavation jack, the whole shield machine is moved forward and as excavation is carried out, the erection jack is extended and segments are assembled into place.

The most important technical subject for the realization of this method is the dealing with eccentric moments developed caused by the extending and withdrawing of the shield jack during segment erection, and the overall positional stability of the shield machine. For the double jack method simultaneous excavation shield machine, the sliding inner body has been designed to be structurally able to resist these eccentric moments. Then, the unbalanced reaction forces inside the erection jack are counterbalanced by naturally occurring differences in pressure, thus making it able to preserve the forward driving stability of the shield machine.

This method was adopted for use on the Yarimizu Shield JV Project for a part of the water mains works commissioned by the Tokyo Metropolitan Government Water Works Bureau. (Kajima Corporation)



Shield Machine Used for
Yarimizu Shield JV Project



Mucking System using Pneumatic Dispatch Capsule for Vertical Shafts

Recently, although the depth of underground structures has been progressing, for methods used until now for mucking by using a lifting bucket, concerns remain on the safety aspects associated with the scattering of soil and accidents from rope breakage, and also the self-weight of the rope markedly decreasing the transportation efficiency. Furthermore, although studies have been made for underground construction at depths of around 1,000m, demands exist for the development of rope-less and highly reliable systems for the movement of goods both for during construction and after completion.

This technique is for transporting excavated debris from a tunnel, which has then been placed in a hopper at the base of the shaft, and which is then loaded into a capsule, which is then sent to the ground surface inside a vertical transport shaft using a pneumatic dispatch system.

The special features of this technique are that the air drive source can be used and be applicable even for vertical shafts of depths around 1,000m, and that transport speed of around 3 times more can be achieved compared to current bucket systems. In addition, as it is transported inside a closed shaft, soil and dirt can not fall out onto below, high levels of safety can be preserved, and using compact equipment and the efficiency of energy saving systems, and the automatic transportation system can reduce manpower and thus reduce costs, and expectations exist for the further application of mucking and vertical transportation systems at great depths using this technique.

This technique has been adopted for use for mucking in the vertical shaft of the Numakuma Sewerage Tunnel works, part of the sewer works commissioned by Hiroshima Prefecture. (Kajima Corporation)



Mucking Capsule



Innovations in Technology

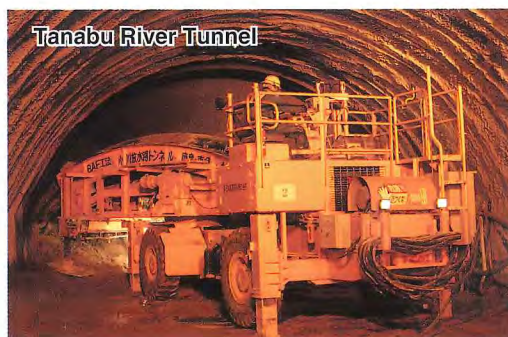
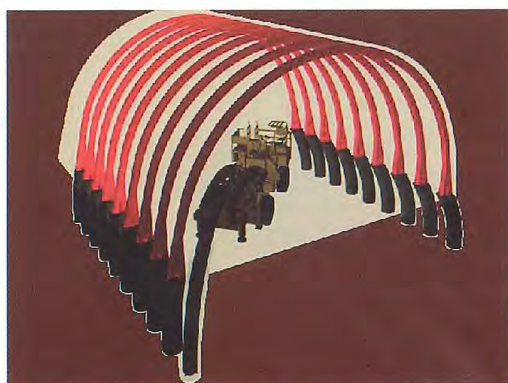
Bent Auger Foot-Pile Method

When adopting mountain tunneling methods in parts of thin overburden coverage and in urban areas, the main task is to minimize ground surface settlements and to strictly reduce the influence on surrounding structures. In particular, settlement of the support leg can be a main cause of ground surface settlement, and foot piles are a representative countermeasure that has often been adopted for reinforcing the tunnel base. However, the traditional foot pile method, as it follows behind the cutting face, can not control well the initial settlements, and as drilling water is used in the construction, the ground is disturbed and weakened, so settlements can increase, making the problem worse.

Thus, for this method, special machinery with an arc-shaped casing and auger is positioned at the tunnel cutting face, and 500mm large diameter mortar piles formed ahead of the cutting face for the support legs, with the aim of reducing settlement. The special feature of this method is that as the auger is arc-shaped, leg reinforcing piles can be built prior to excavation of the cutting face. In addition, as a large diameter high strength improved structure can be made, the effect of restraining the leg settlement is large. Furthermore, as an auger casing is used for the excavation, reinforcing piles can be made without disturbing the surrounding ground. Besides, as the depth of improvement can be freely adjusted as far as 3.5m, this method can eliminate unnecessary improvement.

