Renovation Work of Facilities for Tokyo Metropolitan Government Bureau of Sewerage — Renovation, Measures against Post-Earthquake Energy Shortage, Measures against Climate Change, Introduction of On-Site ICT —

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Abstract

According to recent trends in construction of electrical facilities, renovation work (plant retrofit work) has been most common. Common types of construction works are: renovation work for eco-friendly systems, building and securing emergency power as a result from the Great East Japan Earthquake, and work for energy saving systems. The Tokyo Metropolitan Government (TMG) Bureau of Sewerage has drawn up its management policy plan, smart energy plan, post-earthquake energy shortage measure plan, and plant retrofit plan. These plans promote reinforcement and acceleration on system renovation, flood control, improvement on combined sewers, and measures against post-earthquake energy shortage. It also promotes the sourcing of renewable energy, further energy saving, and adoption of the sourcing of smart intelligent technologies in energy use. In addition, they conducted scheduled renovation work on the aged facilities in sewage systems. Activities relating to greenhouse effect gas emission reduction are also being planned. Drawing on our long-term experience and supply records of sewage-related systems for TMG, we have constructed various electrical facilities for sewage treatment plants. As our new initiative, we are promoting Information and Communication Technology (ICT) introduction for project construction sites. In so doing, we secure safety and quality during the construction work of electrical facilities.

1 Preface

For Tokyo Metropolitan Government (TMG) sewage systems, aged facilities are rapidly increasing after many years of spreading and promoting such systems. Functional improvements are also required to cope with the emergency circumstances like torrential rains and large earthquakes. Against this backdrop, we have been conducting various construction projects of electrical facilities that are a key part of sewage treatment plants. This paper introduces some case studies of our construction projects involving system renovation and measures against post-earthquake energy shortages and measures for climate change. We also show how we introduced Information and Communication Technology (ICT) at project sites.

2 Renovation Work

In the case of renovation work, aged facilities are replaced with new ones while existing facilities remain in operation. Since the facility to be renovated is a critical facility, such renovation work must be completed in the shortest amount of time. The difficulty level of such a project is very high. In such cases, renovation work for power receiving and distribution facilities requires a power outage and such

Fig. 1 Existing V-sub

Renovation work was carried out due to performance deterioration over 30 years of operation.

Fig. 2 Newly Installed Eco C-GIS

A view of C-GIS installation after the renovation work is shown. It is of the dry air-insulated type and the first released model.

work must be carried out while stopping the functions of water reclamation centers and pumping stations. To reduce the number and duration of power outage at the location of an existing facility, work has to be performed in the vicinity of energized power receiving equipment ("energized equipment" hereafter). We introduce below a renovation work project conducted at the Minami-Tama Water Reclamation Center. This project was carried out with consideration to safety.

2.1 Outline of the Facilities

We renewed 66kV ultra-high voltage power receiving and distribution facilities (2-line power receiving (main line and backup line) at the Minami-Tama Water Reclamation Center. Existing equipment was composed of two 7500kVA oil-immersed power transformers and a unit-type gas-insulated switchgear (V-sub). These equipment units were changed to a 72kV cubicle type dry-air insulation switchgear (Eco C-GIS), which is our first product to be release. The Eco C-GIS employs dry air for its insulation medium so no SF6 insulation gas is used inside. This model is very environmentally-conscious. Fig. 1 shows a view of the existing V-sub and Fig. 2 shows a newly installed Eco C-GIS.

2.2 Contents of the Work

We drew up a renovation plan for the Center while considering maintaining its functions and still reducing the number of power outages during such work. Since it employs a two-line power receiving system, renovation work was carried out for one circuit after another in sequence. In this manner, however, either one of the circuits is always energized at 66kV during the duration of construction. It was, therefore, anticipated that work had to be carried out close to the energized equipment. Since this facility received power from an ultra-high voltage transmission line through an aerial service wire, the adjacent 66kV circuit was present in a bare state. Should there be any accident by contact, such an accident could lead to a serious electric shock and lead to either a secondary accident at the power company or damage at other power consumers. As such, we took necessary safety measures to best prepare for a worst-case scenario.

