Development of system that promptly monitors the water supply to the government agencies immediately after earthquake
- Water pressure checking system using a mobile phone line -

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Abstract: A stable water supply to the central organizations in the capital city is an important mission of the Bureau of Waterworks, Tokyo Metropolitan Government (hereinafter referred to as the Tokyo Waterworks). One of the biggest threats to this mission is an earthquake directly under the capital, which is predicted to occur in the near future. Until now, our policy was to dispatch staff to all of these facilities immediately after the large earthquake to check the condition of the water supply on-site, however, the Great East Japan Earthquake of 2011 revealed that this task would take a very long time due to heavy traffic. As a counter measure, we developed a system that measured the target facilities' water supply pressure remotely using PHS, a type of existing mobile phone line, from the Tokyo Waterworks office. In this paper, we introduce this system, which we believe will be an extremely effective tool in the initial stage of a disaster.

Keywords: Risk management; making the water pipe's joints earthquake resistant; government agencies; water pressure check; mobile phone line

1. Introduction

Many functions that keep Japan running and connect it to the world, such as government agencies, financial institutions, news organizations, and foreign embassies, are highly concentrated in the country's capital, Tokyo. Waterworks are used for many purposes, including not only domestic water and firefighting water, but also cooling water for computer equipment, so providing the stable water supply essential for the operations of these organizations is an important mission of the Tokyo Waterworks.

One of the biggest threats to this mission is a magnitude-7 class earthquake directly under Tokyo, which the government predicts has a 70% chance of striking within 30 years. In brought estimates by the Tokyo Waterworks, an earthquake directly under Tokyo will cause water service suspension by knocking loose the couplings of water transmission pipes. Especially in eastern districts of the capital where the ground is weak and shaking is expected to be strongest, estimates showed a water suspension rate in excess of 60%.

Currently, the Tokyo Waterworks is working from various angles on seismic countermeasures, a theme that must be addressed urgently. However, it will take a great deal of time to complete hard measures for preventing damage physically, and these are still underway. Therefore, the danger remains of water supply getting cut off to important facilities such as government agencies, so it is necessary to confirm and secure the water supply situation quickly, in order to support restoration activities in Tokyo. Thus far, the Tokyo Waterworks has considered its challenge to be securing very safe and swift means of transportation in the confusion after an earthquake (such as using motorcycles), in order to move about to confirm the water supply situation. To fundamentally solve this problem, we have developed a revolutionary water pressure checking system that can check the target facilities' water supply pressure and the supply condition from the Tokyo Waterworks office. So far, we have installed the newly developed equipment at three places, and the results are promising, as there is no difference between values measured on-site and values measured by the system. Here, we introduce this system, which we believe will be an extremely effective tool to deal with earthquake disasters.

2. Seismic resistant coupling retrofitting of water pipelines

The water pipeline owned by the Tokyo Waterworks is built from straight pipes 4 to 5 meters in length and shorter elbow pipes, which are joined by rubber rings that keep water from leaking. The pipes are made with high quality material, using ductile cast iron that is highly seismic resistant for 99.8% of the length of all pipelines, so there is no danger of the pipes themselves breaking or bending due to an earthquake. However, in the Great Hanshin Earthquake (magnitude 7.3), couplings came loose from pipelines, causing water service suspension damage in various locations. Learning from this lesson, the Tokyo Waterworks officially adopted seismic resistant coupling-fitted pipes with the ability to keep couplings from coming loose (Figure 1), and we have conducted seismic coupling retrofitting of water pipelines since.

Figure 1 Structure of seismic resistant coupling-fitted pipes, and demo of hanging connected pipes

3. Measures to protect government agencies from an earthquake directly under Tokyo - Seismic resistant coupling retrofitting of supply routes to important facilities

Tokyo Waterworks owns nearly 27,000 kilometers of transmission pipes, and a great deal of time and money is required to do seismic resistant coupling retrofitting of all pipelines. Therefore, in order to realize early benefits from seismic resistant coupling retrofitting, the Tokyo Waterworks has designated critical facilities which play important roles in the initial stages of an earthquake disaster, including government agencies, emergency medical facilities, and evacuation sites, and has given priority to seismic resistant coupling retrofitting of "supply routes", which are important pipelines among those that connect water supply stations with those facilities. (Figure 2)