This method is being used on the Tanabu River tunnel for a river diversion tunnel passing underneath a residential area with a shallow overburden commissioned by Aomori Prefecture.

(Japan Foundation Engineering Co., Ltd.)



QB Segment

Recently for Shield tunnel projects, reducing cost by omitting secondary linings and increasing the length of tunnels etc., are major objectives and the QB (Quick Block) segment has been developed in response to these.

The QB segment has segment joints using a concrete butt joint structure, and ring joints using a pin joint (locked disc spring). It also forms a smooth inner surface and thus it makes high-speed construction possible.

In cases where the ground is relatively good, axial forces are predominant, making the tunnel stable, and it is rational in the design for the segment joint parts to use simple butt joint structures, as a splicing effect can be expected between the segment rings.

The notable characteristics of the QB segment are that as steel joint pieces are reduced and the structure simplified, the cost of the segments is reduced; due to the smooth inner face the secondary lining can be deleted; the segments need only to be inserted in the axial direction by the erector or shield jack and then erected, so making high-speed construction possible and improving construction safety.

Currently, on the National Road No. 19 Kasugai Multiple-Use Tunnel Daisenji Project commissioned by the Nagoya National Road Office of the Ministry of Land, Infrastructure and Transport, QB segments are being used, and as of August 2003, 3,400m of the works were safely completed. In addition to this project, it has been decided to use them for two more in this fiscal year, and further developments are expected using these segments making it possible to delete secondary linings on long distance high speed construction works.

(Kajima Corporation)



Remote Explosive-charging System

During mountain tunneling, workers are exposed to the greatest risk when they charge explosives into the face of the tunnel, because the face has been loosened by excavation.

To address this concern, systems for remotely charging explosives have already been developed and put to use with positive results. A system for handling explosives with a high performance was developed for the project of the Shin-Shunzaka Tunnel (national road tunnel, excavation section 75.2m², length 2904m). Another even larger system was used for the Kakegawa tunnel project on the New Tomei Expressway, having a larger excavation section of 140m² and a length of 1554m.

The principles of the system appeared on the Biennial "Tunneling Activities in Japan 1998": An initiator was passed through the charging tube from a distance of two or three meters from the tunnel face, and required amounts of additional explosive and tamping material were added through the same tube, controlled by optical signal or radio. In both cases, the explosives were charged safely, using the air. These projects confirmed that the safety of workers, our first priority, is dramatically improved, and the workers are freed from tiring and dangerous work. In addition, stable and compact charging improved blasting efficiency. This method has been employed at three other tunneling sites and its use is expanding.

(Kumagai Gumi Co., Ltd.)

Remote Charging Device (Overall View)



Remote Charging Work



Long Face Reinforcement Method with GFRP Tubes

The long face reinforcement method is executed using a drill jumbo at the face. GFRP (Glass Fiber Reinforced Plastic) tubes which can be easily cut, serving as a casing, are pushed into holes. They then reinforce the ground ahead of the face, together with grouting.

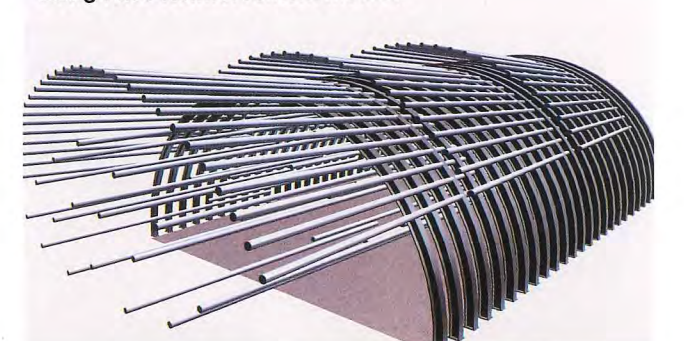
The method is applicable even in hazardous soft and weak ground, where a borehole in the ground is collapsible. The lightweight GFRP tubes have a high tensile strength and a sufficient stiffness to effectively reduce displacements ahead of the face.

A ring bit attached to an inner rod is inserted into the GFRP tube (outer diameter 76mm, inner diameter 60mm, length 3m each). After drilling, the ring bits and the GFRP tubes are left in the holes, and the rod with an adapter is removed. The GFRP tubes are then connected with each other to a specified length.

This method is applied in long face-piling and long fore-piling work in tunneling projects. This technique can be also applied to foot reinforcement ahead of the face and to drainage work. The longest ever recorded face reinforcement by this method is 30m.

