R&D Trends in Communications Infrastructure to Achieve Safe and Secure Access Networks

Fumihide Sugino

Abstract

NTT Access Network Service Systems Laboratories is working on the Civil Systems Project, which involves conducting research and development (R&D) on infrastructure facilities such as conduits and manholes. This article reviews the current state of infrastructure facilities, provides details of our current R&D, and touches on future developments. This article is based on a lecture given at the NTT Tsukuba Forum 2012 workshop held on October 19, 2012.

1. Environment surrounding infrastructure facilities

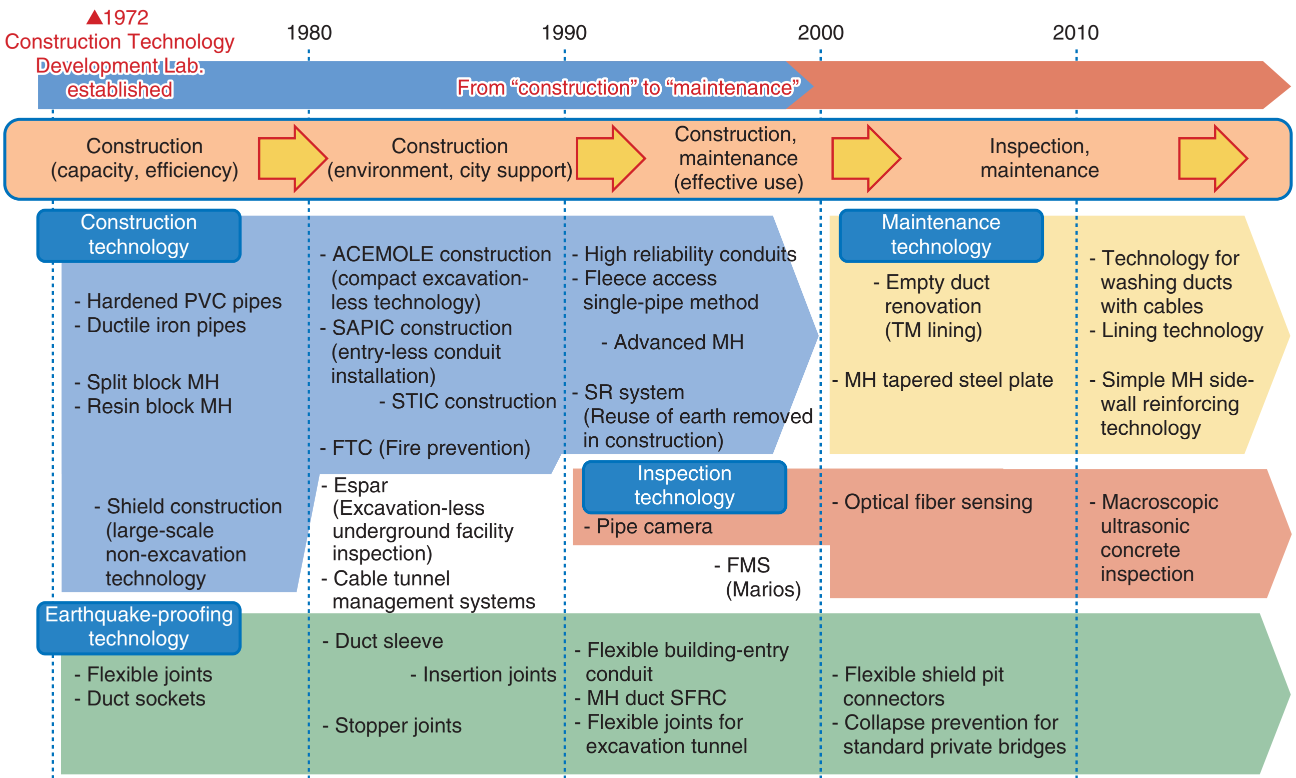
In 2012, NTT Access Network Service Systems Laboratories marked 40 years since its predecessor, the Construction Technology Development Laboratories, was established in Tsukuba (**Fig. 1**). At the time of establishment, a lot of construction was being done to install telecommunication infrastructure such as cable tunnels, manholes, and conduits throughout Japan, so construction technology was the main focus of research and development (R&D). The period from the mid-1960s to the end of the 1970s was a time of rapid construction, and approximately 80% of NTT's conduits and manholes were built during that time. Consciousness of environmental issues increased in the 1980s, and during this time, the focus shifted to developing technology to build conduits without having to excavate, and as the amount of construction gradually decreased, R&D themes shifted from construction to maintenance. Currently, maintenance technologies such as inspection, diagnosis, and repair are the major R&D themes.

