Disaster Prevention and Security Technologies Contributing to Safe and Secure Networks

Hideki Uehara, Susumu Baba, Koji Tanaka†*,*
and Taishi Deguchi

Abstract

To protect communications networks from large-scale earthquakes, we are conducting research and development of earthquake-proof technology for underground communications facilities and of seismic evaluation methods. We are also deploying optical fiber sensing technology, which can measure the distortion or deformation of structures, in business applications outside NTT to allow precautions to be taken against possible accidents. This article introduces disaster prevention and security technologies for supporting infrastructure equipment in communication networks.

1. Earthquake-proof technology supporting network reliability

In Japan, people are becoming more aware of the power of earthquakes and the damage they can cause following several recent large-scale earthquakes, such as the 2004 Niigata Chuetsu Earthquake, and predictions for large-scale earthquakes in the near future announced by the government. Accordingly, we have given a high priority to the development of technologies for constructing earthquake-proof networks to ensure the reliability of future broadband ubiquitous communications services. Seismic countermeasures for NTT's underground facilities have been developed and improved based on analyses of damage caused by actual earthquakes in the past. Because level-II earthquake motions (equivalent to seismic intensity 7) were defined by JSCE (Japan Society of Civil Engineers) after the 1995 Hanshin-Awaji earthquake, we have been implementing seismic evaluations methods and earthquake-proof countermeasures for underground facilities according to this new standard.

† NTT Access Network Service Systems Laboratories
Tsukuba-shi, 305-0805 Japan
E-mail: kojit@ansl.ntt.co.jp

2. Seismic countermeasures

2.1 For cable tunnels

Cable tunnels are designed to withstand a large-scale earthquake with level-II earthquake motions, and cables inside cable tunnels were not damaged even in the 1995 Hanshin-Awaji earthquake. However, water leakage and flooding did occur at connections, so we decided to develop the following countermeasures.

(1) Flexible joint for open-cut tunnel

We have developed a flexible joint because relative displacements occurred in some cases at the attachment point between a building and a vertical shaft when the open-cut tunnel expandable joint was in liquefied ground (**Fig. 1(5)**).

(2) Flexible joint for connection in shield tunnel or vertical shaft

As cracking and water leakage were seen in some cases at the attachment point between a shield tunnel and a vertical shaft, we have developed a joint that can withstand water pressure and can expand and contract lengthwise to maintain the high reliability of cable tunnels (**Fig. 1(4)**).

2.2 For conduit lines

Since a conduit line may be damaged by ground deformation caused by an earthquake, we are improving earthquake resistance by making the connection