From the viewpoint of applicability, economy and effectiveness, its excellent capability has been proven in over 100 cases over a 4 year period (1999 - 2003) (KFC Ltd.)

Long Face Reinforcement Method



Before Face Reinforcing



After Face Reinforcing



Inspection Technology of Highway Tunnels

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Highway Engineering Division,
Engineering Department,
Japan Highway Public Corporation

Currently, the Japan Highway Public Corporation (hereinafter referred to as 'JH') controls around 1,300 tunnels of overall combined length of over 1,100 km. As the tunnels in Japan are underground structures which run through many types and various environments of differing ground formations and different types of soil structures, after construction, stress concentrations caused by degradation of the rock, deformations of the back face of lining through the years, and cracking due to degradation of the concrete lining can arise, which can cause unstable conditions to the tunnel structures and also create traffic obstacles.

Until now, controls have been carried out by making inspections at regular intervals based on the eyesight of the controller and acoustic hitting of the concrete lining, but investigations of cracks and the back face of lining carried out inside the tunnel whilst in operation involves a lot of troublesome work and high expenses.

Thus, JH has been studying the development of methods, techniques and the application of them to improve the efficiency of concrete lining crack investigations and back face surveys.

Crack Survey Technique for Concrete Linings

Correctly comprehending the extent of cracking is an inevitable item for planning tunnel repairs. JH has developed a system to monitor crack propagation through time using a concrete lining inspection vehicle which travels at 50km/hr



using argon laser radiation and continuously reading the amount of reflection to accurately understand the status of cracking, and causing no restrictions to traffic. (Photo 1.2). In addition, by carrying out the crack inspection survey at 50km/hr, an inspection technique using a CCD digital video camera has also been developed (Photo 3)

Inspection Technique for Back Face Lining Cavities

For tunnels not constructed using shotcrete and rockbolts, and through such as the corrosion of sheet pile linings, the washing away of ground etc. can cause cavities to form on the back face of linings, which can have a detrimental effect on the long-term durability of the tunnel, and so it is necessary to have an efficient method to inspect for such cavities. JH is currently developing a system whereby high-speed rotary percussion drills acting on the concrete lining can have real time mechanical data measurements collected on the drill hole speed, impact pressure and rotation pressure, thus enabling the lining thickness, scale of cavities and the relative strength of the concrete and the ground condition to be understood. (Photo 4). Furthermore, the holes made during the inspection can be used as injection holes for grouting works following the inspection.

Themes for the Future

These technologies are currently on trial and their future suitability to attend to problem points are being understood, in order to confirm efficient inspection methods

Furthermore, through the growth of digital equipment technology, new non-destructive inspection techniques are being actively developed, and JH is hoping to swiftly respond to such any new technologies.

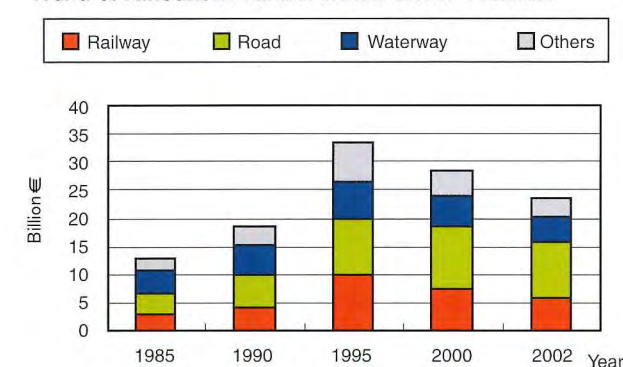


General Aspects of Tunnelling in Japan

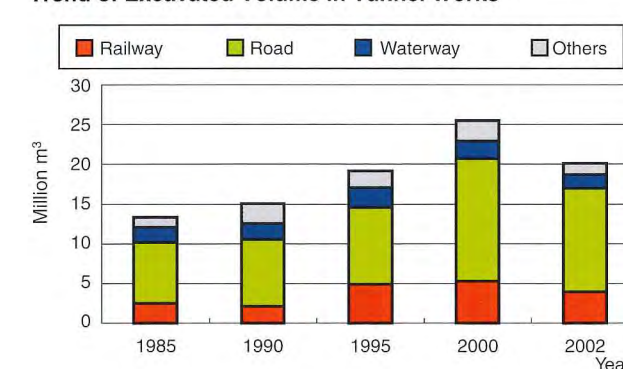
Trend of Construction Investment in Tunnels and Underground Space