1.1 Advancing deterioration of facilities

If current trends continue, in 20 years, approximately 80% of all conduits and manholes will be more than 50 years old and entering their old age (**Fig. 2**). Approximately half of existing conduits are steel and have advanced rust and corrosion, which is becoming an obstacle in installing cable. Moreover, weakening of concrete components such as manholes and cable tunnels due to cracking, peeling, and corrosion of rebar is becoming a concern. It would be ideal to handle these age-related issues by systematically renewing the facilities, but the cost and time required to renew the large amount of infrastructure buried underground would be huge, and it is therefore not practical. Excavation of roadways also significantly disrupts the surrounding environment. Accordingly, a major R&D issue is determining how to enable continuous use of old facilities without renewing them.

1.2 The need to earthquake-proof existing facilities

Developing technology for earthquake-proofing infrastructure facilities has been an ongoing theme at the laboratories ever since its inception. Many large earthquakes have occurred since then, and the knowledge gained from each experience has been accumulated and used to improve earthquake-proofing technologies. The 1964 Niigata earthquake, the 1978 Miyagi earthquake, and the 1995 Kobe earthquake in particular provided opportunities to radically revise



FMS: facility management system
FTC: fire tight compartment
MH: manhole
PVC: polyvinyl chloride
SAPIC: safe pipe construction
SFRC: steel fiber reinforced concrete
SR: soil recycling
STIC: shield tunnel interfaces with conduits
TM: thick membrane

Fig. 1. Trends in infrastructure R&D.

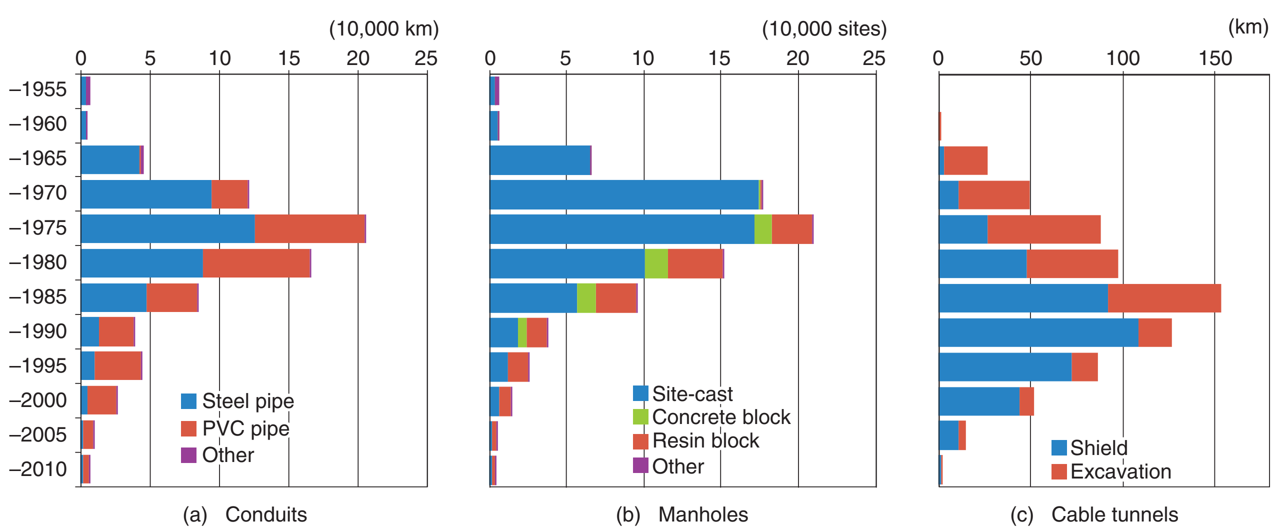


Fig. 2. Amount of infrastructure construction, indicated in 5-year periods.

