EARTHQUAKE RESISTANT DESIGN OF JAPAN'S TELECOMMUNICATIONS NETWORKS

NTT TELECOMMUNICATIONS NETWORKS FACILITIES

EDITORIAL STAFF

INTRODUCTION

Japan's telecommunications networks have evolved into large-scale and high-quality systems, and telecommunication service has become an essential aspect of everyday life. Even temporary interruptions can have a serious adverse impact on society. Communication is especially important during disasters, to enable smooth coordination of rescue and restoration activities.

In Japan, earthquakes occur frequently as well as other natural disasters such as typhoons and heavy rains. Developing measures to prevent communication interruptions caused by natural disasters, especially earthquakes is a major priority of telecommunication service companies. Nippon Telegraph and Telephone (NTT) has long been carrying out research to develop such measures.

This article outlines NTT's disaster prevention measures for telecommunications facilities.

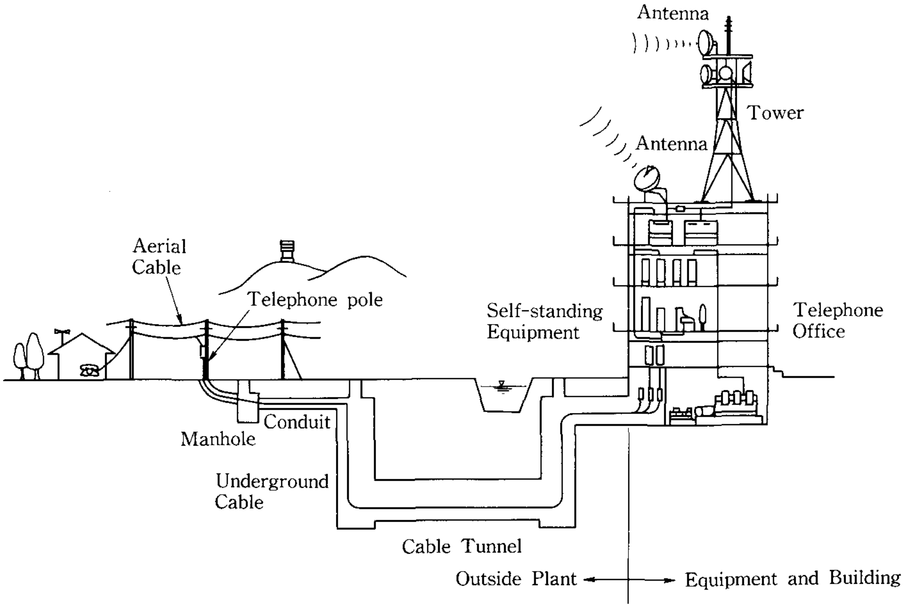

Fig. 1 NTT telecommunications network facilities

1. OUTLINE OF RECENT DISASTER DAMAGE IN JAPAN

NTT began actively developing measures to limit the impact of disasters following the Tokachi-oki Earthquake in 1968. This earthquake severed communications between Hokkaido and Honshu, the main island of Japan, for two hours, during which time nothing was known about condition in Hokkaido. NTT launched an intensive effort to prevent information blackouts and enhance reliability by decentralizing telephone switchboards and introducing redundant transmission routes.

In the Los Angeles Earthquake in 1971, much telecommunications office equipment was destroyed and telephone switchboards were damaged, making communications impossible in some areas. Learning from this earthquake, NTT investigated measures for ensuring communications in disaster-prone large cities. Telephone tunnels were constructed and emergency telephone office facilities and radio equipments ware prepared for use in emergencies.

NTT's preventive measures are based on experience gained from these two earthquakes. Moreover, learning from other disasters that have occurred in the meantime, countermeasures have been further refined and bolstered up to the present (Table 1).