First, we installed a blockade between No.1 and No.2 substation equipment. Except for unavoidable cases, we strictly maintained a "no trespassing" policy at the energized substation area. If access was needed, it was done with the cooperation of our on-site staff in order to avoid anyone getting too close to the energized equipment or compromise safety. Fig. 3 shows a view of work situation near renovation construction work.

Next, as a result of meeting with the power company, we took measures that the power company requested to provide safety isolation of the power distribution lines (both low voltage and high voltage) to be provided with protection covers, however, the ultra-high voltage transmission line was an exception and was not provided with such covers. We consequently had to work under the present conditions.

Because a crane boom is a contact accident danger during construction. We placed a rope and a

Fig. 3 **Work Situation near Renovation Construction Work**

A view of the safety measures taken during the work is shown. The work was conducted close to energized equipment.

Fig. 4 **Crane Work during Carry-in and Carry-out Period**

Preventive measures were taken to prevent abnormal close contact to live wires.

CAUTION plate in a position where the crane operator can see it in order to warn of the limited approach distance. During crane construction work, a dedicated employee was assigned to the site with the specific detail to help prevent any encroachment to the danger zone. To avoid miss-operation, we adopted a crane equipped with a swivel preventive function controlled by computer and worked with this safety measure. **Fig. 4** shows a view of crane work during carry-in and carry-out period.

3 Countermeasure Construction against Past-Earthquakes Energy Shortage

In the event of a disaster such as an earthquake, tsunami, local torrential downpour, or of an emergency grid power outage, in-house emergency power generating equipment plays an important role so that water pumping-up functions can be fully functional at Water Reclamation Center and pumping stations. Each Water Reclamation Center and pumping station is equipped with large-capacity emergency power plants that can feed power to large-scale facilities. This section introduces renovation and expansion work for stable power supply by an emergency power supply. We show installation work for 25,000kVA gas turbine generators (2 units) at the Mikawashima Water Reclamation Center (the capacity was increased).

Fig. 5 **No.1 Existing 12,500kVA (Gas Turbine) Generator System**

After 30 years since the installation, performance deterioration was found to be serious and renovation work was carried out.

3.1 Outline of the Facilities

Formerly, the emergency power supply for the Mikawashima Water Reclamation Center was fed by a 12,500kVA emergency gas turbine generator (No.1 machine) installed around 1979. Along with a recent increase in the volume of processing water, however, the second Asakusa-line Pumping Station came into operation, which led to the addition of another 25,000kVA gas turbine generator facility in 2009 in order to secure a stable emergency power supply. Further in 2014, renovation work was carried out to install a 25,000kVA gas turbine generator, thus establishing a two-unit emergency power system. At that time, the first 12,500kVA gas turbine generator (see **Fig. 5**.) was removed because it had suffered from extreme performance deterioration after 30 years of operation.

3.2 Contents of the Work

The construction period per unit was about three years. Installation was carried out from July 2012 to March 2014. Since this work was intended for renovation, the existing aged power generation system was removed and a new system was constructed under the conditions described below.

(1) Work was carried out in hazardous materials handling facilities.

(2) Existing facilities (No.2 generator: 25,000kVA) were required to maintain the readiness for an emergency.

(3) Items removed include asbestos.

(4) Work was conducted while anti-seismic reinforcement work was in progress.

For example, two points from the above are introduced below.

3.2.1 Construction Work in Hazardous Materials Handling Facilities

No.1 generator was renovated at this time and No.2 generator (already existing) were installed in the same generator room (hazardous materials handling facilities). Prior to starting construction, we consulted with the local fire department in this area and made applications to the department for all necessary approvals.

(1) Application for the approval of the change of a hazardous materials handling facility

(2) Application for the approval of tentative operation

(3) Firefighting plan during the construction period

To distinguish the generator operation area (hazardous materials handling) from the construction area during construction, a partition in the room was installed by using flameproof sheet. Since there was an instance when metallic materials like fuel tubes were cut off at the time from an removal of existing generator facility and could give rise to kerosene or lubricant overflow, we carefully selected spark-free motor-powered cutting tools like a saver saw or a band saw. When using cutting tools, sufficient ventilation was made so that hazardous materials would not pose a threat of explosion.