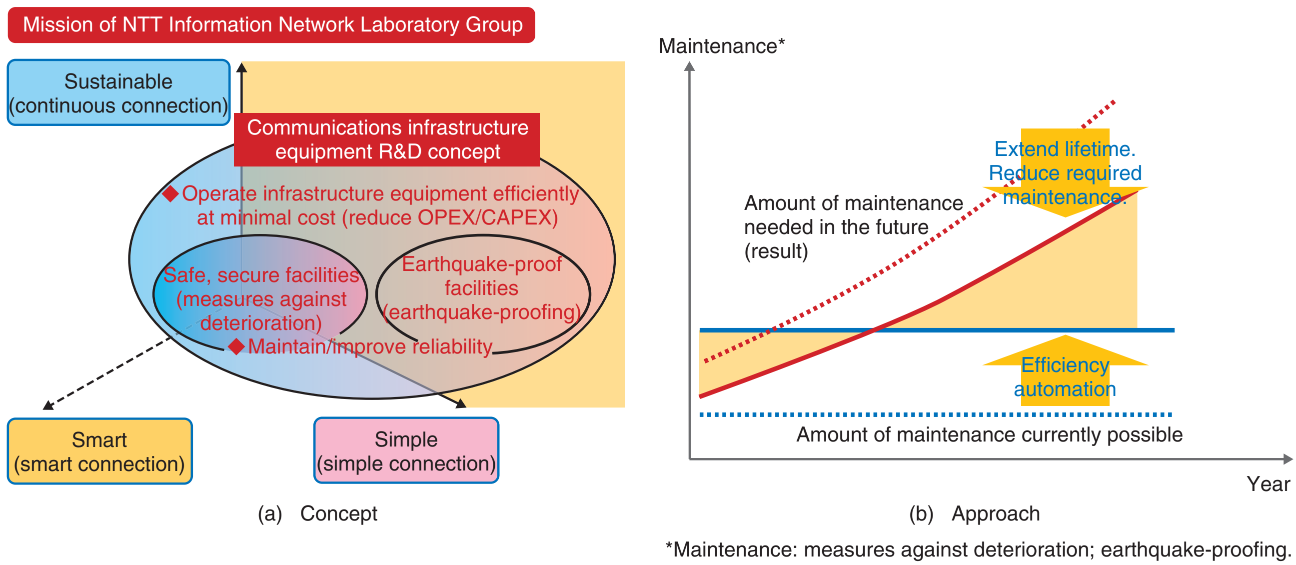


Fig. 3. Infrastructure construction R&D concept and approach.

earthquake-proofing capabilities because of the extent of the damage that occurred.

The Great East Japan Earthquake in 2011 was the largest in recorded history in Japan, and it provided an opportunity to evaluate the performance of infrastructure earthquake-proofing technology applied up to that point. The evaluation revealed that only 1–3% of infrastructure facilities were damaged in most cases, a very low figure. This verified that underground facilities are highly earthquake-proof infrastructures. Furthermore, the facilities that were damaged were built during periods when older standards applied and earthquake-proofing capabilities were lacking. This also confirmed the effectiveness of current standards. In fact, there are still many older facilities that were built before the current standards were introduced. However, even if the renewal of such facilities was restricted to those along major routes and in areas where earthquakes were expected to occur, the cost of renewing all of them to current standards would still be prohibitive and impractical, just as it is in the case of aging infrastructure. Consequently, we expect that developing effective methods of predicting damage to facilities and applying earthquake-proofing measures where they are most needed will be an important R&D theme in the future.

2. Current R&D

In order for customers to use NTT services with confidence, the infrastructure supporting these services must, itself, be safe, secure, and very resistant to earthquakes. Measures against aging and earthquakes, as described above, must be steadily advanced in order to ensure this, but in view of the intensely competitive communications market surrounding NTT and the declining number of skilled specialists in this technology in the industry, the role of R&D is to create technologies that can implement these measures quickly, effectively, and at minimal cost.

Currently, the amount of inspection and maintenance work carried out to address the aging of facilities is limited because of the required cost and labor. However, this aging continues nonetheless, and the number of facilities requiring work increases each year. R&D will use two approaches to fill in this widening gap (**Fig. 3**). The first one involves the use of automation and optimization technologies to increase the number of facilities that can be inspected and maintained. The other one involves the use of technology to extend the lifetime of facilities or make them maintenance-free, which will reduce the number of facilities requiring work. Next, we introduce some technologies used in these approaches.

