Construction of Underground Service Tunnels as Part of Disaster Management

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Abstract.

Japan is one of the most earthquake-prone countries in the world. The Great East Japan Earthquake that struck on March 11, 2011 devastated a vast area centered on three prefectures in the Tohoku region (Fukushima, Miyagi, and Iwate), and there is said to be a more than 70% probability of a magnitude 7 earthquake striking Tokyo—the nation’s capital—within the next 30 years.

Under these circumstances, various measures are being considered for application to a range of facilities, transportation systems, and infrastructure in Japan in order to protect people’s lives and—at the very least—reduce damage in the event of an earthquake, but in reality no one can imagine the kind of situation that would unfold should an earthquake actually occur.

Sandwiched between Tokyo Station and the Imperial Palace in the center of Tokyo, the Otemachi, Marunouchi, and Yurakucho districts (known colloquially as the “Daimaruyu” area) comprise one huge business district where there is a concentration of representative Japanese companies—including major banks, trading companies, and newspapers—and Japan offices of foreign corporations. In addition to protecting human life, this area potentially faces another serious challenge in the event of a major earthquake—preventing disruption to the businesses operating within it.

In order to be able to do this, strengthening and redundancy of infrastructure such as energy, water, and heating and cooling systems are required. In order to achieve this strengthening and redundancy of energy, water, and heating/cooling infrastructure, utility and service tunnels for installing energy, water, and air-conditioning supply pipes are currently being constructed at a depth of 20–30 meters below ground in the Daimaruyu area. This paper provides an overview of the significance and purpose of this service tunnel construction as well as the project content.

1. Introduction

Sandwiched between Tokyo Station and the Imperial Palace in the center of Tokyo, the Otemachi, Marunouchi, and Yurakucho districts (known colloquially as the “Daimaruyu” area) comprise one huge business district where there is a concentration of representative Japanese companies—including major banks, trading companies, and newspapers—and Japan offices of foreign corporations. (Photograph 1)
Within this area, Mitsubishi Estate Co., Ltd. not only operates its office leasing business but also joined together with other local landowners to establish the Council for Area Development and Management of Otemachi, Marunouchi, and Yurakucho, and has been promoting harmonious area-wide development as a community.

In promoting area development, various issues need to be addressed. Of these, earthquake countermeasures are a major issue that is unique to Japan. In the event of a major earthquake, in addition to protecting human life the Daimaruyu area potentially faces another serious challenge—preventing disruption to the businesses operating within it.

This paper provides an overview of the significance and purpose of the project to construct underground service tunnels that is currently being carried out in order to address these issues, as well as the project content.

2. The Daimaruyu area and its development

2.1. Area Development through a Public-Private Partnership with the Council for Area Development and Management of Otemachi, Marunouchi, and Yurakucho

The Otemachi, Marunouchi, and Yurakucho districts (Daimaruyu area) comprise an approx. 120 ha area sandwiched between Tokyo Station on its eastern side and the Imperial Palace on its western side. It is one of Japan’s top business centers, with approx. 100 buildings housing the offices of approx. 4,300 leading Japanese and foreign companies where approx. 280,000 people work.

Amid the burgeoning redevelopment boom of the 1980s, the Daimaruyu area decided as a community to pursue a policy of integrated development, and the Otemachi-Marunouchi-Yurakucho District Redevelopment Project Council was established in 1988 with the participation of the vast majority of landowners (the Council’s roles were taken over by the Council for Area Development and Management of Otemachi, Marunouchi, and Yurakucho (hereinafter referred to as the “Daimaruyu Council”) in 2010), and in the more than 30 years since then, community-centered area development activities have been carried out with the participation of local landowners.

Furthermore, Chiyoda Ward, Tokyo Metropolitan Government, JR East, and the Council for Area Development and Management of Otemachi, Marunouchi, and Yurakucho joined together in 1996 to form the Advisory Committee on Otemachi-Marunouchi-Yurakucho Area Development. The Advisory Committee discussed future visions for the Daimaruyu area based on the three core pillars of the “Future Vision” for the area and the “Rules” and “Methods” for realizing this image. Following these discussions, the agreed-upon items were compiled as “Guidelines for the Redevelopment of the Daimaruyu Area,” and all subsequent Public-Private Partnership (PPP) area development has been carried out consistently based on these guidelines. The structure of the Advisory Committee on Otemachi-Marunouchi-Yurakucho Area Development is shown in Figure 1 below.
It is this guidelines-based Public-Private Partnership (PPP) area development that can be said to characterize development in the Daimaruyu area. The existence of principles and future images for area development such as these that have been formulated through public-private collaboration has made possible the realization of various redevelopment projects within the Daimaruyu area, as well as the large-scale underground construction work that will be discussed later in this paper.