Table 1 Major Disasters and Subsequent Countermeasures

Disaster	Countermeasures
Tokachi-oki Earthquake (May 1968)	Improved reliability • Decentralization of toll switching equipment. • Implementation multiple or duplicate transmission lines. • Construction of looped TV relay transmission lines. • Development of mobile radio equipment to prevent isolation.
Los Angeles Earthquake (Feb. 1971)	Ensured continued service in metropolitan area • Development of mobile telephone offices. • Development of a radio telephone set for emergency use. • Service restoration. • Construction of telephone tunnels.
Miyagi Prefecture Earthquake (June 1978)	Improved reliability • Reinforcement of equipment and it's installation. • Reinforcement of outside plant.
Nihonkai-Chubu Earthquake (May 1983)	Improved reliability • Liquefaction countermeasure for conduits and manholes.

2. PREVENTIVE MEASURES AT NTT

Communications networks are vast systems composed of various types of facilities, buildings, steel towers and underground facilities installed over a large area. It is not easy to build a system in which all components can withstand disasters in all districts. Therefore, the scale of disasters shown in Table 2 is used as a design guideline, which is based on three fundamental principles.

a) Improvement of network reliability

Facilities are physically reinforced and strengthened against disasters. Network reliability is enhanced to minimize the impact of natural disasters.

b) Prevention of isolation

Communications with disaster-stricken districts must never be broken. This means that plans have to be drawn up to ensure the minimum level of essential communications.

c) Rapid restoration of services

Communication services interrupted by damage to telecommunications facilities are restored as soon as possible, using substitute equipment and previously distributed emergency equipment.

Some examples of the preventive measures which have been implemented in line with these three principles are outlined below.

Table 2 Outline of disaster countermeasures implemented at NTT

Concept	Countermeasures
1. Improvement of network reliability	
(1) Reinforcement of facilities	• Aseismatic, fireproof and flood-control design and construction of communication facilities • Preparation of telephone tunnel networks in large cities
(2) Redundant configuration	• Decentralization of toll switching equipment • Implementation of multiple or duplicate transmission lines • Decentralization of power source equipment • Expansion of satellite utilization • Doubling of trunk lines in local areas • Doubling of incoming circuits for relief work
2. Prevention of isolation	
(1) Prevention of isolation of cities, towns or villages	• Stationing of mobile radio equipment (TZ-61) for preventing isolation • Expansion of communications satellite utilization
(2) Ensuring communication for public institutions in cities	• Provision of radio phones (TZ-41) for emergency use during restoration period following disasters
3. Rapid restoration of services	
(1) Hardware countermeasures	• Provision of mobile telephone office systems for emergency use • Provision of various kinds of mobile power source vehicles • Provision of various kinds of portable radio equipment • Implementation of cables for emergency use following of disasters
(2) Provision of mobile telephone office systems for emergency use	• Formulation of emergency plan for disaster measures • Establishment of organization for restoration work • Execution of disaster prevention training

3. IMPROVEMENT OF NETWORK RELIABILITY

The allowable levels of disasters damage for individual facilities making up the NTT network are described below.

3.1 Reinforcement of facilities

Office buildings and steel radio communication towers are designed to withstand earthquakes of the Great-Kanto-Earthquake (1923) class, and their aseismatic performance is confirmed by structural analysis and vibration experiments. Individual equipment is so installed as to prevent panels from springing out or equipment movement due to vibration.

Table 3 **Present criteria for Earthquakes damage levels**

JMA scale VII (Ruinous earthquakes)	A significant decline in the function of communication networks should be prevented.
JMA scale VI (Disastrous earthquakes)	Interruption of services should be prevented even if the quality of communication deteriorates.
JMA scale V (Strong earthquakes)	There should be no interruption in operation.