Due to the special characteristic of the Japanese land, extensive mountainous terrain within a narrow land area, the record of tunnel excavation in Japan is in the top level among the countries of the world. In 2002 alone, the total length of tunnels under construction was as much as 1,178 km. These charts show the amounts of tunnel works under contract and excavated volume at five year intervals from 1985 to 2000 and 2002, categorized by tunnel purpose. Benefiting from active social capital construction in the 90's, the amount of works under contract showed a rising trend, and since 1995 a level of 23 billion euro or more has been maintained mainly in railway and road tunnels. With larger cross section road tunnels and longer railway tunnels, excavated volume showed a rising trend and has exceeded 20,000,000 m³ since the year 2000. (Amount of works under contract is the total contract amount of works that were contracted in that and previous years, and are still under construction in that year.)

Trend of Amount in Tunnel Works under Contract



Trend of Excavated Volume in Tunnel Works

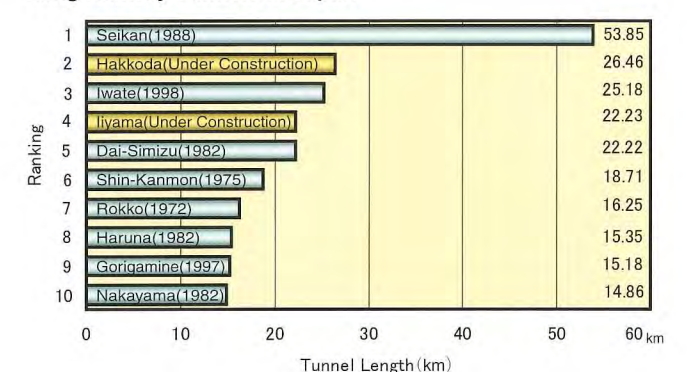


Representative Long Tunnels in Japan

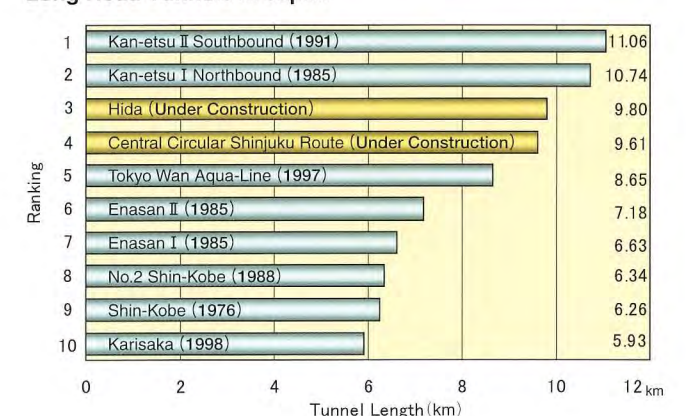
Many more long tunnels have been constructed for railways in comparison with those for roads. First among Japanese railway tunnels is the 53.85 km long Seikan Tunnel, one of the longest undersea tunnels in the world. Following this are the Hakkoda, Iwate and Iiyama tunnels, which strikingly show the trend of longer tunnel length in Shinkansen construction.

Among road tunnel, the 11.06km long Kan-etsu tunnel is the longest, followed by Hida Tunnel, Central Circular Shinjuku Route, Tokyo Wan Aqua-Line and Enasan Tunnel.

Long Railway Tunnels in Japan



Long Road Tunnels in Japan



Use of Deep Underground Space

The Special Measures Act for the Public Use of Deep Underground Space was approved by the Diet in May 2000 and put into force on April 1, 2001.

The Kobe Municipal Government applied this law to a 250 m length of construction works for a water pipeline, so as to enable deep underground use at over 40m depth below private land, and to shorten the route length and reduce the project cost.

The City is aiming to start this construction works in 2007, and this will become the first application of the Special Measures Act for Public Use of Deep Underground. Furthermore, the Ministry of Land, Infrastructure and Transport has decided to apply the this ACT in order to promote the construction of a section of the Tokyo Outer Ring Road Project between Nerima and Setagaya (approx. 16km). This will avoid the necessity of difficult land purchases etc., and can help reduce costs.