2.2. Promoting Improvement of Underground Infrastructure Networks

The Guidelines for the Redevelopment of the Daimaruyu Area state that urban infrastructure should be organically networked within the Daimaruyu area, promoting in particular area-wide networking of walkways, parking lots, and district heating and cooling systems on underground levels. Figure 2 is the future image of the underground pedestrian walkway network shown in the Guidelines for the Redevelopment of the Daimaruyu Area. Tokyo’s first underground walkway was constructed in 1937 and comprised an approx. 100 m long underground passage connecting Tokyo Station and a nearby office building. These underground passages proliferated to the extent that today there is a network of underground walkways covering the entire Daimaruyu area measuring a total length of 14 km.

Figure 1. Structure of the Advisory Committee on Otemachi-Marunouchi-Yurakucho Area Development

Figure 2. Structure of the Advisory Committee on Otemachi-Marunouchi-Yurakucho Area Development
Figure 2. Future image of the underground walkway network

2.3. Disaster Preparedness Initiatives for the Daimaruyu Area
The Daimaruyu area is located in Tokyo, which was struck by the Great Kanto Earthquake approx. 100 years ago in 1923. This magnitude 7.9 earthquake wreaked enormous damage, and so ever since then large-scale disaster preparedness drills have been carried out in the Daimaruyu area every September to coincide with the anniversary of this earthquake.

From the perspective of recent disaster preparedness activities, there is increasing awareness of the importance of businesses with offices located within the Daimaruyu area to not only implement self-help measures to protect their own company and employees but also work together with other businesses to provide mutual assistance in the event of a disaster, jointly aiding people who just happened to be in the area due to work or sightseeing when the disaster struck. Recently English-language disaster-preparedness drills have been held in the Daimaruyu area for foreign-national employees of companies located in the area who have no experience with earthquakes.

Furthermore, following the Great East Japan Earthquake (magnitude 9), which struck the Tohoku region in 2011, revisions were made to the Act on Special Measures Concerning Urban Renaissance in 2012 so that areas around transportation hubs in major cities, such as the Daimaruyu area were required to formulate plans for securing safety in order to ensure the safety of people staying in priority development areas for urban renaissance in the event of a major earthquake. Under the Otemachi, Marunouchi, Yurakucho District Urban Revitalization and Safety Securement an energy plan was also formulated with the aim of securing energy sources to allow businesses within the area to continue operating in addition to enabling commuters stranded in the area after a disaster strikes to stay in the area safely for 72 hours. As described in the following chapter, improvement of the Marunouchi Nakadori Street underground service tunnel is also positioned as construction works under the Otemachi, Marunouchi, Yurakucho District Urban Revitalization and Safety Securement Plan.

3. District Heating and Cooling in the Daimaruyu Area

3.1. District Heating and Cooling Initiatives in the Daimaruyu Area
Marunouchi Heat Supply Co., Ltd. was established in 1973 by Mitsubishi Estate Co., Ltd. and other landowners in the Daimaruyu Area. Today, the company operates its heat supply business from 23 plants located in six districts of Tokyo—Otemachi, Marunouchi 1-chome, Marunouchi 2-chome, Yurakucho, Uchisaiwai-cho, and Aoyama. The company began supplying heat in the Otemachi district in 1976 with the aim of reducing pollution as air pollution within the Daimaruyu area was so severe at that time that the pine trees in the gardens of the Imperial Palace were dying. Ever since then, the energy network has been upgraded to keep pace with the Daimaruyu area’s evolution, constantly sustaining the center of Japan’s economy 24 hours a day, 365 days a year for more than 40 years. Today, the company supplies low-temperature heat to 85 buildings, 18 subway stations, and 3 underground walkways in the 111 ha Daimaruyu area (total supply area of 7 million m²). Figure 3 shows the network of District heating and cooling facilities in the Daimaruyu area.