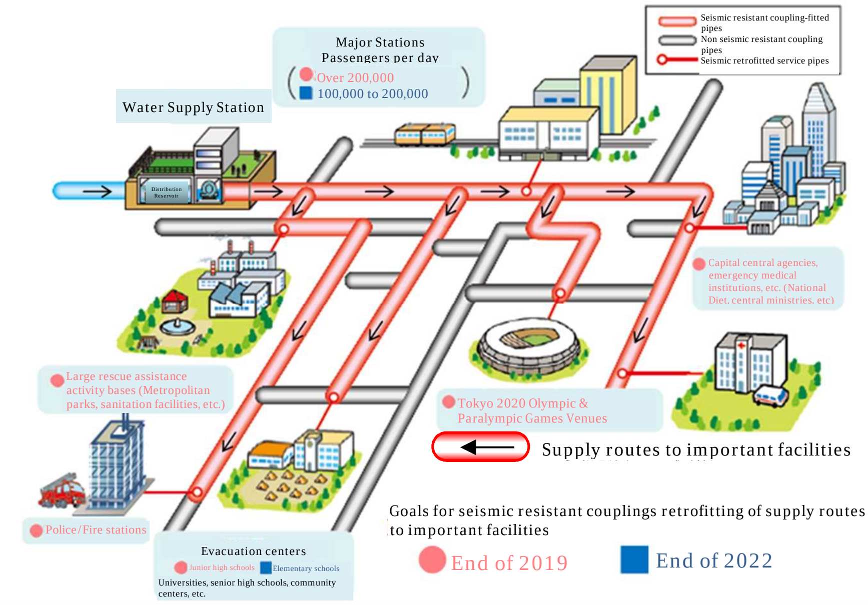

Figure 2 Seismic resistant coupling retrofitting of supply routes to important facilities (conceptual diagram)

Furthermore, in 2007 the Tokyo Waterworks established an organization entitled the “Waterworks Emergency Service Unit” stationed in our offices 24 hours per day 365 days per year in order to improve our seismic countermeasures. This team is responsible for rushing to all government agencies among important facilities immediately after a disaster strikes, and checking the water supply situation. When they find a facility that has inadequate water pressure, leaks in the vicinity of the supply route are isolated by closing gate valves in the supply route branch pipes, quickly restoring water pressure of these facilities. (Figure 3)

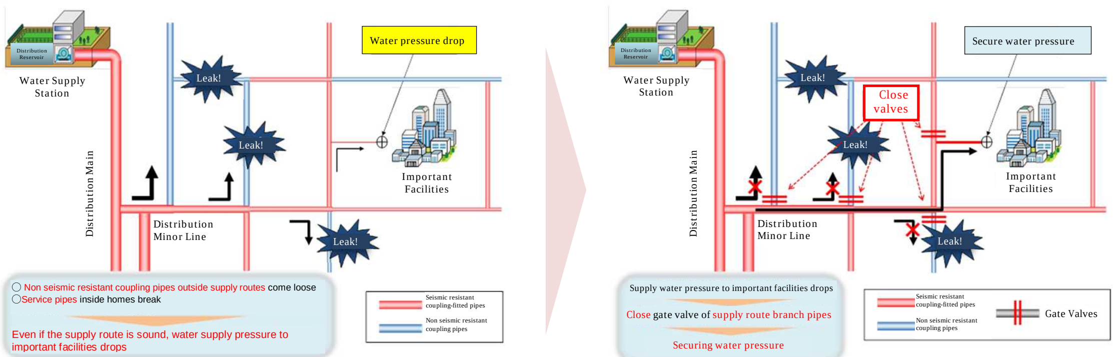

Figure 3 Conceptual image of securing water pressure to important facilities

4. Issues that have emerged and the proposal for this system

After the 2011 earthquake and tsunami, even far from the epicenter in Tokyo heavy traffic flooded major trunk roads, the unexpected situation was occurred. Staffs who were deployed for water supply situation checks needed a very long time to reach their destinations (Expected time of 15 hours ended became actual time of 22 hours). In anticipation of an even more dramatic earthquake directly under Tokyo, it has become necessary to make fundamental improvements to our methods for confirming water supply situation.

Therefore, we have decided to more effectively restore water supply to important facilities by developing a new system that makes it possible to not only have staff check the water supply situation visually, but to check the water supply situation remotely from the Tokyo Waterworks office, and deploy teams only to respond to facilities that have problems (Figure 4). According to rough estimates for an event in which half of all facilities are affected by the earthquake, introducing this system is expected to reduce time needed for restoration from the currently expected 63 hours to about 40 hours (a reduction of 40%).