PUBLIC CORPORATIONS, LOCAL AUTHORITIES AND OWNER COMPANIES

East Japan Railway Company

2-2-2, Yoyogi, Shibuya-ku, Tokyo 151-8578
TEL:3-5334-1288, FAX:3-5334-1289
<http://www.jreast.co.jp>

Japan Highway Public Corporation

3-3-2, Kasumigaseki, Chiyoda-ku, Tokyo 100-8979
TEL:3-3506-0111, FAX:3-3506-8870
<http://www.jhnet.go.jp>

Japan Railway Construction, Transport and Technology Agency

6-50-1, Honcho, Naka-ku, Yokohama-shi 231-8315
TEL:45-222-9101, FAX:45-222-9090
<http://www.jrtt.go.jp/>

The Tokyo Electric Power Company, Incorporated

1-1-3, Uchisaiwai-cho, Chiyoda-ku, Tokyo 100-8560
TEL:3-4216-1111, FAX:3-4216-4369
<http://www.tepco.co.jp>

Tokyo Metro Co., Ltd.

3-19-6, Higashiueno, Taito-ku, Tokyo 110-0015
TEL:3-3837-7132, FAX:3-3837-7208
<http://www.tokyometro.jp/>

SOCIETIES AND ASSOCIATIONS

Japan Road Association

3-3-1, Kasumigaseki, Chiyoda-ku, Tokyo 100-8955
TEL:3-3581-2211, FAX:3-3581-2232
E-mail:info@road.or.jp
<http://www.road.or.jp>

Japan Railway Contractors' Association, Inc.

2-5-1, Hatchobori, Chuo-ku, Tokyo 104-0032
TEL:3-3551-2494, FAX:3-3551-4954
E-mail:tekenkyo@mx2.alpha-web.ne.jp
<http://www.tekkenkyo.or.jp>

Railway Technical Research Institute

2-8-38, Hikari-cho, kokubunji-shi, Tokyo 185-8540
TEL:42-573-7223, FAX:42-573-7355
E-mail:infocenter@rti.or.jp
<http://www.rti.or.jp/>

GENERAL CONTRACTORS

Asunaro Aoki Construction Co., Ltd.

2-14-5, Shiba, Minato-ku, Tokyo 105-8454
TEL:3-5439-8508, FAX:3-5439-8531
E-mail:eigyo-tokatsu@aaconst.co.jp
<http://www.aaconst.co.jp/>

Daiho Corporation

1-24-4, Shinkawa, Chuo-ku, Tokyo 104-8289
TEL:3-3297-7008, FAX:3-3551-4005
E-mail:info@daiho.jp
<http://www.daiho.co.jp>

DOWA Construction Co., Ltd.

31-10, Chikkousakaemachi, Okayama-shi 702-8609
TEL:86-262-9200, FAX:86-262-9215
E-mail:yo-yoshii@dec.co.jp
<http://www.dec.co.jp>

Hazama Corporation

2-5-8, Kita-Aoyama, Minato-ku, Tokyo 107-8658
TEL:3-3423-1801, FAX:3-3405-1854
E-mail:suzukim@hazama.co.jp
<http://www.hazama.co.jp>

HONMA Corporation

3300-3, Sanno-cho, Nishiminatomachi-dori, Niigata-city 951-8650
TEL:25-229-2511, FAX:25-229-4726
E-mail:koutarou-sasaki@honmagumi.co.jp
<http://www.honmagumi.co.jp>

Ishida Doboku Co., Ltd.

11-19, Higashimachi, Saiki, Oita 876-0814
TEL:972-23-5811, FAX:972-22-3882
E-mail:honsha@ishidadoboku.co.jp
<http://www.ishidadoboku.co.jp>

JDC Corporation

4-9-9, Akasaka, Minato-ku, Tokyo 107-0052
TEL:3-3403-3311, FAX:3-5410-5808
E-mail:jdc-pr@n-kokudo.co.jp
<http://www.n-kokudo.co.jp>

Kabuki Construction Co., Ltd.

3-31-5, Takada, Toshima-ku, Tokyo 171-8560
TEL:3-3984-4115, FAX:3-3984-4139
E-mail:nogiwa.t@kabuki.co.jp
<http://www.kabuki.co.jp>

Kajima Corporation

1-2-7, Motoakasaka, Minato-ku, Tokyo 107-8388
TEL:3-3404-3311, FAX:3-5474-9145
<http://www.kajima.co.jp>

Konoike Construction Co., Ltd.

Konoike Bldg, 3-6-1, Kita-kyuhoji-machi, Chuo-ku, Osaka 541-0057
TEL:6-6244-3553, FAX:6-6244-3690
<http://www.konoike.co.jp/>

Kumagai Gumi Co., Ltd.

