Aseismic Capacity of Telecommunication Conduit Repaired with Linings

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SUMMARY:
The lining technologies are used for repairing existing degraded underground conduits. It is expected that the lining will improve the cable protection function of underground conduit against earthquake since the constructed lining members have considerable intensity. Therefore, the aseismic capability of underground conduit repaired with lining is being examined. Through analytic and experimental examinations, it became clear that linings have cable protection function against earthquake, and possibility to upgrade earthquake-proof capability of existing degraded conduits.

Keywords: Telecommunication Conduit, Lining, earthquake-proof, seismic deformation method

1. INTRODUCTION

As optical services continue to be upgraded and expanded, there are more and more instances of optical and metal cables coexisting in telecommunication conduits. To enable more effective utilization of conduits, multi-cable laying, which installs two or more cables in one conduit, is proceeding rapidly. At present, multi-cable laying amounts to 3000 km per year on average. However, inspection results for such conduits show that more than 60% of them are faulty. Most faults are caused by rusting and erosion of conduits made of metals like steel and cast-iron.

As the solutions to these issues, technologies to renovate degraded telecommunication conduits containing cables with lining have been developed in NTT Access Network Service Systems Laboratories and introduced in October, 2010.

Since the lining members have certain intensity required for buried conduit and improvement of cable protection function of existing conduit was expected, the aseismic capability of the lining has been examined parallel to the development of lining technologies. This paper presents the effectiveness of the linings against seismic motion and ground deformation due to earthquakes.

2. DAMAGE SITUATION DUE TO THE GREAT EAST JAPAN EARTHQUAKE

The damage investigation of telecommunication infrastructure facilities regarding the Great East Japan Earthquake (11th, March, 2011) showed that damages are likely to occur around the boundary of bridge abutment and at sections crossing over culverts in liquefied ground, soft ground or reclaimed land (Fig. 2.1). These damages are similar to those of previous earthquake disasters.

As the earthquake-proof measures at these parts, sliding joint and sliding joint with stopper has already been developed and standardized (Fig.2.2). However, there are following issues. 1) Most of existing facilities were constructed before introduction of measures. 2) It is difficult to apply to conduits

containing cables.
Regarding conduit damages due to the Great East Japan Earthquake, earthquake-proof measures applicable to conduits containing cables were expected.

(a) Damages at section crossing over culvert (b) Damages around bridge abutment (c) Manhole in liquefied area

Figure 2.1. Damages due to the Great East Japan Earthquake

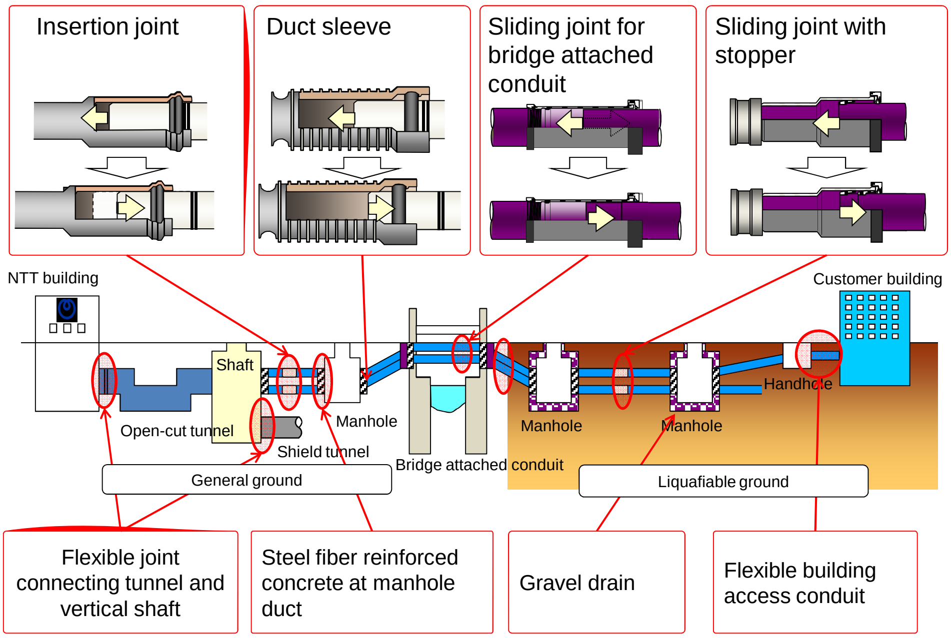


Figure 2.2. Examples of Earthquake-proofing measures for Underground Facilities

3. OUTLINE OF LINING TECHNOLOGIES

The lining technologies presented in this paper are called “Pipe Insertion Type Lining”, “PIT-Lining” in short. The outline of PIT-Lining is shown in Table 3.1 and Fig. 3.1.