JMA (Japan Meteorological Agency Intensity) Scale		Modified Mercalli Scale	
JMA scale	Ground surface acceleration	MM scale	Ground surface acceleration
V	80~250	VIII	94~202
VI	250~400	IX	202~432
VII	400~	X	432~

unit: gal (cm/s²) 1 G=980 gal

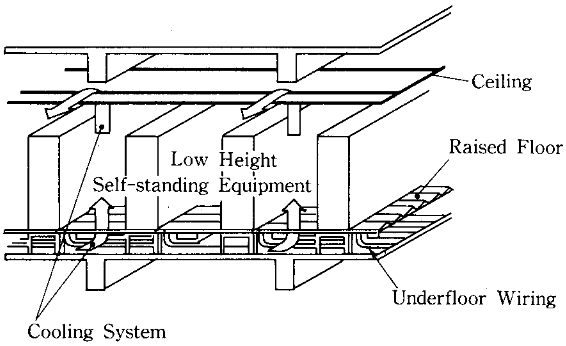

Fig. 2 Aseismatic reinforcement of ISDN room

A seismatic reinforcement of an ISDN room is shown in Fig. 2.

Unique to telecommunication facilities are cables and their protective conduits. Conduits are constructed with sliding joints to minimize earthquake damage. Further, stopper joints are applied in soft ground where uneven settling can occur due to earthquakes or other disturbances. Thus, conduits are designed so that the effects of an earthquake do not extend to the communication cables. In the area there are the possibility of liquefaction at the earthquake, graveldrain method is made for the manhole as the liquefaction countermeasures.

In large cities like Tokyo and Osaka, main branch offices and business offices are connected by telephone tunnels which can withstand during great earthquakes.

In existing conduit cable networks, new facilities possessing aseismatic capabilities are mixed with old facilities. Therefore, we've developed a new method for quantitatively evaluating the reliability of outdoor facilities against earthquakes, an example of which is the TELecommunications Seismic Accident Prediction Program (TEL-SAPP) shown in

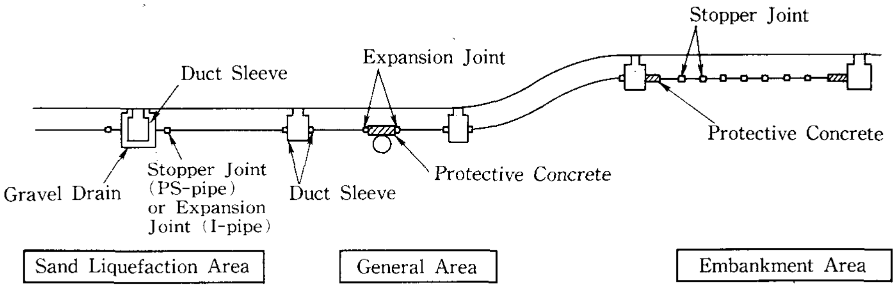

Fig. 3 Desirable Conduit Configuration Outline

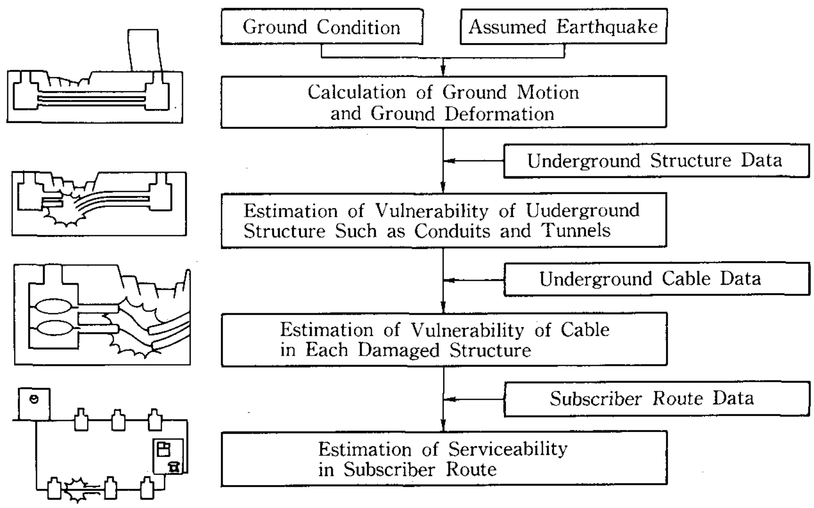

Fig. 4 Outline of TEL-SAPP

Fig. 4. The latest results of research on earthquake engineering and the findings of various experiments and analysis have been incorporated into the program. TEL-SAPP can accurately evaluate the combined reliability of facilities, from conduits to underground cables.