2-1, Tsukudo-cho, Shinjuku-ku, Tokyo 162-8557
TEL:3-3260-2111, FAX:3-5261-5576
<http://www.kumagaigumi.co.jp/>

KYOWA EXEO Corporation

3-29-20, Shibuya, Shibuya-ku, Tokyo 150-0002
TEL:3-5778-1111, FAX:3-5778-1230
E-mail:S.takashima@en2.exeo.co.jp
<http://www.exeo.co.jp/>

Maeda Corporation

J.CITY, 5-8, Takamatsu, Nerima-ku, Tokyo 179-8903
TEL:3-5372-4968, FAX:3-5372-4768
E-mail:nasimotoy@jcity.maeda.co.jp
<http://www.maeda.co.jp/>

Natomu-Giken Kogyo Co., Ltd.

1962, Akamine Mie-machi, Ono-gun, Oita 879-7111
TEL:974-22-0686, FAX:974-22-6954
E-mail:natm1962@green.ocn.ne.jp

Nishimatsu Construction Co., Ltd.

1-20-10, Toranomon, Minato-ku, Tokyo 105-8401
TEL:3-3502-7692, FAX:3-3580-2745
E-mail:overseas@nishimatsu.co.jp
<http://www.nishimatsu.co.jp>

Obayashi Corporation

Shinagawa Intercity Tower B, 2-15-2 Konan, Minato-ku, Tokyo 108-8502
TEL:3-5769-1301, FAX:3-5769-1970
<http://www.obayashi.co.jp/>

Okumura Corporation

2-2-2, Matsuzaki-cho, Abeno-ku, Osaka 545-8555
TEL:6-6621-1101, FAX:6-6623-7692
<http://www.okumuragumi.co.jp/>

Penta-Ocean Construction Co., Ltd.

2-2-8, Koraku, Bunkyo-ku, Tokyo 112-8576
TEL3-3816-7111, FAX:3-3816-7158
<http://www.penta-ocean.co.jp/>

Sato Kogyo Co., Ltd.

4-12-20, Nihonbashi-honcho, Chuo-ku, Tokyo 103-8639
TEL:3-3661-9477, FAX:3-3661-0187
E-mail:skip@satokogyo.co.jp
<http://www.satokogyo.co.jp>

Shimizu Corporation

Seavans South, 1-2-3, Shibaura, Minato-ku, Tokyo 105-8007
TEL:3-5441-0566, FAX:3-5441-0515
E-mail:t.chiba@shimz.co.jp
<http://www.shimz.co.jp/>

Shiraishi Corporation

1-14, Kandaiwamoto-cho, Chiyoda-ku, Tokyo 101-8588
TEL:3-3253-9111, FAX:3-3253-4566
E-mail:okamotoy@shiraishi.com
<http://www.shiraishi.com/>

Sumitomo Mitsui Construction Co., Ltd.

13-4, Araki-cho, Shinjuku-ku, Tokyo 160-8577
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E-mail:hkuwabara@smcon.co.jp
<http://www.smcon.co.jp>

Taihei Kogyo Co., Ltd.

1-23-4, Shinkawa, Chuo-ku, Tokyo 104-0033
TEL:3-5543-6031, FAX:3-5543-6038
<http://www.taiheikogyo.co.jp/>

Taisei Corporation

1-25-1, Nishi-Shinjuku, Shinjuku-ku, Tokyo 163-0606
TEL:3-3348-1111, FAX:3-3345-9444
<http://www.aisei.co.jp>

Takenaka Civil Engineering & Construction Co., Ltd.

8-21-1, Ginza, Chuo-ku, Tokyo 104-8234
TEL:3-3542-6321, FAX:3-3248-6545
<http://www.takenaka-doboku.co.jp>

Tekken Corporation

2-5-3, Misaki-cho, Chiyoda-ku, Tokyo 101-8366
TEL:3-3221-2166, FAX:3-3265-3776
<http://www.tekken.co.jp/>

Tobishima Corporation

2, Sanban-cho, Chiyoda-ku, Tokyo 102-8332
TEL:3-5214-8200, FAX:3-5214-7081
E-mail:information@tobishima.co.jp
<http://www.tobishima.co.jp>

Toda Corporation

1-7-1, Kyobashi, Chuo-ku, Tokyo 104-8388
TEL:3-3535-1354, FAX:3-3564-6713
<http://www.toda.co.jp/>

Tokyu Construction Co., Ltd.

Metro bldg., 1-16-14, Shibuya, Shibuya-ku, Tokyo 150-8340
TEL:3-5466-5272, FAX:3-3797-7547
<http://www.const.tokyu.com/>

Toyo Construction Co., Ltd.