The PIT-Lining has three cable laying spaces which are for one existing cable and two additional cables. Each space has capability to install one thousand cores optical cable (Fig.3.2). The PIT-Lining is constructed at site by assembling main member, rubber joint and sheath pipe (Fig.3.3). Components are fabricated at factory, made of hard vinyl chloride which is stable in quality. It is possible to install in curved section since member length is short and joint has expansion and bending capability.

Table 3.1. Outline of PIT-Lining

Item	Content
Material	Hard vinyl chloride
Dimension	Length: 230mm, Max. Diameter: 78mm
Construction Method	Existing cable is wrapped with the lining component manufactured by continuation extrusion molding, which is connected to following component with a joint and pushed into the existing conduit.
Characteristics	Construction quality is stable in order to use components molded at factory. It is possible to lay two 1000 core optical cables additionally without using inner pipes It is possible to apply at curved sections

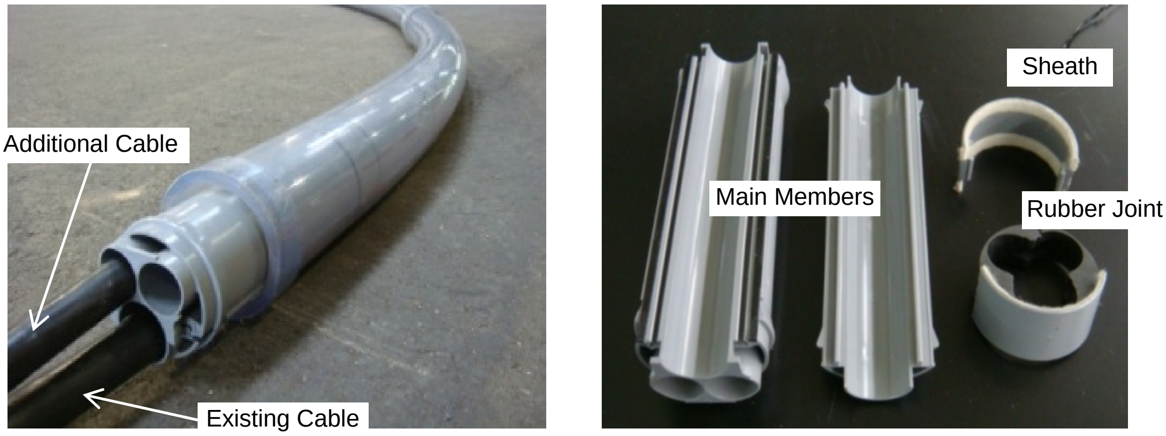


Figure 3.1. Appearance of PIT-Lining

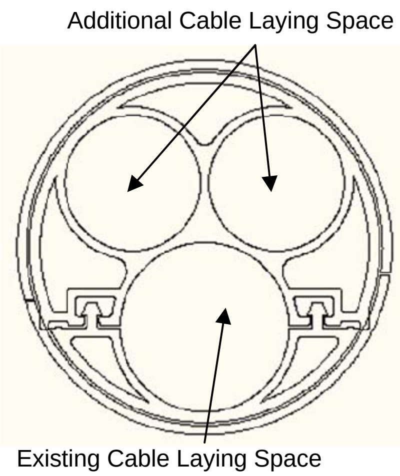


Figure 3.2. Sectional View of PIT-Lining

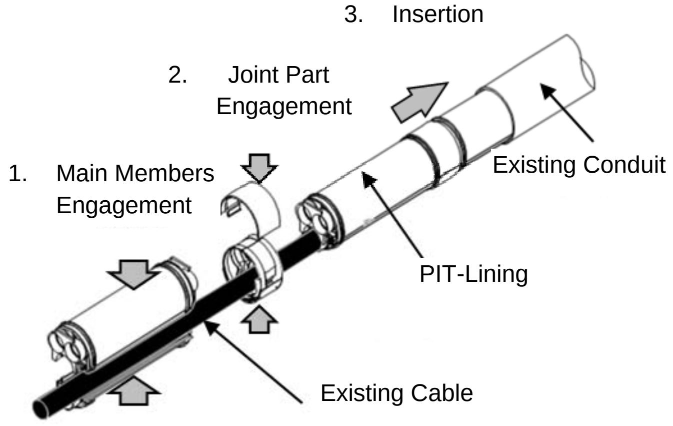


Figure 3.3. Outline of Assembling Work

4. ANALYTIC EARTHQUAKE-PROOF EVALUATION ON LINING

The lining technologies which repair the inner surface of existing conduit are introduced also in the sewer. However, the view or evaluation techniques of the earthquake-proof design of the conduit that are lined have not been established yet.