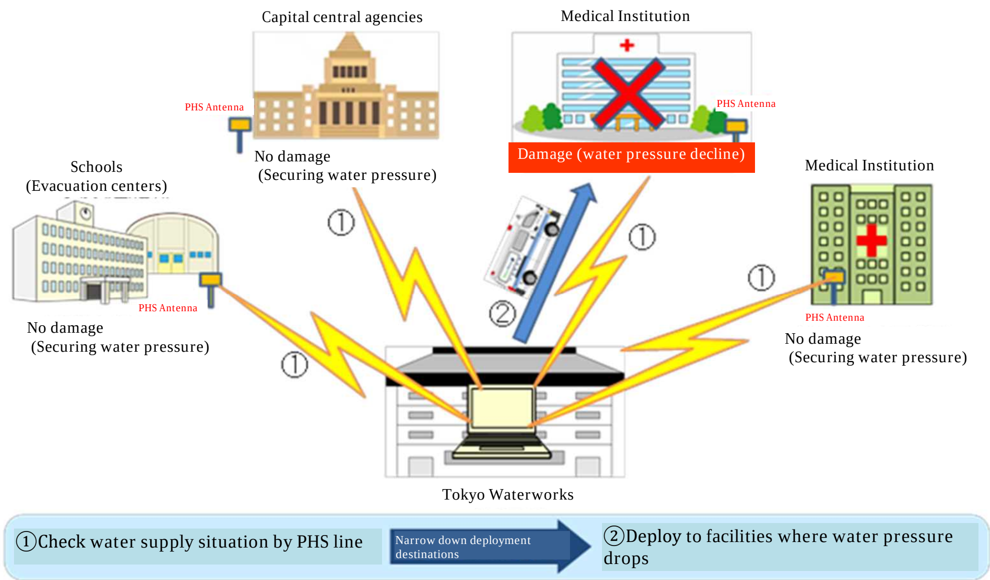

Figure 4 Conceptual diagram for the new system
(Tokyo Waterworks checks the situation and only deploys to facilities with problems)
*In this figure, priority is given to deployment to the medical institution where water pressure decline has been seen

4. Development and demonstration of new systems
- Remote surveillance of water supply pressure using mobile phone lines -

(1) Conditions required for the water supply check system

The water supply situation of target facilities is judged by evaluating the water supply pressure to the target facilities, and for the new system we have examined methods that satisfy the following requirements.

1) Able to check the supply water pressure of target facilities at any time from the Tokyo Waterworks office.

2) Evaluate whether or not water is being supplied to a facility by measuring the pressure in service pipes branching from transmission pipes.

3) Water pressure meters installed in target facilities (which measure water supply pressure and transmission/reception of data) shall

not rely on outside power sources.

(2) Development of water pressure check systems

The Tokyo Waterworks has thoroughly examined a system that satisfies conditions (a) to (c) shown in part (1), and adopted the following specifications to conduct development.

(a) Collect water pressure data via wireless communication by installing transceivers in the Tokyo Waterworks offices and pressure measurement points in the service pipes of target facilities. (Figure 5)

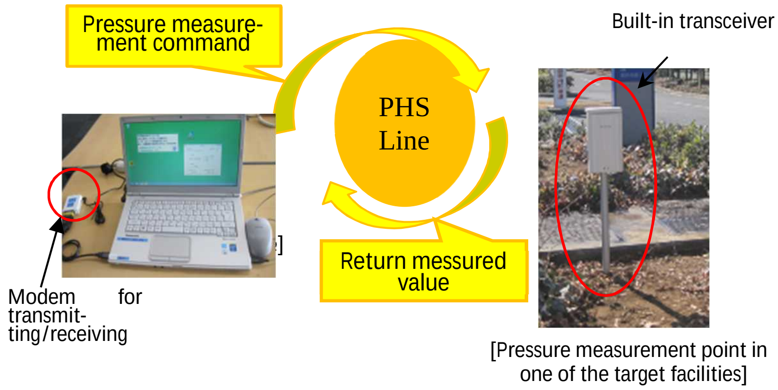

Figure 5 Collection of water pressure data

We installed a notebook computer connected to a transceiver modem for collecting data. Also, in order to reliably check water supply pressure of the many target facilities, we developed new software with the following features.