In general, district heating and cooling plants are installed with equipment such as chillers and boilers, supply buildings and other facilities with chilled water and steam as heat media. Plants in the Daimaruyu area use electricity and gas as heat-source energy, ensuring reliability through redundant energy systems. Furthermore, coordinating the operations of different plants ensures that the latest heat source equipment installed in plants are constantly in operation, enabling a continuous supply of highly efficient heat. District piping for supply heat comprises a four-pipe system (two chilled water pipes and two steam pipes), with overhead piping systems in service tunnels used in much of the network to facilitate easy maintenance access.
Figure 3. Network of district heating and cooling facilities in the Daimaruyu area.

3.2. Outlook and Issues for District Heating and Cooling
The Paris Agreement was recently adopted at COP21, and in Japan as well there is a strong desire for global warming countermeasures, especially low-carbonization in the private sector; accordingly, the role played by district heating and cooling systems is growing more and more important. The district heating and cooling of the Daimaruyu area is, as in the development of the Yurakucho district described below, being pursued with the aim of the creation of a total energy system that improves the attractiveness and value of the city and can always be relied upon as an essential urban...
infrastructure, not only through stable heat supply but also through the eager use and supply of area-wide energy sources, and the strengthening of environmental friendliness and disaster preparedness.

4. Nakadori Underground Service Tunnel Construction Project

4.1 The Nakadori Underground Service Tunnel Construction Project and Its Significance

Previously in the Yurakucho district, under the guidance of the Tokyo Metropolitan Government, in June 1969 Mitsubishi Estate Co., Ltd. commenced district heating and cooling by connecting nine Mitsubishi Estate company buildings in the area to district conduits. Subsequently, Marunouchi Heat Supply Co., Ltd. took over these operations in 1990, supplying steam only from two steam plants as our heat supply business.

Because the plant facilities were ageing and the steam was supplied to users via steam pipelines laid inside the plant building, it constantly ran up against the challenges of the cost and effort required to re-lay the steam pipelines inside the buildings; each time the need to address the problem of seismic resistance or deal with plans to reconstruct the building in which the steam pipelines had been laid occurred, the issue of the impact that doing so would have on the demolition of the existing buildings and the construction of new facilities inevitably arose.

Accordingly, this project aimed to resolve these issues by constructing a new plant—the Marunouchi Nijubashi Building Plant—in the affected area, while at the same time building highly earthquake resistant service tunnels underneath Marunouchi Nakadori Street and gradually concentrating steam pipelines in these service tunnels. Figure 4 shows the district heating and cooling facilities to be constructed together with the redevelopment of the Marunouchi Nijubashi Building.
Figure 4. District heating and cooling facilities to be constructed together with the redevelopment of the Marunouchi Nijubashi Building

The new plant was planned based on the concept of supplying energy (heat and electricity) at times of emergency while seeking greater energy-saving than provided by previous plants and improving supply reliability. The project is characterized by its use and development of high-efficiency heat source equipment and utilization of unused district energy through the introduction of a thermal storage system, as well as its introduction of peak shifts for daytime electricity and gas engine (combined heat and power (CHP), an independent distributed generation system).

Chilled/hot water pipelines are also to be laid inside the service tunnels, both in preparation for forthcoming development of the entire Yurakucho area as well as to improve energy efficiency and supply reliability through coordination with new plants in the future. In addition, in accordance with the plan for constructing an underground walkway network, one of the contributions of the Marunouchi Nijubashi Building as part of the national strategic special zone, the project will make it possible to improve heat supply reliability through bidirectional backup by creating a steam network with the Marunouchi 2-chome area adjoining the underground pedestrian space, as well as improve environmental-friendliness by newly installing high efficiency boilers over a wide area.

Inside the service tunnels are to be installed not only heat supply pipelines but also private electricity distribution lines, information networks, and recycled water pipelines for use in emergency situations, (the information networks and recycled water pipelines are planned for the future) . In the event that commercial electricity sources are interrupted in a major disaster, the emergency power generators installed in the Marunouchi Nijubashi Building and part of the CHP power system installed in the Marunouchi Nijubashi Building Plant will provide electricity to spaces for stranded commuters in the Marunouchi Nijubashi Building as well as those in five existing buildings nearby. With regard to recycled water, the plan includes construction of a system capable of supplying water stored in thermal storage tanks inside the plant as emergency recycled water to nearby buildings.