2.1 Concrete pole inspection technology (automating and streamlining inspection)

NTT has approximately eight million concrete poles nationwide. Inspections of these poles are done mainly by visually inspecting them for cracks, which

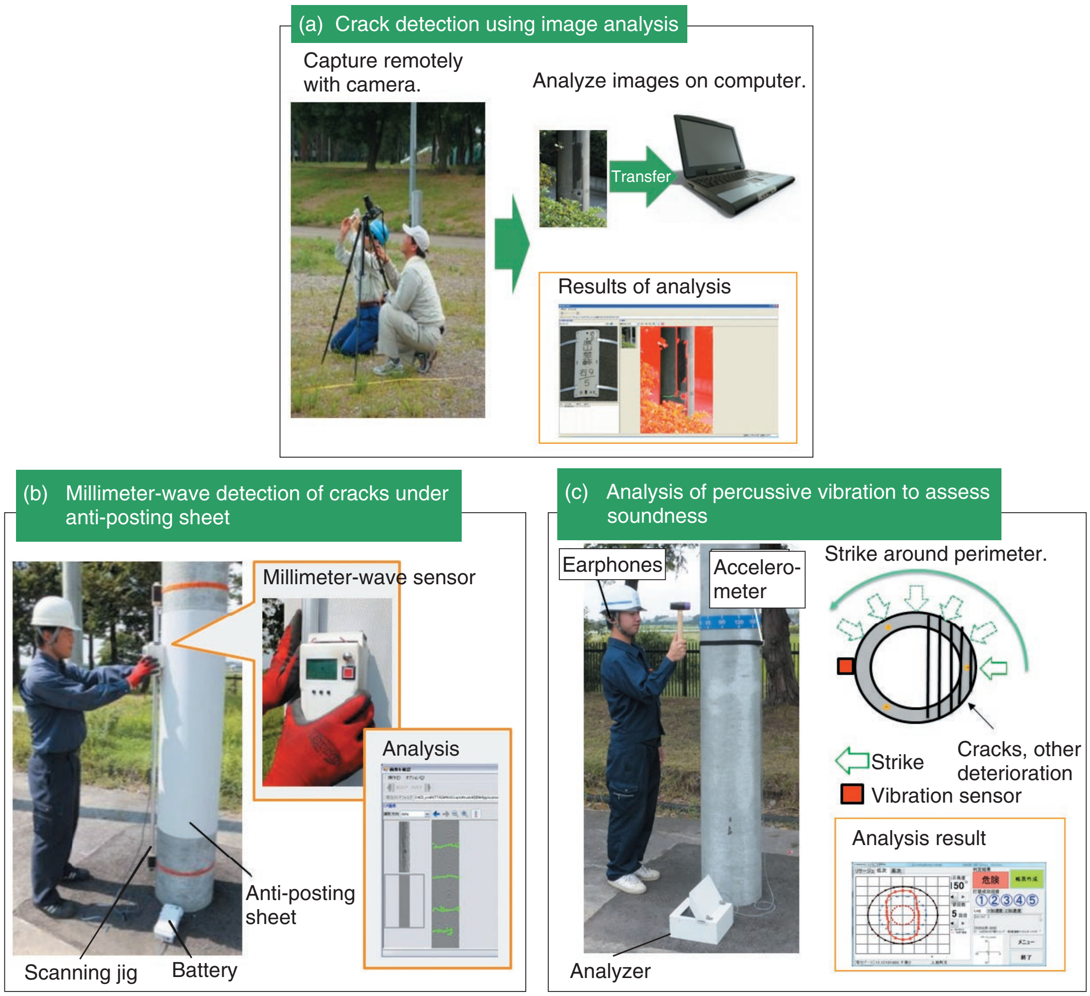


Fig. 4. Technology for inspecting concrete telephone poles.

requires a certain level of skill. Furthermore, the upper part of concrete poles must be checked using binoculars, which is labor intensive and raises concerns that problems could be overlooked. Three technologies have been developed to enable this inspection work to be done more efficiently and effectively (**Fig. 4**).

