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DEVELOPMENT OF EARTHQUAKE DAMAGE ESTIMATION METHOD OF TELECOMMUNICATION CONDUITS BY CONSIDERING LAYING CONDITIONS

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Abstract

Communications conduits contribute to more-efficient operation and maintenance of underground cables, and must provide protection for the cables within the conduits when earthquakes occur. For protection from unexpected large-scale disasters, Nippon Telegraph and Telephone Corporation (hereafter, NTT) has been tackling various measures based on the basic anti-disaster policies to enhance communication network reliability. In this study, a new logic tool for evaluating the seismic of underground communications conduits and implementing seismic countermeasure of lining pipes on a vast quantity of underground conduits efficiently and effectively. This new logic evaluates the weakness points of pipeline by analyzing conduits information (available from various in-house shared database), the ground type (detailed geological data about Japan), and earthquake parameter (PGV, PGA, Vs, etc.), as well as the probability of damage estimated from damage data (such as that for the 2011 Tohoku Earthquake). This paper will show the seismic assessment flow and a case study to prove the applicability of this method. More effective countermeasures must be taken by performing comprehensive evaluations that combine the above information while taking into account reliability, economy, feasibility, environmental conservation, and other factors in the future.

Keywords: Underground telecommunications conduit; seismic assessment; seismic-response analysis; metal deterioration

1. Introduction

As for seismic measures for underground telecommunications conduits, facilities (including that possessing elasticity and flexibility at joints) are continuously being improved on the basis of past experiences of disasters due to earthquakes. However, since these earthquake-resistant conduits are only installed during constructions of new facilities, the majority of these conduits are complying with old specifications, but without sufficient seismic resistance. At NTT, to make seismic measures for these obsolete conduits, a construction method for strengthening conduits by forming a self-sustaining lining inside the conduits has been developed, and it is planned to apply this method to existing equipment on a permanent basis. It is supposed that these large numbers of old-specification conduits installed during Japan’s rapid economic growth period are turning obsolete continually, and a staggering number of strengthening measures will be required from now onwards. To comprehend the retained strength and degree of strength deterioration of individual lines of conduits, a method for predicting places which require seismic strengthening is developed, and the appropriate strengthening measures for those places are proposed in the present study.

2. Challenges concerning conventional seismic-assessment methods and approaches taken in the present study

Up until now, to assess which underground conduit will be damaged during an earthquake, a method by superposing damage rates due to past earthquakes onto the distribution of supposed ground motion (of which information is published by government agencies, etc.) is generally used. The strength of conduit regarding seismic motion is estimated by numerical analysis when maximum-class earthquake motion (as generated by past earthquakes) is acting on a straight conduit. However, as for the strength limits of conduits and joints used in the numerical analysis, values for new installations is used, and deterioration of strength accompanying aging deterioration is not considered. Consequently, in the case of using the conventional seismic-assessment method for underground conduits, a huge amount of old-specification conduits are likely to be damaged uniformly, and it is a problem that prioritization concerning which conduit to be strengthened is not clear. As an example, the flow of seismic assessment for telecommunication conduits in Uemachi Osaka of Japan is shown in Figure-1. By following this flow, the damage will be predicted by this conventional damage-prediction method. It is clear from the figure that a huge amount of old-specification conduits are assumed to be damaged, and the appropriate places to implement strengthening measures cannot be determined.

To solve this problem, our team has come up with a method for estimating the seismic performance of individual sections of conduits. According to the experience up till now, conduits with sharply curving forms (so as to avoid other buried objects) are often damaged during a major earthquake and at places where ground firmness rapidly changes (where protection concrete is poured at shallow buried sections and bridge abutments). By considering the experience talked above and the strength deterioration that accompanies aging, as well as the characteristics of environment in which the conduits are buried, our team developed the seismic-assessment method which will be discussed in the following sections of this paper in detail.

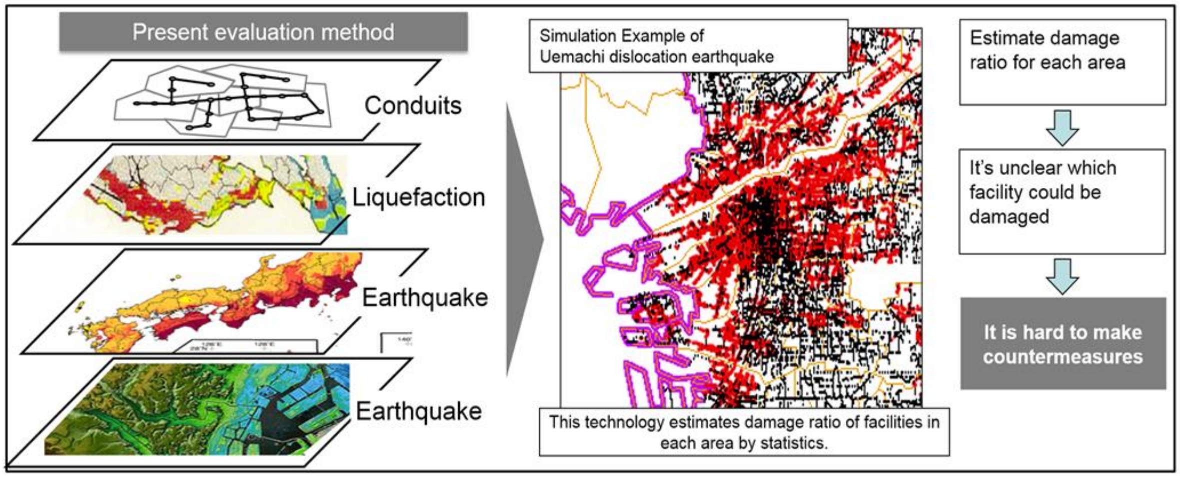

Fig-1: The result of a simulation of damage to telecommunication conduit by a conventional damage-prediction method