Using this highly earthquake-resistant service tunnel network, the project is endeavoring to construct an area-wide energy system supplying the Yurakucho area with “heat”, “emergency electricity”, “water”, and “information” with the aim of expanding the electricity supply network and utilization of CHP exhaust heat over the entire area, as well as building an independent distributed generation system, thereby strengthening binary-coded decimal function and sustaining the area’s central business function. Figure 5 shows a comparison of the current and future situations regarding district heating/cooling and other lifelines in the Yurakucho area.
Figure 5. Current and future situations regarding district heating/cooling and other lifelines in the Yurakucho area.

4.2. Scheme for the Nakadori Service Tunnel Construction Project
As mentioned above, the “Otemachi, Marunouchi, Yurakucho District Urban Revitalization and Safety Securement Plan” has been formulated for the Daimaruyu area. This plan promotes securing the safety and peace of mind of people staying in the area as well as strengthening the continuation ability of businesses located here, with concrete measures implemented in tandem with building redevelopment. Construction of the Marunouchi Nijubashi Building and the simultaneous construction and development of the Nakadori Underground Service Tunnel are representative examples of this. Under the Otemachi, Marunouchi, Yurakucho District Urban Revitalization and Safety Securement Plan, the Marunouchi Nijubashi Building is designated as a “Disaster Prevention Base Building”; thus it not only has an seismic performance 1.5 times the standard prescribed under the Building Standards Act, but also is equipped with a co-generation system using medium-pressure gas and dual-fuel emergency power generators, ensuring the building has a high capacity for handing disaster situations. Furthermore, due to the location of the Marunouchi Heat Supply Co., Ltd. district heating and cooling plant underneath the Marunouchi Nijubashi Building, it will be possible to supply five nearby buildings with heat, emergency electricity, and recycled water, etc., through the high seismic performance service tunnels being constructed underneath Nakadori Street. Thus the building is playing a role in assuring the strengthening and stabilization of energy supply to the surrounding area.
In addition, although construction of these service tunnels and supply pipelines requires a huge amount of expenditure, these expenses are partially covered by fixed-rate subsidies from the national government and Tokyo Metropolitan Government as facility maintenance costs for sustaining business operations in the event of a disaster. These subsidies make it possible for enterprises to make improvements while only bearing a portion of the overall costs.

In this way, Japan has established systems whereby private enterprises carrying out redevelopment projects that also have a highly public nature, such as infrastructure development, can receive subsidies from the national government and/or their local government body. Utilizing these frameworks, renewal of inner-city areas is being carried out in a manner integrated with infrastructure development. Photograph 2 below shows a service tunnel underneath Nakadori Street following segment assembly using the shield tunneling method, while Photograph 3 shows a service tunnel after piping has been laid.

Photograph 2. A service tunnel following segment assembly using the shield tunneling method
Photograph 3. A service tunnel after pipelines have been laid
5. Conclusion

This paper introduced an example of a project that increases the business continuity of companies located in an inner-city area by constructing service tunnels in spaces 20–30 m underground, creating electricity, heat, and other energy networks connecting multiple buildings, and strengthening resilience to earthquakes and other disasters.

It is considered that there remain many more ways in which networks can be constructed, problems affecting an entire area solved, and functions enhanced by utilizing underground space in ways such as this. However, such initiatives only become possible when there is cooperation based on agreement among all the relevant parties within the area. As discussed above, the direction of area development for this area has been discussed by a council comprising local landowners for around 30 years, with the landowners agreeing on this direction and area development proceeding in accordance with this shared understanding as well as confirmation with administrative bodies. In future, we intend to promote effective underground space utilization in various forms based on this trend.

References

(1) The council for Area Development and Management of Otemachi, Marunouchi and Yurakucho
(http://www.otemachi-marunouchi-yurakucho.jp/)
(2) Marunouchi Heat Supply Co., Ltd (https://www.marunetu.co.jp/)