3-7-1, Kandnishiki-cho, Chiyoda-ku, Tokyo 101-8463
 TEL:3-3296-4611, FAX:3-3296-4633
<http://www.toyo-const.co.jp/>

SPECIALITY CONTRACTORS**Ishida Doboku Co., Ltd.**

11-19, Higashimachi, Saiki-shi, Oita 876-0814
 TEL:972-23-5811, FAX:972-22-3882
 E-mail:honsha@ishidadoboku.co.jp
<http://www.ishidadoboku.co.jp>

Japan Foundation Engineering Co., Ltd.

15-17, Sakuragaoka-cho, Shibuya-ku, Tokyo
 TEL:3-3476-5701, FAX:3-5489-7821
<http://www.jafec.co.jp>

Nisshin Techno Inc.

1063-785, Yamamoto Atsubetsu-cho, Atsubetsu-ku, Sapporo 004-0069
 TEL:11-892-7266, FAX:11-892-7344
 E-mail:info@nisshintechno.com
<http://www.nisshintechno.com>

Raito Kogyo Co., Ltd.

4-2-35, Kudan-kita, Chiyoda-ku, Tokyo 102-8236
 TEL:3-3265-2551, FAX:3-3288-0896
<http://www.raito.co.jp>

Seiken Co., Ltd.

1-12-14, Koishikawa, Bunkyo-ku, Tokyo 112-0002
 TEL:3-5689-2351, FAX:3-5689-2361
 E-mail:touketsu-eigyoku@seikenn.co.jp
<http://www.seikenn.co.jp/>

Sanshin Corporation

1-2-7 Koraku, Bunkyo-ku, Tokyo 112-0004
 TEL:3-3816-2151, FAX:3-3816-2178
 E-mail:sales@sanshin-corp.co.jp
<http://www.sanshin-corp.co.jp/>

**CONSULTING AND
ENGINEERING FIRMS****Central Consultant Inc.**

2-16-2, Minami-kamata, Ota-ku, Tokyo 144-0035
 TEL:3-5703-6161, FAX:3-5703-6151
 E-mail:overseas@central-con.co.jp
<http://www.central-con.co.jp/>

Chuo Fukken Consultants Co., Ltd.

11-10, Higashinakajima 4-chome, Higashiyodogawa-ku, Osaka 533-0033
 TEL:6-6160-1139, FAX:6-6160-1239
 E-mail:tanaka_r@cfk.co.jp
<http://www.cfk.co.jp>

Japan Transportation Consultants, Inc.

7-11-1, Ueno, Taito-ku, Tokyo 110-0005
 TEL:3-3842-9170, FAX:3-3842-9177
 E-mail:jtc@jtc-con.co.jp
<http://www.jtc-con.co.jp>

JR East Consultants Co., Ltd.

2-2-6, Yoyogi, Shibuya-ku, Tokyo 151-8512
 TEL:3-3373-6003, FAX:3-3373-5801
 E-mail:hdoi@jrc.jregroup.ne.jp
<http://www.jrc.jregroup.ne.jp>

Kyukun Sekkei Co., Ltd.

3-43, Nishihama, Saiki-shi, Oita 876-0822
 TEL:972-22-4126, FAX:972-24-2966
 E-mail:kyukun@q-ken.co.jp

Metro Development Corporation

5-4-9, Akasaka, Minato-ku, Tokyo 107-0052
 TEL:3-3505-5381, FAX:3-3583-1590
 E-mail:gijutu1@metro-dev.co.jp
<http://www.metro-dev.co.jp>

Nikken Gijutsusha, Corp.

1-1-48, Okubo, Shinjuku-ku, Tokyo 169-0072
 TEL:3-3208-6401, FAX:3-3208-6454
 E-mail:somu@nkg.co.jp

Nippon Koei Co., Ltd.

5-4, Kojimachi, Chiyoda-ku, Tokyo 102-8539
 TEL:3-3238-8305, FAX:3-3265-6469
 E-mail:a1803@n-koei.co.jp
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Oriental Consultants Co., Ltd.

Shibuya Chikatetsu Bldg.6F, 1-16-14, Shibuya, Shibuya-ku, Tokyo150-0002
 TEL:3-3409-7551, FAX:3-3409-0208
 E-mail:tech@oriconsul.co.jp
<http://www.oriconsul.co.jp>

Pacific Consultants Co., Ltd.

1-7-5, Sekido, Tama-shi, Tokyo 206-8550
 TEL:42-372-0111, FAX:42-356-6081
 E-mail:eigyoku@ss.pacific.co.jp
<http://www.pacific.co.jp>

Road Engineering,Co., Ltd.