At the time of the dismantling and removal of a gas turbine and generator's main body, a smelt-cut method for steel materials was occasionally used when motor-powered tools would not suffice. At those times, the cutting was made in an area protected by a flameproof sheet. **Fig. 6** shows a view of the area covered with a flameproof sheet. This is an area for work requiring a source of heat or flames.

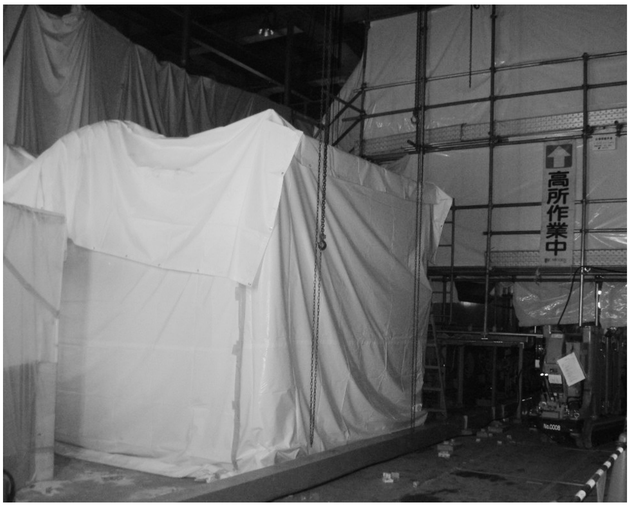


Fig. 6 **Designated Controlled Area Covered with a Flameproof Sheet during Work Using Heat or Flame**

When the work involves the heat or flame for unavoidable reasons, the surrounding area was surrounded by a flameproof sheet. Such work was carried out in a space covered with the sheet.

Select ventilation was used within the designed area and dedicated supervisory staff were present during such work. After each cutting work, the staff rechecked for presence of smelting embers for 30 minutes.

3.2.2 Removing Items Containing Asbestos

Prior to starting work, we investigated for the presence of asbestos. The presence of asbestos in the gas turbine main body was indicated in the ordering specification documents. After the investigation, however, asbestos was found also in piping gaskets, suction air/ventilation/exhaust duct gaskets, coil resin in the generator's main body, and heat insulators of exhaust fume ducts. As such, the removal of asbestos was unavoidable. At the time of the removal of asbestos, we submitted applications to the regional labor standards inspection office, ward office, and Tokyo Metropolitan Government office. Asbestos removal work was carried out as follows:

(1) Gas turbine engine

The whole engine was sectioned and removal work was conducted in designated controlled area (see **Fig. 7**.).

(2) Generator main body

Portions containing asbestos were brought back to our factory. We set up a designated controlled area. Where asbestos was removed (see **Fig. 8**.).

Fig. 7 Removal of Asbestos from Turbine Engine

The whole engine was covered with a flameproof sheet and asbestos removal work was then carried out.

Fig. 8 Removal of Asbestos from Generator Main Body

Resin used for generator windings was found to contain asbestos. The removed generator was taken back to the factory and asbestos removal work was carried out within the designated controlled area.

Fig. 9 Removal of Asbestos from Flange Gaskets of Fuel Pipes

The front and rear parts of each duct flange were cut off and the fuel pipes (after being cut) were brought into the designated controlled area where their gaskets containing asbestos were removed.

Fig. 10 Disposal of Flange Gaskets from Air Conditioner Ducts

Since they were known to contain stabilized asbestos, they were disposed of without breaking the flange bodies.

(3) Gaskets for fuel pipes

After the front and rear parts of a pipe flange were cut off, they were transported without breaking the flange. Inner gaskets were removed within a designated controlled area on site (see **Fig. 9**.).

(4) Gaskets for ducts

The front and rear parts of the duct flange were cut off and handled carefully without breaking the flange. This industrial waste was disposed of as a stable asbestos contained material (see **Fig. 10**.).