These techniques are now employed when selective the routes for optical cables. Existing routes have also been evaluated and the results were reflected in reinforcement and renovation plans, as well as in restoration plans.

A remote supervisory system has been installed in telephone tunnels to provide early warning of disasters and equipment problems.

3.2 Redundant configuration

To prevent the complete interruption of telephone service in a district where communication facilities are damaged, the following measures have been adopted in the exchanges and transmission lines.

(1) Decentralization of toll switching equipment

When regional or group centers, which are critical nodes in the network have been damaged, all calls are stopped except those connected by traversal trunks. Therefore, subtandem switches have also been installed in regional centers for cities more than 50 km away (an earthquake decreases in JMA scale by 1 at a distance of 50 km). Due to the importance of Tokyo, Nagoya and Osaka, diversification have been provided to a few other cities (Fig. 5). When digital networks were first constructed, this idea was incorporated and every group center (GC) is under two higher tandem offices (ZC).

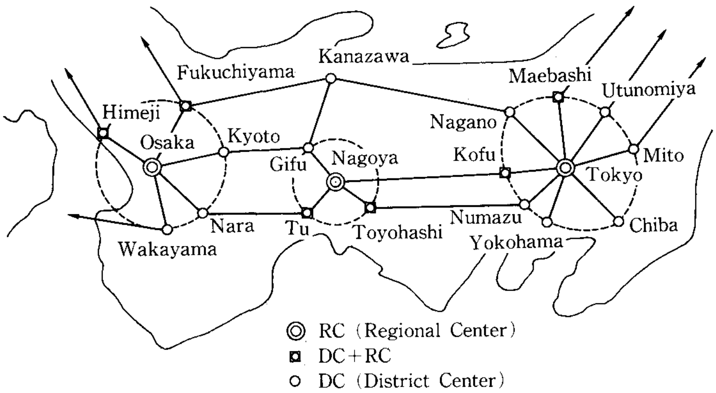

Fig. 5 Decentralization of tandem switches and multiple redundancy in trunk transmission routes

(2) Multiple or duplicate transmission routes

The construction of transmission lines is also based on the same way of thinking. Failures in trunk transmission lines not only make toll calls in that area impossible, they also paralyze switchboards, and affect calls in other areas, causing confusion throughout the entire network. Therefore, alternate transmission routes have been installed so that call transmission can be automatically transferred to another line in the events particular line goes out of order. This limits the damage impact by distributing and accommodating circuits in another alternative route. This system is now in place between almost all toll centers and end offices. Recently, alternative circuits for telephone offices in mountainous areas and other places where transmission lines are difficult to construct have been provided by satellite links.

(3) Route doubling and double accommodation of subscriber lines

Telephone circuits from telephone offices to customers have been doubled to prevent the system from going out of order. However, in the cable fire at the Setagaya office, all the cables into the office were damaged, and route doubling had no effect. Thus, to prevent disruption, multiple route services (double accommodation) which can accommodate a circuit at several telephone offices have been adopted.

3.3 Traffic control

When there is a trouble-stricken or traffic overload in the network, procedures such as network operation control and first connection route control are used to direct calls through routes other than the normal connection route. This assures smooth call connection. If, however, these measures are insufficient, important calls are connected to a trouble-stricken district while general calls are controled. This prevents confusion spreading throughout the whole network.

4. PREVENTION OF ISOLATION

Limited communication is ensured even if the circuits for communicating with a disaster-stricken area go out of order.

4.1 Prevention of isolation of cities, towns and villages

Some cities, towns and villages have only one transmission route. If all the toll lines were damaged, for example, by a landslide, a community could become isolated. To prevent this, the TZ-60 radio system has been installed in town offices and public buildings. When handset is set up, an operator can be called and then calls can be relayed to any telephone in Japan. At present, about 6,300 emergency radio telephones have been installed in 3,200 cities, towns, villages. This system operates on the VHF radio band. Since there are districts that suffer from poor radio reception, a new satellite-based system was introduced in fiscal 1986.