The first is a technology to detect cracks using image processing. Software is used to eliminate factors such as cables and dirt, which obstruct the detection of cracks, from the color and texture of images captured using an off-the-shelf digital camera. This enables automatic detection of cracks.

The second technology uses millimeter-wave radiation to detect cracks underneath the anti-posting sheet placed on the concrete pole. The previous image-processing technique is unable to detect cracks hidden by the anti-posting sheet, but millimeter waves are reflected by cracks and scattered in all directions, and this can be used to automatically detect cracks that are concealed by the anti-posting sheet.

The third technology is used to assess the condition of the pole by analyzing the vibrations that result from striking it. The purpose of this is not to detect cracks, but to measure the characteristic frequencies generated when striking the concrete with a hammer to automatically determine if the pole's rigidity has decreased.

2.2 PIT (pipe insertion type) new-conduit method for facility repair, maintenance-free conversion, and earthquake-proofing

One problem with conduit facilities is deterioration of steel pipes. Over 60% of conduits, where multi-

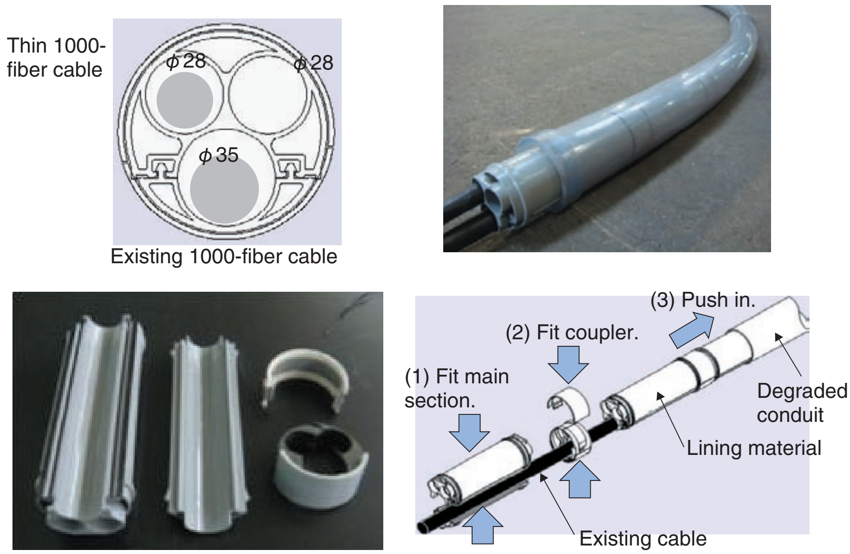


Fig. 5. PIT new-conduit method.

cable installations are planned, are diagnosed as faulty. Most of this is due to rust and corrosion of steel pipes. Technology to repair empty conduits that were faulty due to rust and corrosion already existed, but there was no way to repair them after the cable had been installed. The PIT new-conduit method resolves this issue (**Fig. 5**).

This method involves inserting a PVC inner pipe into a metal conduit that already has a cable installed. This new pipe encompasses the existing cable. The duct is replaced by the PVC pipe, so rust is no longer an issue, and no further maintenance is required. Use of this method can create capacity for three cables in one duct. The space for the existing cable (35 mm in diameter) accommodates up to a 1000-fiber optical cable, and the remaining two spaces (28 mm in diameter) can accommodate two new thin 1000-fiber cables, for a total capacity of 3000 fibers. The inner conduit also protects the cables, which increases the earthquake resistance of the conduit. This enables conduit earthquake-proofing without having to do the construction work of excavating roadways.

We are currently studying ways to expand the range of application areas for this technology. This includes reducing the diameter of the PVC pipe to apply it to narrower conduits that are *weak* or *deteriorated*, increasing the lengths of spans in which installation is possible, and supporting use in colder regions where cables must be protected from freezing groundwater.