The gaskets were removed from fuel pipe lines due to the piping materials being contaminated by fuel. Without any treatment, such industrial waste could not be accepted by any waste disposal service company. The most difficult work was to remove heat insulators from the inner surface of the fume duct 30 meters high. The upper and lower parts of the duct were closed and scaffolds were built inside the duct. The duct was divided into four sections, and we conducted concrete chipping work by using air picking, debris collection work, and carry-out work. In the end, we removed a total amount of asbestos-contained heat insulators equivalent to ten 4t trucks.

This work was carried out in mid-summer of August and workers had to face temperatures of 38℃ wearing Tyvek protective clothing and full masks. Due to this challenge, employees were required to take a break every 60 minutes. A shower was installed next to the designated controlled area.

The work was conducted by teams of two at a time.

It took about half a year to remove the existing 12,500kVA generator facilities. After that, new 25,000kVA generator facilities were carried in and installed. The total mass of the gas turbine engine was 30t and that of generator was 60t. We went through series of handling heavy items, heavy machinery work, and high-place work: construction was completed safely in March 2014.

4 Construction Work for Taking Measures against Climate Change

This section introduces construction work of electrical facilities for dehydrated sludge incineration at Shingashi Water Reclamation Center defined as part of measures against Climate Change. The purpose of this work is the installation of a No.3 turbo type fluidized bed furnace (turbo furnace hereafter) of the second-generation incinerator. (No.1 turbo furnace was installed in the Asakawa Water Reclamation Center and No.2 turbo furnace in the Kasai Water Reclamation Center.)

4.1 Outline of the Facilities

The turbo furnace is a combination of a conventional foam fluidized bed furnace and a supercharger. When the energy of incineration exhaust gas is utilized to drive a supercharger turbine to feed incineration air, this makes a fluidizing blower unnecessary. This can reduce power consumption. In addition, since incineration efficiency is improved