4.2 Ensuring communications for relief organizations in cities

In the event of a large scale disaster, a minimum level of communications is needed for relief organizations. For this purpose several thousand TZ-41 radio telephones have been distributed mainly to prefectural offices. They are used if the telephones in those offices become inoperable. In the event of a disasters, the radio telephones are taken to relief centers.

5. RAPID RESTORATION OF SERVICES

Communication services interrupted by damage to telecommunications facilities are restored as soon as possible, using substitute equipment and previously distributed emergency equipment.

5.1 Switchboards

When switchboards are damaged, it takes several days to restore them. Therefore, a large capacity mobile telephone office system and digital system are always available.

5.2 Power supplies

Telephone offices are powered by commercial electricity supply and batteries. In the event of a power failure, generators automatically take over, or in offices without generators, back-up batteries are used.

At present, in view of the condition of roads following a disaster and the time required for mobile power source vehicles to arrive at a disaster site, high-capacity batteries and portable generator-rectifier equipment are utilized to provide the minimum level of necessary power facilities. Several hundred mobile emergency power supply trucks with capacities from 50 KVA to 1000 KVA are stationed throughout Japan.

In addition, there are many mobile units capable of providing all the power needed for an entire telephone office. One such unit is in a constant state of readiness.

5.3 Radio equipment

When cables are damaged due to landslides or road damage, the disaster site is often unapproachable. In such situations, radio systems are mainly used. Radio equipment ranges from one-man portable sets, which can handle only three circuits, to sets that can replace damaged radio repeater offices.

5.4 Satellites

Satellites are quite effective during disasters, because they cover wide service areas, provide circuits immediately and can handle TV relay lines and temporary telephone circuit. NTT possesses 12 ground stations mounted on vehicles which are quite effective in assuring communications following a disaster.

Table 4 NTT's Quick Restoration Equipment Following Disasters

Equipment Type	Restoration Replacement
Switch	Mobile Switches
Power	Power Source Cars Portable Generators
Transmission	Used in Relief of Micro wave and Coaxial Transmission Lines. • Portable Radio Equipment • Mobile Ground Stations for Communications Satellites Used in Relief of Carrier and Trunk/Subscriber Loop Cables. • Portable Radio Equipment • Portable Carrier Equipment • Mobile Ground Stations for Communications Satellite Used in Relif of Cables. • Emergency Metal/Coaxial/Fiber Cables Used to Provide Portable Telephone Service to 128 users. • Portable Cellular Telephone System

5.5 Emergency cables

The most time consuming work in restoring circuits is connecting cable cores. Several thousand sets of emergency cables, which simplify connection work by means of connectors (various kinds for use in local areas and toll areas, and for coaxial and optical cables) have been distributed throughout in Japan.

Optical fiber emergency cables are light and easy to transport, and have a wide range of uses. They can be connected to electrical optical converters and used in restoring metallic circuits. Optical fiber cables will be used extensively to restore service in the event of a disaster affecting a wide area.

6. CONCLUSION

The diversification of telecommunications services has also diversified the limits customers will accept with regard to damage to communications functions caused by disasters. This situation has prompted a need for clarification and upgrading of disaster prevention and restoration capabilities.

In order to identify these capabilities in telecommunication systems quantitatively, it is necessary to apply simulation techniques such as TEL-SAPP. Based on the resulting information, measures should be implemented in a planned fashion to reinforce weak points in the systems.

Moreover,

(1) In order to ensure high disaster prevention capabilities countermeasures must be developed for individual facilities.

(2) The way, in which resulting cost increase should be shared between the service supplier and customers, must be clarified.

(3) It is also necessary to provide disaster prevention systems within the company, which can assure the high level of capabilities required.

Concerning these various subjects, studies are presently under way at NTT and the results obtained will be utilized to construct telecommunications networks with higher reliability.