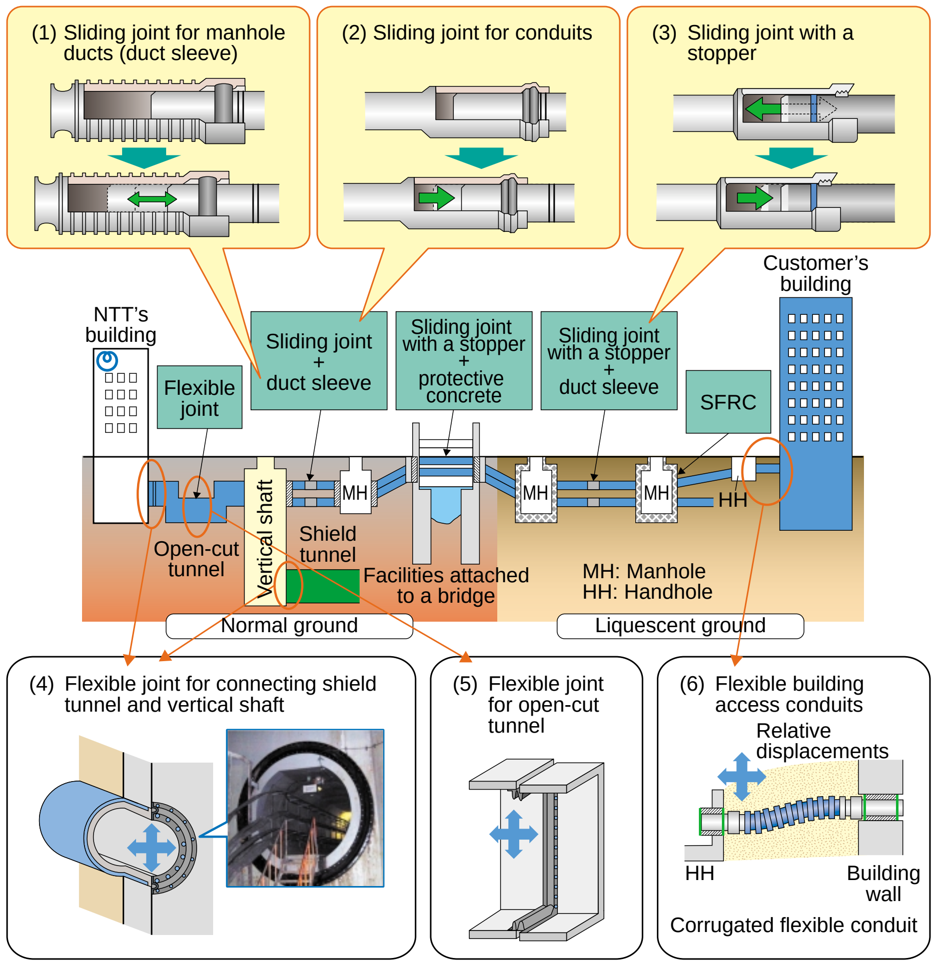

Fig. 1. Seismic countermeasures for NTT's underground facilities.

part flexible.

(1) Sliding joint for conduits

We have changed the joint structure from screw type to sliding type to improve earthquake resistance and to make construction work more efficient (i.e., faster and easier) (**Fig. 1(2)**).

(2) Sliding joint for manhole ducts (duct sleeve)

We introduced a duct sleeve, which acts as a sliding joint, to enable connections to manholes to follow to the shape of ground deformation (**Fig. 1(1)**).

(3) Sliding joint with a stopper for conduits

By applying a sliding joint with a stopper to areas such as those susceptible to liquefaction and those with bridge sections, we have improved the reliability of conduit lines because the stopper limits the range of movement. (**Fig. 1(3)**).

(4) Flexible building access conduits

We installed a flexible building access conduit leading between a handhole and a customer's building to absorb large relative displacements due to uneven settling of the ground (**Fig. 1(6)**).

2.3 For manholes

As the duct part of a manhole is a connection point with the conduit, a large relative displacement may be generated in an earthquake, causing flaking of concrete blocks or damage to communications cables. We have improved its ability to withstand heavy loads by introducing steel fiber reinforced concrete (SFRC).

2.4 For telecommunications bridges

Telecommunications bridges are special bridges that are used when NTT's communications cables cross a river or other obstacle. About 3000 telecommunications bridges are in place across Japan. They range in length from several meters to several hundred meters and there are various types of bridge including rolled-beam bridges and truss bridges. A telecommunications bridge is a structural component consisting of infrastructure facilities together with conduits, manholes, and cable tunnels. Unlike other infrastructure facilities, they are located on the ground instead of underground, so they are easily affected by seismic motions. That makes them possibly the weakest point of infrastructure facilities. In fact, damage such as the breakage of supports, buckling of main girders, and depression of the rear sides of abutments has occurred in past earthquakes (**Fig. 2**).

Telecommunications bridges have light bridge beams because the load to be supported is smaller than the load on a road bridge, and they are narrow because they only carry communication cables. Thus, their design goals differ from those of road bridges. For these bridges, it is important to prevent them falling in a lateral direction. To implement seismic countermeasures efficiently and effectively, we rated the earthquake resistance required for telecommunications bridges taking into account the possibility of secondary damage occurring and the importance of the facilities. From that we determined whether or not it is necessary to apply the measures. In cases where there is a danger of secondary damage resulting from bridge collapse, we will implement the required seismic countermeasures as a fail-safe (**Fig. 3**).

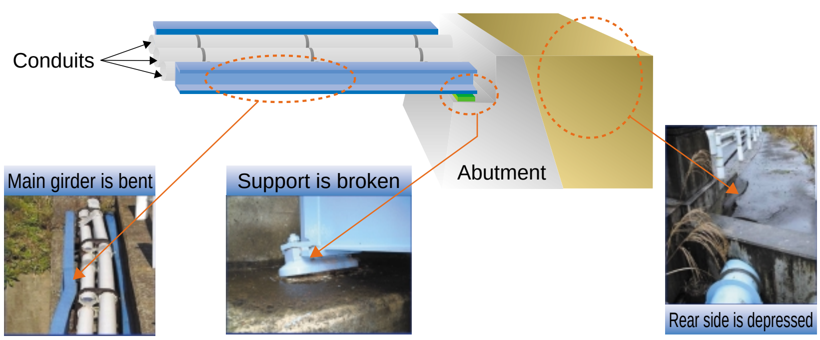

Fig. 2. Damage that occurred in past earthquakes.