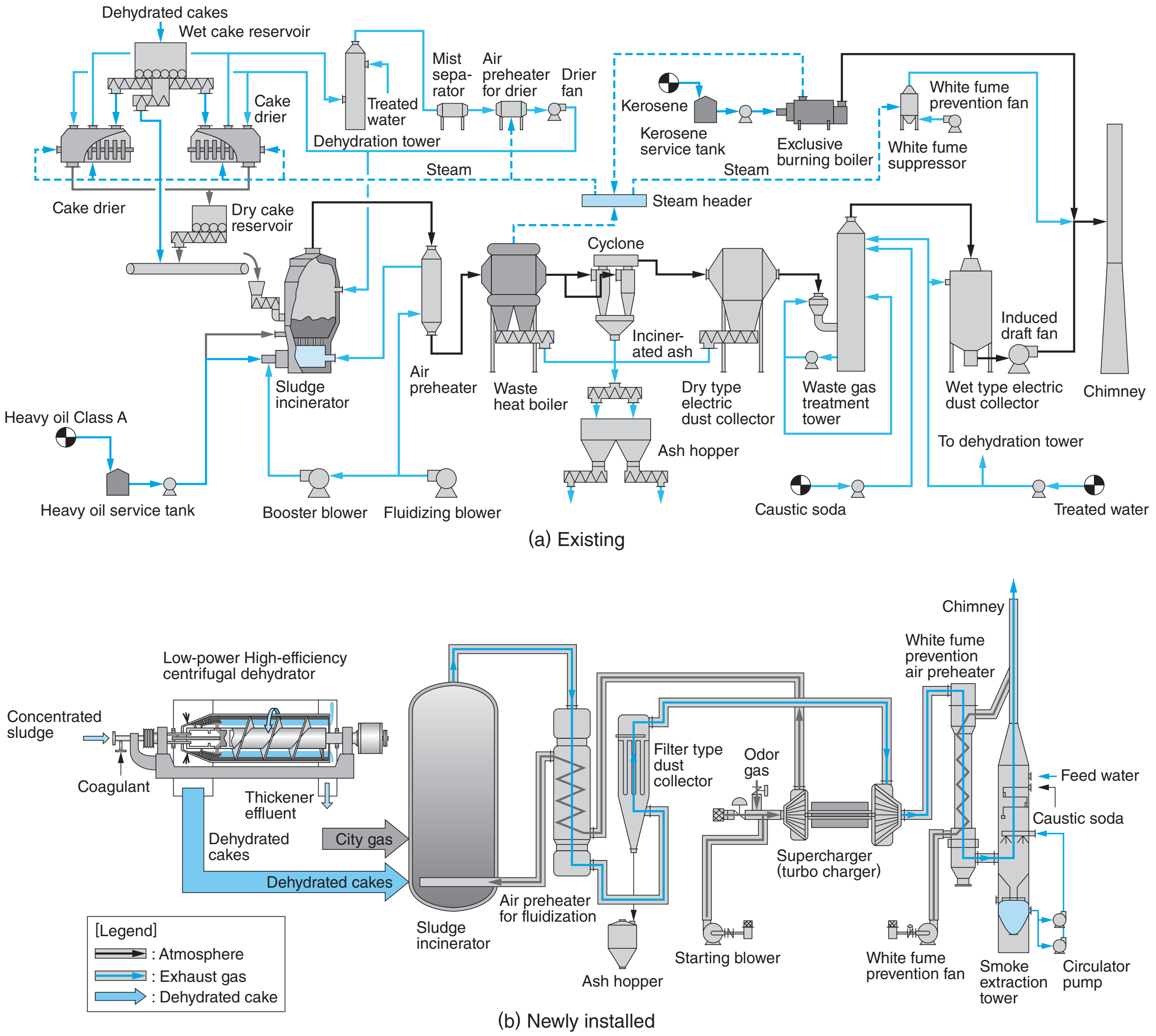


Fig. 11 Flow Diagrams of Existing Facilities and New No.3 Incinerators

A processing flow diagram for the foam fluidized bed furnace is shown in (a) and another processing flow diagram for the turbo type fluidized bed furnace is shown in (b).

as a result of high-temperature incineration under high pressure, N_2O gas, or a greenhouse effect gas can be remarkably reduced. Still more, when a sludge dehydrator is installed at the top of a steel framework rack in the vicinity of an incinerator, electric power consumed for transferring dehydrated sludge cakes can be saved. These are features of a turbo furnace. Facility equipment consists of the following:

(1) Turbo-furnace: 250t/day, 1 unit (SANKI ENGINEERING CO., LTD.)

(2) Centrifugal dehydrator: 50m^3/h, 3 units (METAWATER Co., Ltd.)

(3) Other subsidiary facilities: 1 set

(4) Electrical facilities needed for incinerator facility operation (high voltage switchgears, low voltage switchgears, etc.): 1 set of new installation. There is an existing 1 set of supervisory control equipment

Fig. 11 shows flow diagrams of existing facilities and new No.3 incinerators.

4.2 Contents of the Work

Construction work for electrical facilities relating to normal combustion incinerators takes about two years. This time frame for work was, however, very difficult because an existing incinerator had to be decommissioned first and a new incinerator required some time for start-up and commercial operation.

At the Shingashi Water Reclamation Center, water treatment and sludge processing facilities plus three existing incinerators were in operation. The facility switchover work was executed while present facilities remained in operation. This was difficult to accomplish because there were limitations in permissible facility shutdown scope and shutdown time. In fact, there were normally about 200 people working on the project site area of 37 × 17m^2. Under such circumstances, detailed coordination was made with TMG Bureau of Sewerage and various machinery facility suppliers with respect to scheduled daily working areas, materials, and machinery carry-in time. This was to prevent the occurrence of any accident due to the overlapping work area. We completed the work without an accident. Regarding the renovation work of the supervisory control facility, system switchover work had to be made 15 times. We united two supervisory control transmission loops into one. To not adversely affect system operation, system switchovers were carried out while keeping facility shutdown to the shortest amount of time: thus the operation of new turbo furnaces started and the existing first-generation incinerators, once called the biggest scale facilities in the East, would be abolished one after another. Fig. 12 shows the installation of an existing and new No.3 incinerators.

(a) Existing

(b) Newly installed

Fig. 12 Installation Situation of Existing and New No.3 Incinerators

An installation view of the existing foam fluidized bed furnace (200t/day) before removal work is shown in (a) and the installation of new turbo type fluidized bed furnace (250t/day) is shown in (b).