3. R&D in the future

NTT currently uses a preventative maintenance approach in managing the maintenance of infrastructure facilities. Preventative maintenance reduces the risk of equipment failure because periodic inspections are conducted of all equipment comprehensively, uniformly, and indiscriminately, and repairs and renovation are carried out as needed. However, with NTT's large amount of infrastructure and with the advancing deterioration, even conducting only the inspections entails a high cost and a large amount of work. As such, future R&D will continue to focus on finding ways to reduce the cost and the amount of work required for inspections and repairs as much as possible so that preventative maintenance can be done smoothly. We will also take on the challenge of redefining what maintenance the facilities will require in the future and revise it if necessary. Maintenance standards based on a preventative maintenance approach are already established, but when compared to people, it is like applying the same medical examination to all patients regardless of their age, physical condition, lifestyle, or medical history. The fact that a facility is old means that useful data for individual evaluation have been gathered from that facility.

Analytical technology is advancing throughout the industry. More advanced preventative maintenance is possible by evaluating the state of each facility,

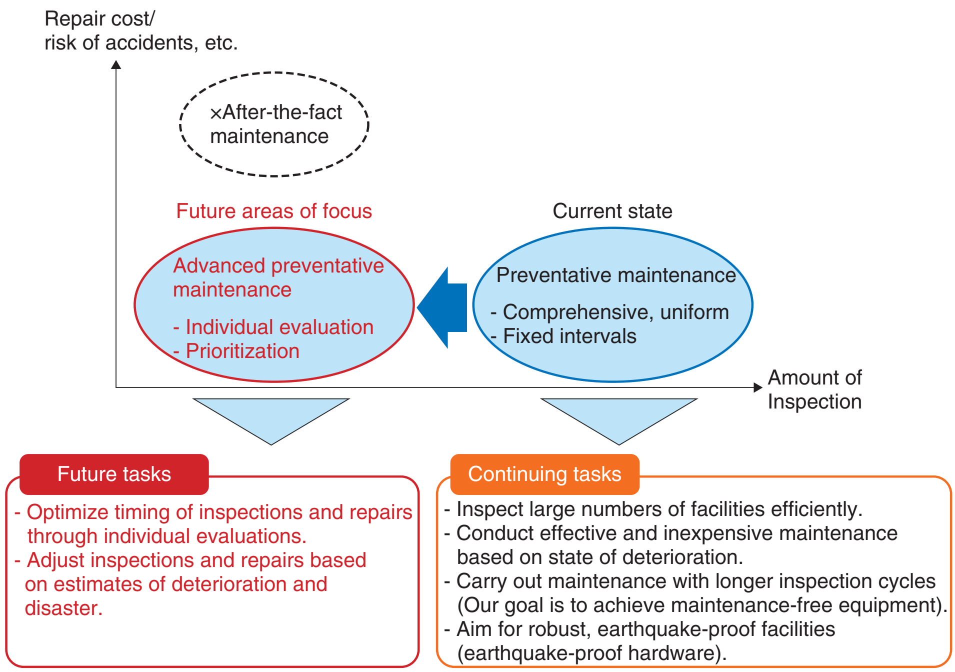


Fig. 6. R&D in the future.

estimating the degradation or damage, and conducting inspections and repairs effectively at the optimal times. We have already begun initiatives in this area. For example, we are researching ways to prioritize manhole inspections for manholes that are likely to be in more advanced states of deterioration by doing a rough estimate of their condition (soundness and deterioration) based on type of construction, installation environment, and external load conditions. This enables us to find deteriorated equipment quickly and to control inspection costs. We are also researching methods to evaluate the level of earthquake resistance by estimating the susceptibility to earthquake damage for each span of a conduit based on factors such as conduit line type or ground conditions. This enables us to apply effective earthquake-proofing measures starting where they are needed most (**Fig. 6**).

4. Future development

Currently, most initiatives in infrastructure facility R&D involve so-called hard technologies such as inspection tools and maintenance methods. In the future, research and development will advance in areas such as facility management based on specialist knowledge and past experience in order to manage infrastructure facilities appropriately while minimizing cost. We hope that the NTT Group will be able to contribute in these areas.

Profile

■ Career highlights

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

Fumihide Sugino received the B.E. degree in civil engineering from Hokkaido University in 1987, after which he joined NTT. He has studied ACEMOLE construction technology, which is a method of construction without road excavation. He has also worked at NTT Access Network Service Systems Laboratories and NTT EAST, where he mainly worked on telecommunication infrastructure including cable tunnels and underground pipeline systems. He has been in his present position since 2012. His current work involves studying NTT infrastructure.