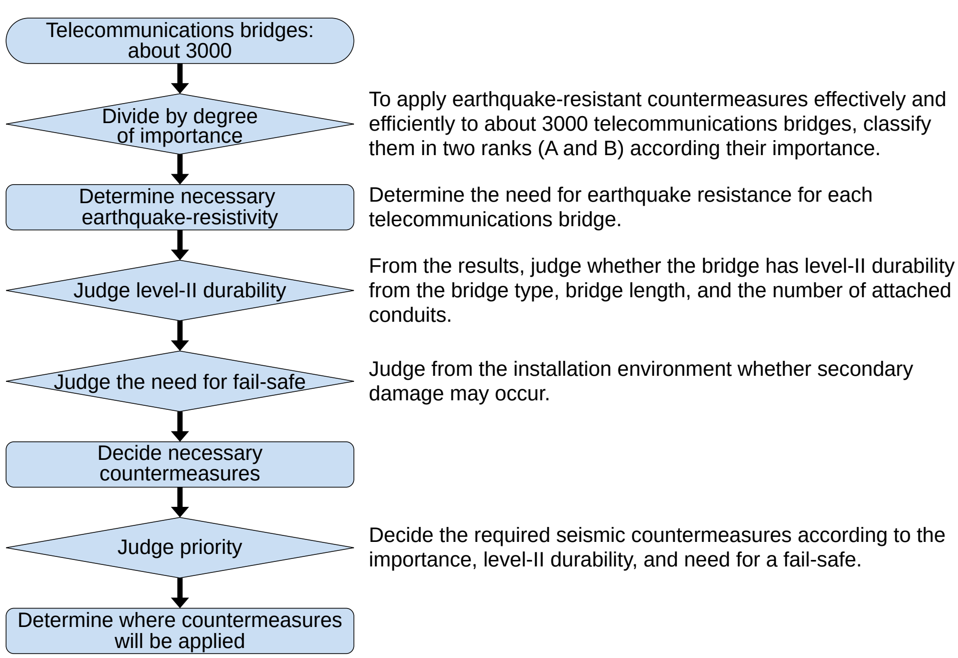

Fig. 3. Flow for deciding the seismic countermeasures for telecommunications bridges.

In the future, we are planning to evaluate the earthquake resistance of the cable conduits attached to road bridges, in addition to improving the ability of road bridges to resist earthquakes by, for example, making them seismically isolated.

3. Evaluation of seismic performance of access system underground routes

To implement seismic countermeasures on a vast quantity of underground facilities efficiently and effectively, it is necessary to evaluate the equipment from the viewpoint of the possibility of it suffering damage and to execute appropriate countermeasures according to priority assessment within a limited budget. As a tool for doing this, we have developed software for evaluating the seismic performance of underground facilities. It can evaluate their earthquake resistance based on 1) information about the facilities (available from various in-house shared databases), the ground (detailed geological data about Japan), and earthquakes (magnitude, epicenter, depth, etc.) and 2) the probability of damage estimated from historical damage data such as that for the 1995 Hanshin-Awaji earthquake (**Fig. 4**).

By performing simulations with this software before an earthquake occurs, we can predict the seismic intensity and occurrence of liquefaction in specific areas and utilize the results to make effective plans for updating equipment taking into account the importance of communications lines and to select appropriate countermeasures. In addition, this software will help us in making plans for surveying damage and performing restoration work after an earthquake. And it will be useful in actually implementing effective restoration by making it possible to execute prioritized restoration work, beginning from the most effective place or in making a restoration plan in cooperation with other lifeline companies that also have underground facilities (**Fig. 5**).

At present, we are adding damage probability data that was obtained from cable damage data and experimental results. This is enabling us to enhance the software's ability to identify the weak points of access system underground routes so that we can eliminate them.