5 Special Construction Work

Many pumping stations are distributed in residential areas and each station is installed in a narrow space. As this is the case, there are various restrictions for equipment carry in and carry-out. It is difficult to carry equipment by conventional surface transportation because of these restrictions.

As such, a barge was used to deliver and carry equipment along the Sumidagawa River that flows near the Machiya Pumping Station. This section introduces facility expansion work for power generation facilities at the Machiya Pumping Station.

5.1 Contents of the Facilities

The Machiya Pumping Station is used to transfer sewage water to the Mikawashima Water Reclamation Center. While the capacity of the main power transformer there was 2500kVA, the existing emergency generator was half of that (1250kVA). Such a capacity was not enough to fully supply the power for the pump-up function in the event of an emergency. Accordingly, an emergency power generation facility (1250kVA) was newly installed.

5.2 Contents of Work

The Machiya Pumping Station is situated in a residential area and is surrounded by small factories. It is close to the Sumida River. This pumping station is constructed on a very small location where almost no space is available for this kind of construction work. At the busiest season of the project, there is no sufficient parking space for construction vehicles. Under such conditions, the installation of an emergency generator system was planned. We had to work out the issues stated below while the installation work was in progress.

(1) Noise and vibration issues at the installation site of the emergency generator

The installation location was formerly used for an aged transformer on the east side of the pumping station, which was surrounded by the pumping station building, neighboring factory, condominium, and the river bank. Because of soft ground, piles had to be driven deep down to the hard layer. Since factories and a condominium were located nearby, careful consideration was needed concerning vibration and noise during the piling work. The steel pipe piles adopted for this time had a structure whose vanes were attached to the tip of the pile. The pile is rotated and driven down to the hard layer. Unlike concrete piles, this type of a pile does not generate very much vibration or sound during piling and it is unnecessary to dispose of earth resulting from piling.

For this project, a simple installation type power unit (gas turbine generator system) was installed. It was the stationary double-package type model and equipped with a distribution panel. Fig. 13 shows the 1250kVA simple installation type power unit. To meet the zoning requirements around the Machiya Pumping Station (semi-industrial zone), the low noise type was adopted. The audible sound level for this type is 55dB (Characteristic A) measured at 1 meter apart from the machine. The dual structure enclosure type was adopted. The exhaust silencer was also a special design. Due to such measures, sound level was suppressed. Even if standing near the generator in operation, one might not even be aware it is in operation.

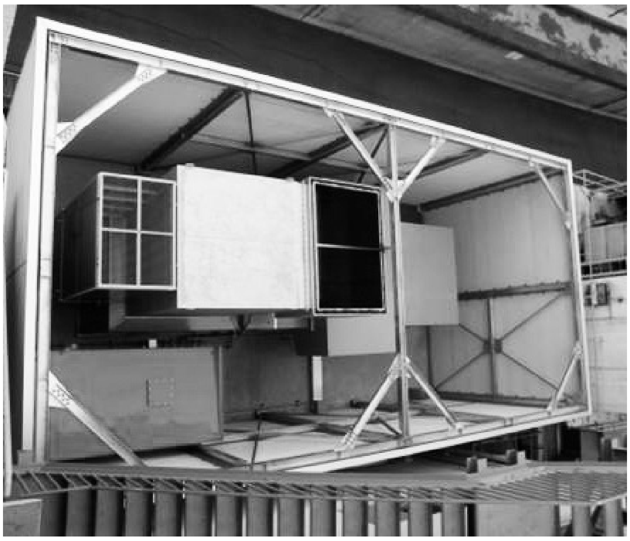


Fig. 13 1250kVA Simple Installation Type Power Unit

An installation view of the simple installation type power unit surrounded by sound insulation walls is shown.

(2) Work adjacent to the subway shield structures

Steel pipe piles were driven as deep as 28 meters down into the hard layer. In fact, subway shield structures were crossing beneath the pumping station. Since the project work had to be carried out extremely close to the structures, only 1.8 meters at the closest, we had several meetings parties, the TMG Bureau of Sewerage, and a subway-related firm. This was to determine the piling positions. At the time of the work near the subway shield structure, representatives from the Bureau of Sewerage and a subway-related firm observed the work on site. Piling work was thus conducted with the utmost care. The subway network is one of the most important social infrastructures. We finished the piling work safely without causing any damage to the shield structures. Fig. 14 shows a view of piling work for the generator foundation.