[Software Features]

- A transmission function that can work at any time, and scheduling function that obtains data at specified times and days of the week
- Simultaneously measures water supply pressure values, as well as remaining battery life and electric field strength of the data conversion and transmission equipment, and displays this on the screen and automatically saves it in Excel file format
- Capable of making settings for each target facility within the scope of normal pressure

For wireless communication, we selected PHS lines from among the existing mobile phone lines. The PHS line is a type of cellular phone line used in Japan on the frequency band of 1.9 GHz, and is a wireless communication standard that enables high-quality information transmission at low power and cost. Furthermore, the PHS line was not subjected to communication restrictions even when there was heavy access to mobile phone lines during the Great East Japan Earthquake, giving it high communication reliability at the time of the earthquake disaster.

(b) The pressure of service pipes in target facilities are measured by cutting a flange equipped with a water proof pressure sensor set in a service pipe near the water meter that measures the amount of water used. In addition, in order to prevent breakage during metering, a plastic protective guard was installed on the pressure sensor (Figure 6).

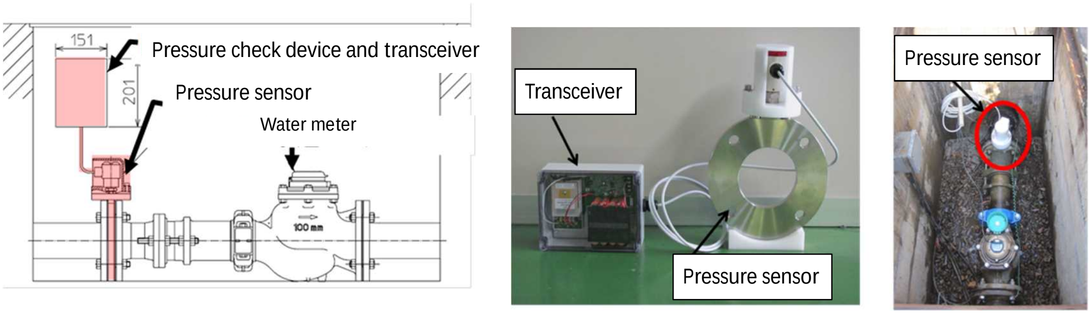

Figure 6 Structure of water supply pressure measurement points

Values measured by the pressure sensor are sent from a transceiver installed nearby through PHS lines to the transceiver installed in the Tokyo Waterworks. (Figure 7)

This transceiver is installed inside the water meter bath or on the ground nearby, so we put it inside a water proof plastic case equivalent to IP67 in IEC (International Electrotechnical Commission) standards (measuring 201 mm wide, 151 mm high, 80 mm deep).

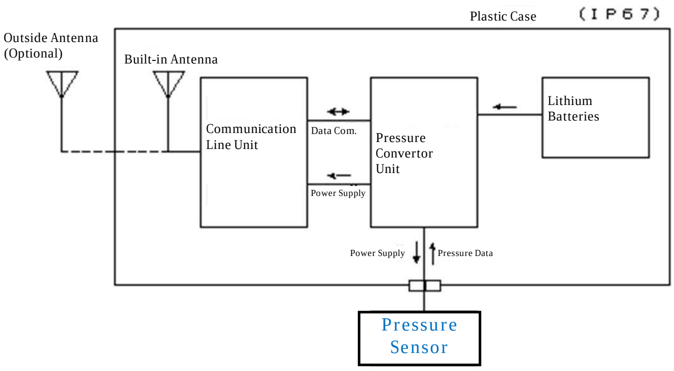

Figure 7 Structure of terminals (pressure sensor, pressure check device, and transceiver)

(c) We installed lithium batteries in the transceiver of the water pressure meter installed in the target facility. (Figure 8)

In order to make the water meters inserted into service pipes use only water pressure as a power source and require no electric power, because they are often installed in environments with no outside electricity source nearby, we installed batteries internally. We installed 20 batteries, calculating their battery life so as to enable continuous use without replacement for 10 years or more in planned operating conditions. The devices are also designed for the batteries to be replaceable.

[Planned Operating Conditions]

・ Transceiver communications lines are kept in a waiting state.

・Transmission and reception is done once per day to check operating status.