4. Optical fiber sensing technology

Brillouin optical time domain reflectometry (BOTDR) is an optical fiber sensing technology developed by NTT [1]. It has been put into practical

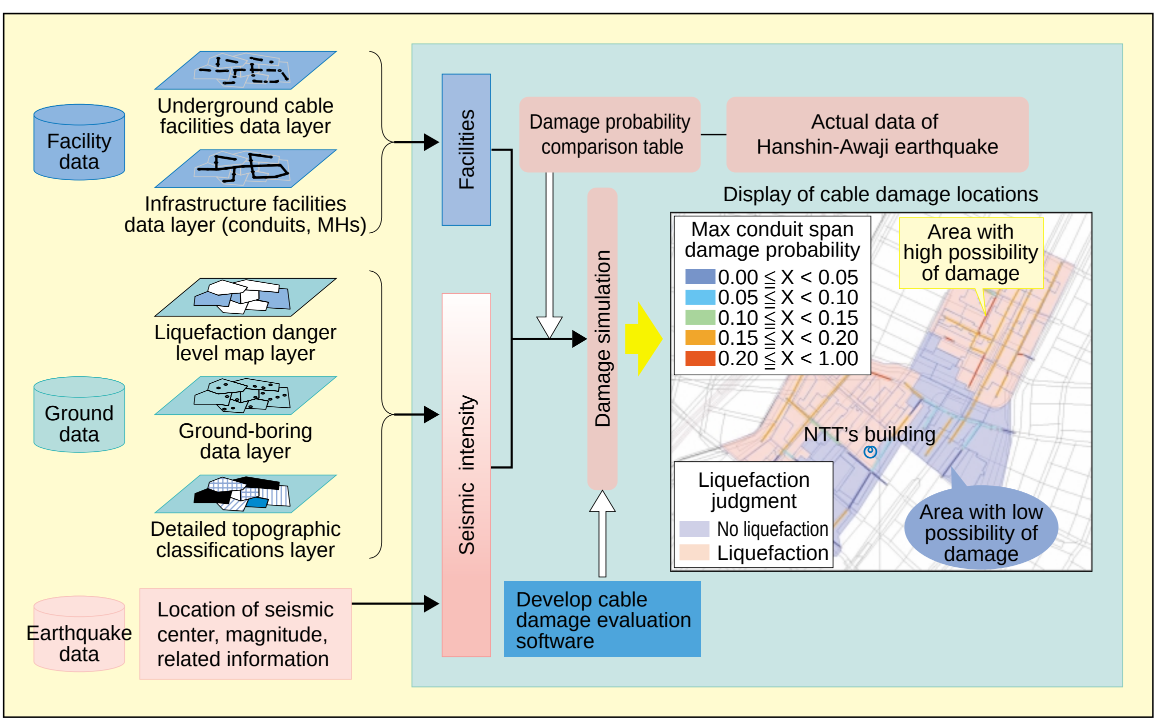

Fig. 4. Algorithm of evaluating the seismic performance.

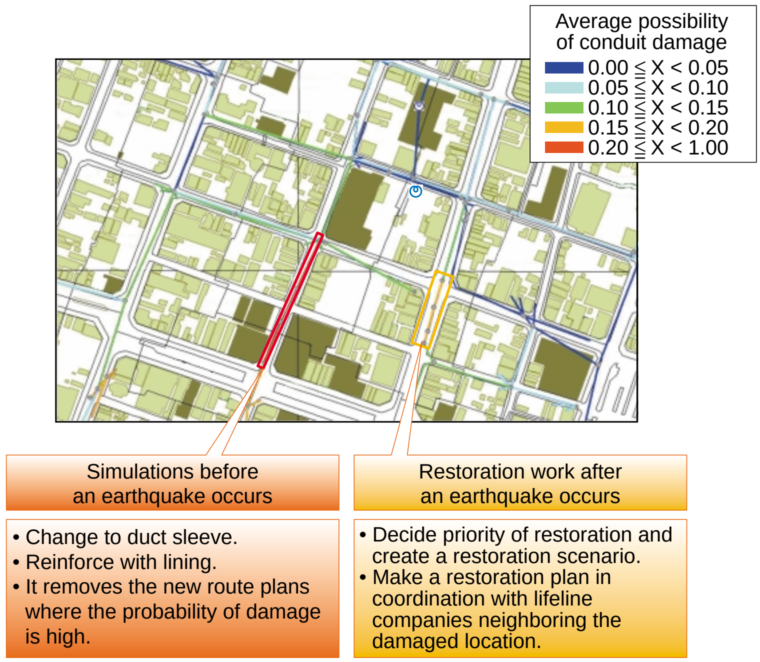

Fig. 5. Examples of effective simulations.