(3) Carrying-in work for generator system

In installing the generator system in a space on

Fig. 14 Piling Work for the Generator Foundation

A view of piling work is shown. The work was performed close to subway shield structures.

the east side of the pumping station, we initially examined a method to carry it in by land transportation: however, nearby roads were too narrow to move large-sized cranes and transportation vehicles. In order to carry a large machine to the site, equipment had to be carried over the roof of the pumping station building. As a result, the crane size had to be large. In addition, the working site was very close to the neighbor's land and it was difficult to set up a large-sized crane. We then selected to transport the system with the Sumida River that flowed through near the pumping station. It was, however, soon after the Great East Japan Earthquake in 2011 and many firms sent barges to the Pacific coast of Tohoku region for post-earthquake reconstruction. Consequently, we had a difficulty in securing an available barge.

(4) The transportation route

After surveying the site by actually passing through the river by a ship, we checked the height of the various bridges, the width of the river, and determined the most suitable route. This route passes through the Arakawa River its wide width and gentle curves. The necessary time estimated was about 6 hours for transport. (The barge went up Tokyo Bay and the Arakawa River from Shinkiba, Koto City and arrived at the Machiya pumping station via the Iwabuchi water gate which was a turning point with the Sumida River.) Since there were several bridges above the barge passing route and the generator height was 2.9 meters, there was possibility of collision with the bridge. As such, we adopted a box

(a) A view of the river transport

(b) A view of transportation near the pumping station

Fig. 15 Generator System Transportation by Barge

A view of transportation on the river is shown in (a) and the transportation near the pumping station is shown in (b).

type barge with a hollowed inside. We tried to minimize generator system disassembly level in order to save on-site reassembly time after the equipment was delivered. The disassembled enclosures and suction/exhaust hoods were transported on a flat barge. Fig. 15 shows a view of the generator system transportation by barge.

(5) Carrying-in work from barge

Equipment was transported from upstream of the Sumida River to the destination-the Machiya Pumping Station. Since equipment was carried in over the river bank, the working area was very wide and the working radius was 28 meters. A 100t crane barge was used because the weight of carry-in equipment was 11t (Max.). Because of presence of the bank, the crane operator could not see the project site from the crane cockpit. Then, the cargo-lifting was carried out while using radio communications. During the carrying work, equipment swayed

Fig. 16 Generator System Transportation by Barge

A view of the generator system lifting and carry-in by using a 100t crane barge is shown.

by the waves each time there was a wake from traffic of other ships. We thus were challenged in the equipment installation and adjustments. This carry-in work was uncommon and it was impossible by a conventional method. By thinking outside the box, we thought of the idea to use the river more effectively by making the transportation, carrying-in work, and installation of equipment more successfully. Fig. 16 shows a view of generator system transportation by barge.

6 Introduction of ICT to the Project Site

Recently, major general contractors began to use ICT devices on project sites. We also introduced computers and communication technologies for the improvement of safety and quality control as well productivity and efficient on-site project management work. This section introduces some examples of the active use of ICT devices at the project site by using a tablet PC and webcams for improved safety and quality control.

6.1 Our Initiative

Fig. 17 shows an example of active use of a tablet PC. The contents of drawings, report form, and check lists used for the project site were designated from paper for the tablet PC. In so doing, we simplified safety control for the security on site and improved quality control. As a result, overall work efficiency was improved. By using the special drawing management software and report form management software, our intent was to reduce the tasks to check lists, record test data, and write patrol reports