5-24-7, Nishi-nippori, Arakawa-ku, Tokyo 116-0014
 TEL:3-3891-0711, FAX:3-3891-0701
 E-mail:info@road-eng.co.jp

Yachiyo Engineering Co., Ltd.

1-10-21, Nakameguro, Meguro-ku, Tokyo 153-8639
 TEL:3-3715-1231, FAX:3-3715-5910
 E-mail:yec@yachiyo-eng.co.jp
<http://www.yachiyo-eng.co.jp>

**MANUFACTURER AND
TRADING FIRMS****Fujimi Koken Co., Ltd.**

3-11-18, Iidabashi, Chiyoda-Ku, Tokyo 102-0072
 TEL:3-3264-4825, FAX:3-3264-4832,
<http://www.japanlink.co.jp/fujimi/>

Hitachi Zosen Corporation

1-1-1, Hitotsubashi Chiyoda-ku, Tokyo 100-8121
 TEL:3-3217-8483, FAX:3-3217-8544
<http://www.hitachizosen.co.jp>

Ishikawajima Construction Material Co., Ltd.

1-12-1, Yurakucho, Chiyoda-ku, Tokyo 100-0006
 TEL:3-5221-7211, FAX:3-5221-7297
 E-mail:webmaster@ikk.co.jp
<http://www.ikk.co.jp>

KATECS CO., Ltd.

1-3-3, Kami-Maezu, Naka-ku, Nagoya 460-8331
 TEL:52-331-8821, FAX:52-332-0164
 E-mail:construction@katecs.co.jp
<http://www.katecs.co.jp/>

Kawasaki Heavy Industries, Ltd.

World Trade Center Bldg., 4-1, Hamamatsu-cho, 2-chome,
 Minato-ku, Tokyo 105-6116
 TEL:3-3435-2200, FAX:3-3436-3039
 E-mail:saito_kiyohiro@khi.co.jp/, <http://www.khi.co.jp/>

KFC Ltd. Tokyo head office

2-5-10, Shiba, Minato-ku, Tokyo 105-0014
 TEL:3-3798-8511, FAX:3-3798-8516
 E-mail:yoneda.motohiko@kfc-net.co.jp

Komatsu Ltd.

2-3-6, Akasaka, Minato-ku, Tokyo 107-8414
 TEL:3-5561-2727, FAX:3-5561-2905
 E-mail:webmaster.um@komatsu.co.jp
<http://www.komatsu.co.jp/um/>

Kubota Corporation

3-1-3, Nihonbashi-Muromachi, Chuo-ku, Tokyo 103-8310
 TEL:3-3245-3560, FAX:3-3245-3591
<http://www.kubota.co.jp>

Mitsubishi Heavy Industries, Ltd.

2-16-5, Konan, Minato-ku, Tokyo 108-8215
 TEL:3-6716-3111, FAX:3-6716-5833
 E-mail:qqh000701@mhi.co.jp
<http://www.mhi.co.jp/tekken/>

Mitsui Miike Machinery Co., Ltd.

Mitsui No.2 Bldg.,2-1-1, Nihonbashi-Muromachi, Chuo-ku, Tokyo103-0022
 TEL:3-3270-2006, FAX:3-3245-0203
 E-mail:koken@mail.mitsumiike.co.jp
<http://www.mitsumiike.co.jp>

Nihon Koki Co., Ltd.

Fuji Bldg., 2-11-1, Shiba-Daimon, Minato-ku, Tokyo 105-0012
 TEL:3-3431-9331, FAX:3-3431-1634
<http://www.nihonkoki.co.jp>

Nippon Concrete Industries Co., Ltd.

1-8-27, Kounan, Minato-ku, Tokyo 108-0075
 TEL:3-5462-1021, FAX:3-5462-1040
 E-mail:nc@star.ncic.co.jp
<http://www.ncic.co.jp>

Pozzolith Bussan Co., Ltd.

3-16-26, Roppongi, Minato-ku, Tokyo 106-0032
 TEL:3-3582-8814, FAX:3-3583-3800
 E-mail:ugc@nmb-pbk.co.jp
<http://www.nmb-pbk.co.jp>

Taiku Machinery Co., Ltd.

3-6-5, Haginaka, Ota-ku, Tokyo 144-0047
 TEL:3-3741-3131, FAX:3-3741-6457
 E-mail:taikuu@par.odn.ne.jp

Toho Chikakoki Co., Ltd.

1-2-2, Uchisaiwai-cho, Chiyoda-ku, Tokyo 100-0011
 TEL:3-3591-8301, FAX:3-3591-8310
 E-mail:thdrillt@blue.ocn.ne.jp
<http://www.tohochikakoki.com>