use in a communication tunnel management system and it has been customized and introduced for disaster prevention and security for social infrastructures such as roads, tunnels, and bridges by NTT Group companies such as NTT InfraNet. BOTDR is attracting global attention as an alternative to conventional electrical sensors. For example, it is currently being examined for use in monitoring deformations in underground mines (**Fig. 6**).

(1) Slope collapse monitoring function

Across Japan, disasters frequently occur as a result of landslides caused by heavy rains or storms. We have developed optical fiber slope displacement, underground displacement, and water-level sensors to quickly provide information about the possibility of disasters, even small landslides, within a large monitored area.

(2) Bridge monitoring function

Bridges are very important facilities. They are strategic points in times of disaster as well as being vital for day-to-day transportation and traffic. Therefore, performing maintenance and management, ensuring safety, and improving earthquake resistance are critical themes for road administrators. We have developed a small optical fiber displacement sensor that can detect and measure the amount of displacement of bridge beams to enable us to evaluate the bridge's condition and decide whether it is safe to use.

(3) Tunnel monitoring function

Communication tunnels are places where many communication cables are concentrated, so their structural performance must be maintained for very long periods of time. We are using optical fiber sensing technology to monitor the amount of tunnel deformation caused by nearby construction work. In recent years, accidents involving concrete flaking off and concrete fragments falling from the ceilings of road and railway tunnels have been reported. For such cases, our optical fiber sensing technology has been attracting attention as a way to perform multipoint measurement on long-span structures effectively and remotely.

(4) Example of applications abroad

The use of information technology (IT) in the mining industry is rapidly progressing around the world and optical fiber sensing technologies are expected to be introduced in this field soon. At present, we are conducting joint feasibility tests of mine tunnel monitoring methods in Chile with a local copper mining company [2]. By monitoring the rock deformation caused by mining operations, we can pick up signs of impending disaster such as rocks falling from the tunnel ceiling. We are conducting experiments to verify the reliability of optical fiber sensing systems under severe conditions and to establish a system that can