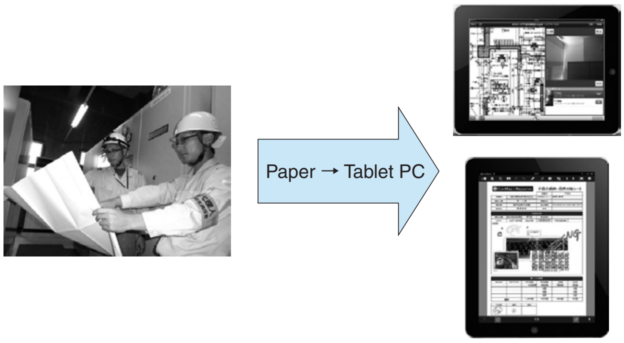


Fig. 17 Example of Active Use of Tablet PC

The contents of drawings, report form, and check lists used on the project site were digitized from paper for the tablet PC. By this digitally, we aim to improve the work efficiency.

(a) A scene of checking an as-built drawing

(b) A scene of giving advice to a worker

Fig. 18 Example of Active Use of Drawing Management Software

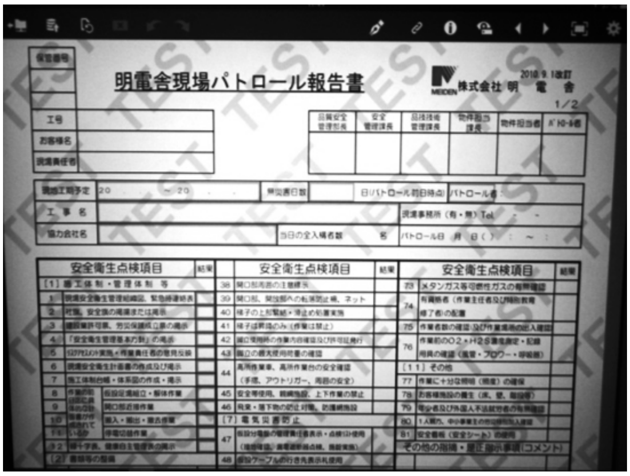
Many drawings and documents can be managed on the tablet PC. Data can be displayed under weak communicating conditions such as underground.

on site. In addition, drawing the project site inspection with the project owner we could quickly show drawing and control values to the customer. This could enabled us to make speedy web communication. In the case of an unexpected disaster or an accident, by using communication technology, we can respond immediately.

Webcams which connected the cloud network are also installed so that the intrusion of suspicious persons onto the project site and theft of equipment and materials could be prevented. These devices are also useful as communication tools between our office and the project site, and for disaster prevention drills. Figs. 18 to 22 show examples of active use.

6.2 Challenges

By actively using the digital information communication on the Web in communicating with the



(a) Tablet operation screen

(b) A view of checking the work done

Fig. 19 Example of Active Use of Report Form Management Software

During the work at the project site, we can draft reporting documents.

(a) Views by Webcams

(b) Tablet PC screen

Fig. 20 Example of Active Use of Webcams

Field information can be obtained in a timely manner and monitoring can be done from an outside location.

(a) A webcam connected to the cloud network

(b) Views by webcams connected the cloud network

Fig. 21 Example of Active Use of a Cloud-Based Camera

A stockyard can be monitored through a PC, a mobile phone, or a tablet PC at the project site office. Our goal is to prevent a theft.

Fig. 22 Example of Active Use of Communication Tools

A communication tool is actively utilized between our safety management section and the project site office. It is monitoring equipment carry-in work.

project owner, we aimed to enable the monitoring team of the project owner to grasp site conditions and share the key information. There are currently many our people at the project sites who are not familiar with the tablet PC. As such, younger members mainly use of the on-site ICT. We promote sharing the project site with our project owners. In so doing, we aim to secure safety and improve installation quality at each project site.

7 Postscript

This paper introduced the contents of our renovation work, countermeasures against post-earthquake energy shortage, climate control, and technology based ICT adopted at our project sites.

Lastly, we would like to express our sincere thanks to the project-related members of the TMG Bureau of Sewerage for their guidance and advice on on-site safety and project schedule planning. We completed the project without any accidents. We would like especially like to express our appreciation to TMG's project management and supervision department for their guidance and advice for facility management and safety control. In addition, we express our gratitude to many project-related people at the project site for their work and effort while keeping safety paramount. Going forward, we will promote the more active ICT use at project sites for ever-improving better future construction sites.