In this examination, analysis adapting the response displacement method, generally used for earthquake analysis of underground structures, on the lining was tried. In the analysis of a lining, the spring modeling the binding force characteristic between an existing conduit and a lining is set. The earthquake response of lining is calculated by adding displacement of existing conduit, which is calculated with the basic response displacement method, to a lining via the spring. The concept of analysis is shown in Fig. 4.1.

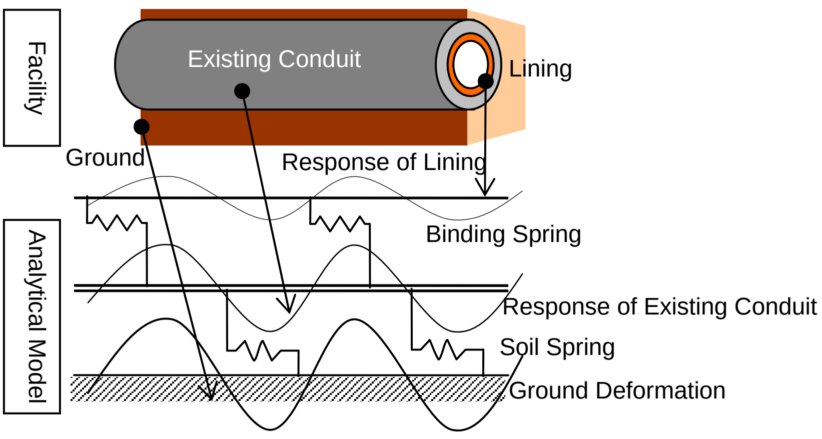


Figure 4.1. Concept of Analysis

The longitudinal wave of 1% ground distortion was set up as input earthquake motion supposing the massive earthquake. Although it varies with phases of seismic waves, if ground distortion becomes larger than 0.4%, the response value of the existing conduit joint will exceed full limits and result in destruction. However, since the response value of the lining was below the valuation-basis value, it is presumed that the lining will not result in damage. The reason the response value of a lining becomes small is as follows. 1) Since lining is not stuck with the existing conduit, transfer of displacement is small. 2) Since there are many joints at a short interval and share displacement, each amount of joint elasticity is small, thus generating strain of a component is also small.

5. EXPERIMENTAL EXAMINATIONS ON LINING

Influences to the PIT-Lining which are difficult to confirm in analysis were examined by experiments.

5.1. Influence of Seismic Wave

Specimens with lining and containing a joint were created, and enforcement displacement was added to this specimen so that the amount of joint elasticity corresponds to 1% ground distortion obtained in analysis. Outline of the experiment is shown in Fig. 5.1.