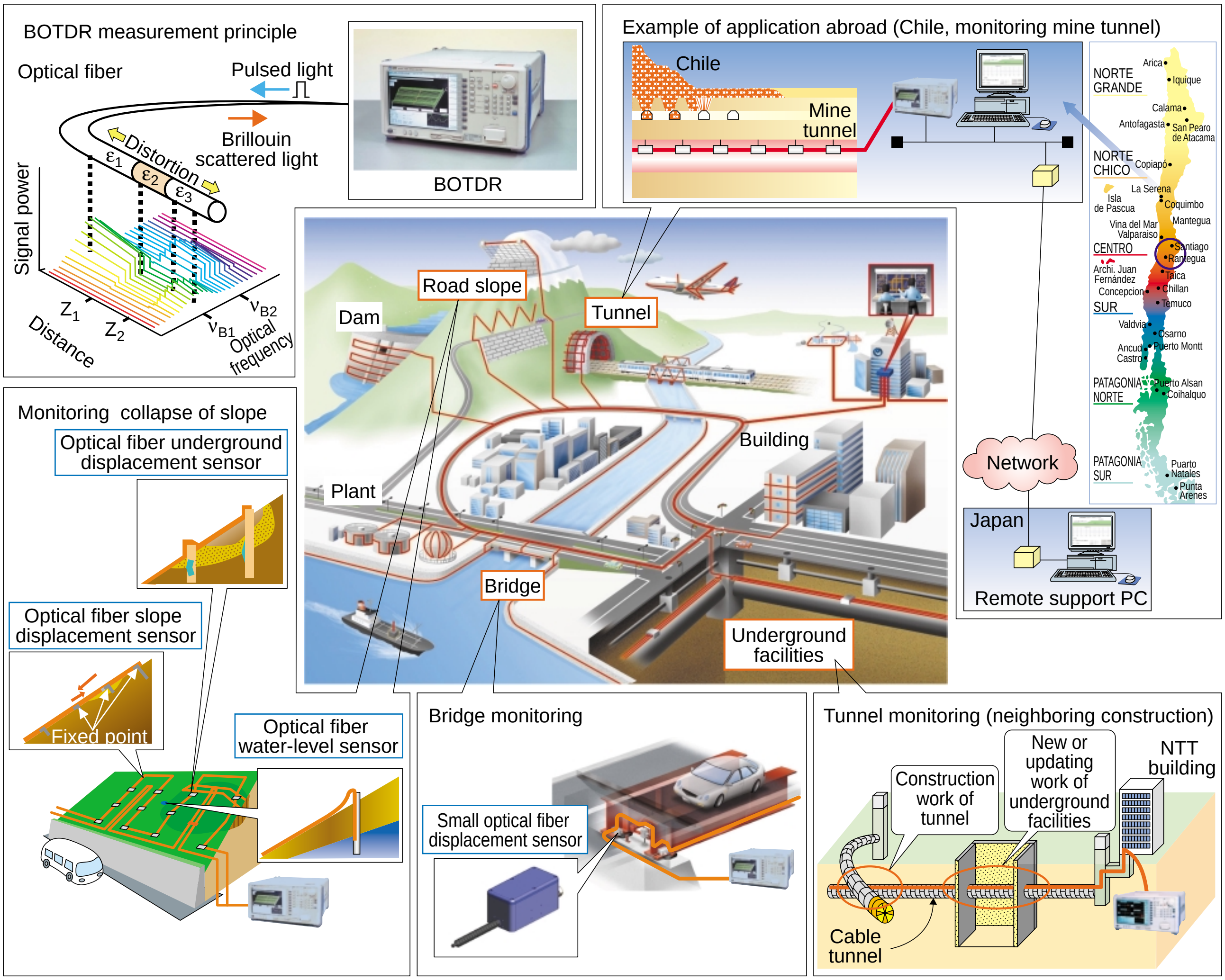

Fig. 6. Overview of BOTDR.

ensure the safety and efficiency of mining operations. Changes in the rock status are monitored continuously in both the local office in Chile and in Japan via a network. Field test results to date show that the experimental system accurately caught changes in the tunnel caused by excavation and confirm the applicability of optical fiber sensing to efforts to improve mine safety against disasters. We are planning further deployments of optical fiber sensing technologies to test its applicability to other applications.

References

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[2] K. Nozawa, K. Noguchi, M. Shoji, H. Uehara, and R. Ohmoto, "International Joint Feasibility Experiment with a Copper-mining Company in Chile," NTT Technical Review, Vol. 4, No. 1, pp. 44-49, 2006.

Hideki Uehara
Senior Research Engineer, Supervisor, Civil Engineering Project, NTT Access Network Service Systems Laboratories.

He received the B.E. degree in civil engineering from the University of Tokyo, Tokyo, in 1983. In 1983, he joined Nippon Telegraph and Telephone Public Corporation (now NTT), Tokyo. He worked mainly in the telecommunication facility planning section. After 2000, he worked in the multimedia communication section and the customer service section. He took up his present post in 2003. He is a member of the Japan Society of Civil Engineers (JSCE) and Japan Association for Earthquake Engineering.

Koji Tanaka
Research Engineer, Civil Engineering Project, NTT Access Network Service Systems Laboratories.

He received the B.E. degree in civil and environmental engineering from Yamanashi University, Yamanashi, in 1990. He joined NTT in 1990 and developed no-dig repair technologies for underground conduit lines. In 2005, he was transferred to NTT Access Network Service Systems Laboratories. He is currently engaged in research on earthquake-proof technology. He is a member of JSCE.

Susumu Baba
Research Engineer, Civil Engineering Project, NTT Access Network Service Systems Laboratories.

He received the B.E degree in civil engineering from Kisarazu National College of Technology, Chiba, in 1980. He joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1980. Recently, he has been engaged in research on earthquake-proof technology.

Taishi Deguchi
Research Engineer, Civil Engineering Project, NTT Access Network Service Systems Laboratories.

He received the B.E. degree in civil engineering from Kanazawa University, Ishikawa, in 1992. He joined NTT in 1992 and was transferred to NTT Access Network Service Systems Laboratories in 2003. He is currently engaged in the development of applications using BOTDR.