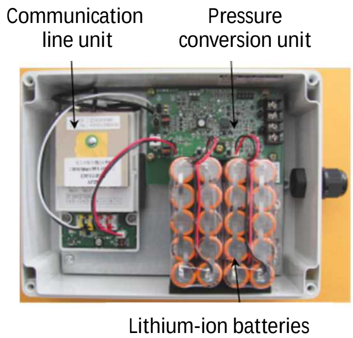

Figure 8 Transceiver

(3) Results of the demonstration experiment

As a demonstration experiment, we installed the devices at three target facilities in Tokyo (Facilities A, B, and C), and evaluated communication. We checked the communication at noon every day for 3 months. The transceiver was set up on a pole adjacent to the water meter bath above the ground (Figure 9) in facilities A and B, and in the water meter bath at target facility C (Figure 10).

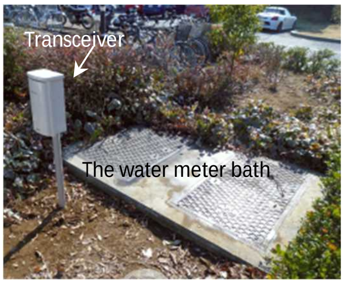

Figure 9 Transceiver installation (Facilities A and B)

Figure 10 Transceiver installation (Facility C)

We conducted communication 6,549 times, but data acquisition failed 22 times. The electric field strength was as shown in Figure 11. We were able to transmit and receive data at about 20 dBμV/m, even in facility C which had the poorest conditions. Communication failures were caused by generation of a weak electric field due to the shielding of radio waves, such as cars stopping in front of the transceiver, or the interruption of communication due to the base station being busy. To solve this problem, we added a one-time retry function, and all communications were successful thereafter.

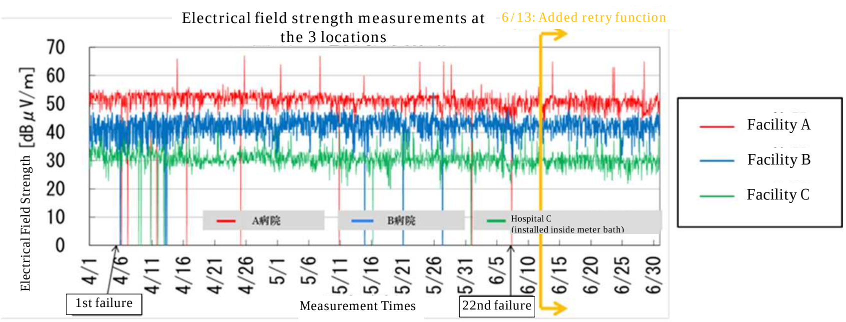

Figure 11 Communication test and electrical field strength

We also investigated whether local water supply pressures measured with the pressure sensors were accurate, and found that water supply pressure at target facilities was almost no different from measured values at fire hydrants nearby, confirming that remote measurements are accurate. Furthermore, we also confirmed that water supply pressure data transmitted through terminals installed on site to terminals in the Tokyo Waterworks offices was collected and saved correctly. (Figure 12)

	Block	Facility Name	Collection Date & Time	Collection	Pressure (MPa)	Battery	Remarks
83	Test	Facility B	2014/02/04 00:00	OK	0.29	Normal	
84	Test		2014/02/04 01:00	OK	0.31	Normal	
85	Test		2014/02/04 02:00	OK	0.31	Normal	
86	Test		2014/02/04 03:00	OK	0.32	Normal	Weak PHS signal
87	Test		2014/02/04 04:00	OK	0.32	Normal	
88	Test		2014/02/04 05:00	OK	0.31	Normal	

Figure 12 Water supply pressure data checked in the Tokyo Waterworks offices

5. Future Development

Currently, the Tokyo Waterworks is proceeding with the installation of this system for 137 government agencies and emergency medical institutions in Tokyo. We aim to complete the installation in 2018. After that, we plan to install this system in about 800 facilities spread throughout Tokyo, such as evacuation centers which are important evacuation bases at the time of the disaster. Using knowledge gained from future operation of the system, we plan to develop a system necessary to more effectively check the water supply situation at important facilities.

The Tokyo Waterworks will steadily advance seismic resistant coupling retrofitting of supply routes to important facilities that will serve as bases in the event of an earthquake disaster, and the initiatives introduced in this report, in order to further enhance our emergency countermeasures.