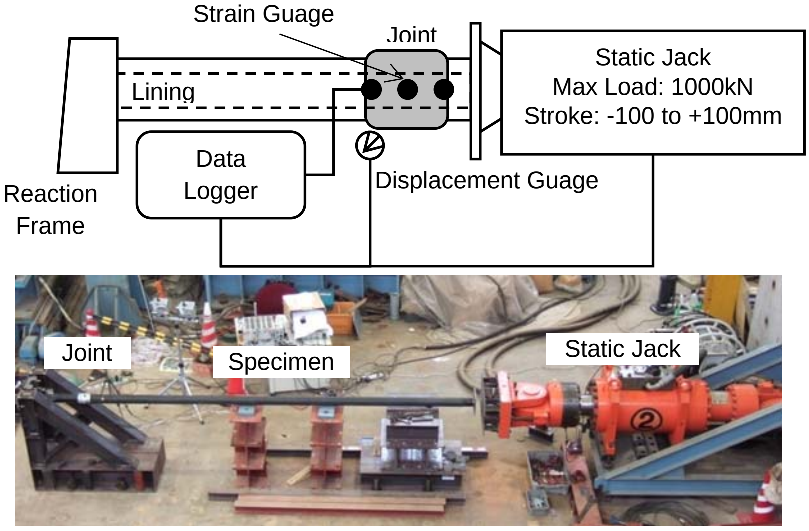


Figure 5.1. Outline of Joint Destruction Experiment

The state of the specimen after the experiment is shown in Table 5.1. There was no influence on lining in neither case.

Table 5.1. Result of Joint Destruction Experiment

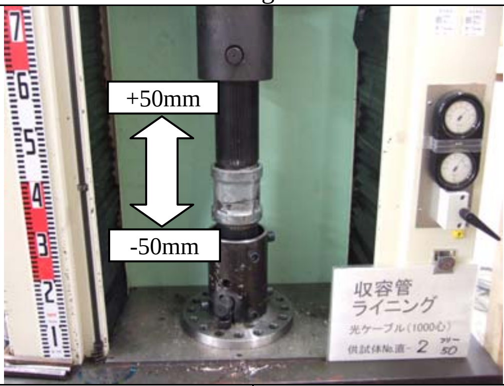
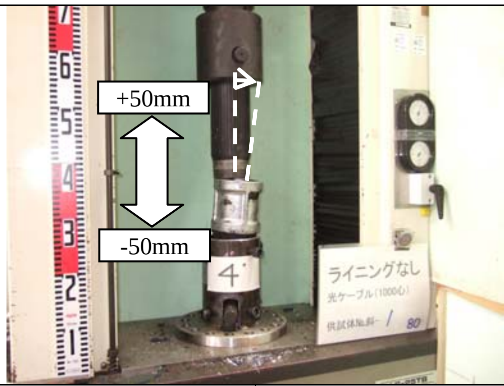
	Screw joint		Sliding joint	
	Tension	Compression	Tension	Compression
Existing conduit				
Lining				

When a screw joint is pulled, it will be destroyed explosively at the moment screw threads crush. It turned out in experiments that there is no influence on lining material due to the shock at that time, and it can maintain continuity and cable laying space.

Against enforcing displacement, a sliding joint hardly resists but follows directly. The lining pipe absorbs displacement by elasticity of a joint. Neither secession of a joint nor influences on cable laying space occurred.

Safety against the collisions repeated after joint breaks away was also confirmed by experiment. Specimens without lining and specimens with lining were both created. A specimen was installed in the testing machine and three cycles of periodic compression and tension with amplitude of 50 mm were loaded. Not only straight specimens, but also crooked specimens were tested.

Table 5.2. Result of Collision Experiment

<table>
<tr><th colspan="2">Straight</th><th colspan="2">Crooked</th></tr>
<tr><td colspan="2">
</td><td colspan="2">
</td></tr>
<tr><td>Without lining</td><td>With lining</td><td>Without lining</td><td>With lining</td></tr>
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When there is no lining, a screw joint was damaged greatly due to collision, and it may damage a cable. On the other hand, when there is a lining, the continuity and the section of inner space are held and a cable can be protected. When there was crookedness, the behaviour of the pipe end, after joint breaks away, became unstable. Therefore, when there was no lining pipe, the cable damage grade became large. On the other hand, when there was a lining pipe, it acts as a guide. As a result, behaviour of outer pipe was stabilized comparatively and the cable was able to be protected.

5.2. Influences due to ground deformation

The ground deformation due to earthquakes is mentioned as a destructive factor of underground structures. It occurs mostly in the liquefaction ground, soft ground, and land developed for housing lots. Moreover, it has turned out that much damage occurs at the place where state of facility is not uniform, such as approach to the bridge abutments, the intersection of underground structures and so on.
Although countermeasures which arrange elastic joints in such places have already been standardized, there were some examples which conduits were damaged at the place where countermeasures have not been coped with.

Thus, capability of the lining pipe to follow ground deformation was tested in the experiment.

It turned out that a lining pipe can follow much ground deformation than the sliding joint with stopper which is a standard countermeasure, and keep the continuity even after outer conduit joint breaks.

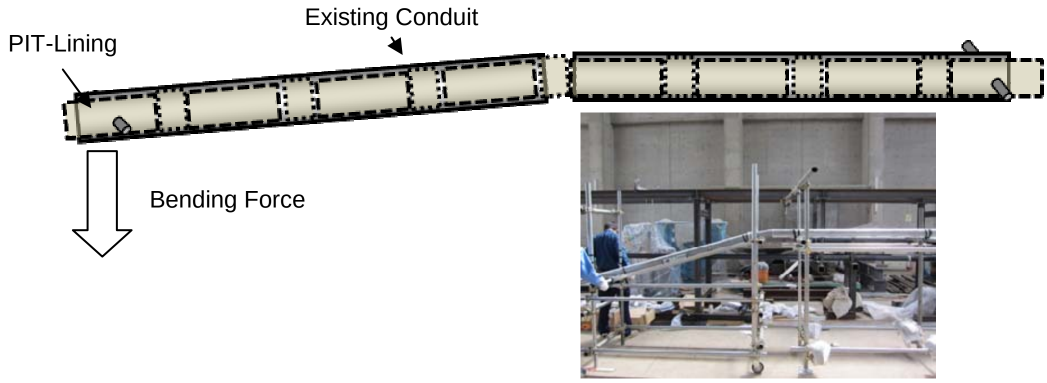

Figure 5.2. Outline of Ground Deformation Following Experiment

Furthermore, the experiment supposing the case where road surface load acts on a conduit as shearing force locally due to differential settlement was also conducted. As a result, even if outer conduit joint is broken, it turned out that a cable can be protected with a lining pipe.

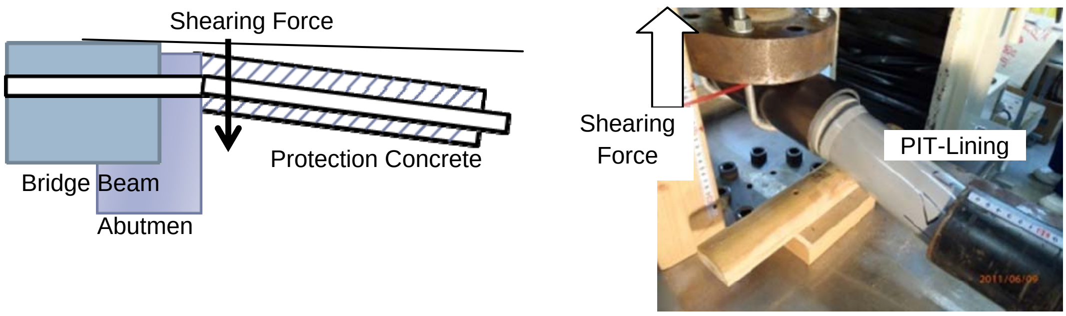

Figure 5.3. Outline of Shearing Force Loading Experiment

6. CONCLUSION

Since the earthquake-proof countermeasures of conduit facility are introduced based on earthquake damage experiences, there are many existing facilities which are less than the present earthquake-resistant criteria. Though the importance of earthquake disaster prevention is being considered, it cannot be said that earthquake-proofing of existing facility is enough.

This technology is compatible in the renewal and the earthquake-proof improvement in the conduit facility which continues to get old or degrade.

In order to expand application also to existing conduits with a smaller diameter, components with smaller diameter are recently being developed, and the earthquake resistance of lining being developed will be examined continuously.

Moreover, through the investigation and analysis on damage situation by the Great East Japan Earthquake, the validity of the existing quakeproof engineering will be verified, a potential examination subject will be extracted and the efforts to improve network reliability will be continued.

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