3. Procedure for seismic assessment of existing conduit

According to the analysis of seismic damage during the 2011 Tohoku Earthquake, our team developed the evaluation method to prioritize places which require seismic-strengthening measure is shown in Figure-2. Based on this procedure, it is impractical to individually evaluate the seismic performance of all sections of conduit. Accordingly, conduits with a high likelihood of suffering damage are extracted firstly by a proposed method developed by Shoji et al. [1]. On the basis of the applicable number of four parameters, namely, peak ground velocity (PGV) (more than 50 cm/s), conduit type (i.e., old-specification cast-iron pipe, old-specification screw-joint steel pipe, and old-specification adhesive-joint rigid-vinyl tube), length of conduit (more than 100m), and microtopography (i.e., mountain terrain and base of mountain regions, hills and volcanos, valley lowland, infilled swamps, river deltas, coastal lowland, and river plains (including those suffering liquefaction)), the screening method extracts conduits which with a high likelihood of suffering seismic damage.

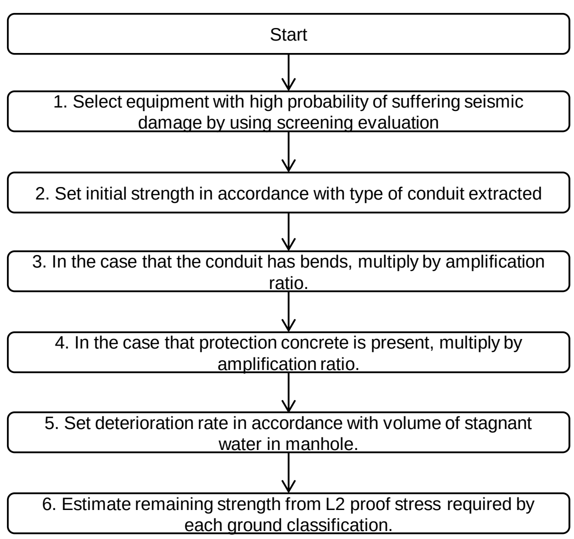

Fig-2 Flow of seismic assessment for existing conduit

Next, seismic performance is evaluated from the characteristics of environment in which each installation is buried. According to a study by Wakatake et al. [2], in the case when the span of the conduit contains tight curves, the amplification ratio affecting underground conduit during an earthquake will increase, to be set as 1.1 for the case of curved sections with intersection angles of 10 to 60 degrees in the conduit span. Moreover, based on another study of Wakatake et al. [3], in the case that protection concrete exists in the conduit span, the response value during an earthquake is also amplified. For this case, the amplification ratio is set as 1.2 in the present study. In addition, in the case when both tight curves and protection concrete exist, the amplification ratio is set as 1.5.

Furthermore, for the case of steel pipes, it is considered that the strength of the conduit will decrease because of corrosion degradation. According to the study on corrosion rate of telecommunications conduit reported by Ito et al. [4], the corrosion rate will be varied in different environment in which the conduit is buried. For the purpose of easy judgments for on-site technicians, the corrosion rate is separated in accordance with the volume of stagnant water inside a manhole (which is recorded during periodic inspections inside manholes). The study shows that in the case that the stagnant water is abundant or present, the strength-reduction ratio is assumed to be 0.22% per year, and in the case that the stagnant water is scarce, the corrosion rate is set to be decreased by two-thirds [5]. Existing strength is understood by comparing individual retained strengths of conduits obtained from the procedure given in Figure 2 and L2 (Japan Earthquake Resistance Standards) seismic resistance of each type of ground where conduit is buried (set by referring to seismic design guidelines, etc. stipulated by the Japan Gas Association).

By following the flow, it is possible to evaluate seismic strengthening of conduits. The estimation result will be explained as follows.

4. Case Study

In order to verify this method, the proposed method is applied to a real case of M area. M area suffered from the 2011 Tohoku Earthquake, and some of the underground conduits were damaged. These damaged conduits are all predicted to be strengthened preferentially when using proposed screening seismic-assessment shown in Fig-3. The effects of the proposed screening has been confirmed, however, some of the undamaged conduits are also contained in the "to be strengthened preferentially group" according to the screening result. It is possible to apply countermeasure to all the conduits which with priority based on the results in a limitative area, but it is hard to do this all over Japan since NTT maintains about 5,500 times conduits comparing to M area. Therefore the developed method is applied to do further assessments with the procedure shown in Fig-2.

The following situations have been considered to adjust the amplification ratio: if the span of the conduit contains tight curves, whether protection concrete exists in the conduit span, the stagnant water in manhole is abundant or scarce. As for correction of initial strength, the initial strength is set according to the kind of conduit extracted by the previously described screening method, and correction is achieved by subtracting the response-magnification-factor increment (which depends on the presence or absence of bends or concrete protection in the conduit span).

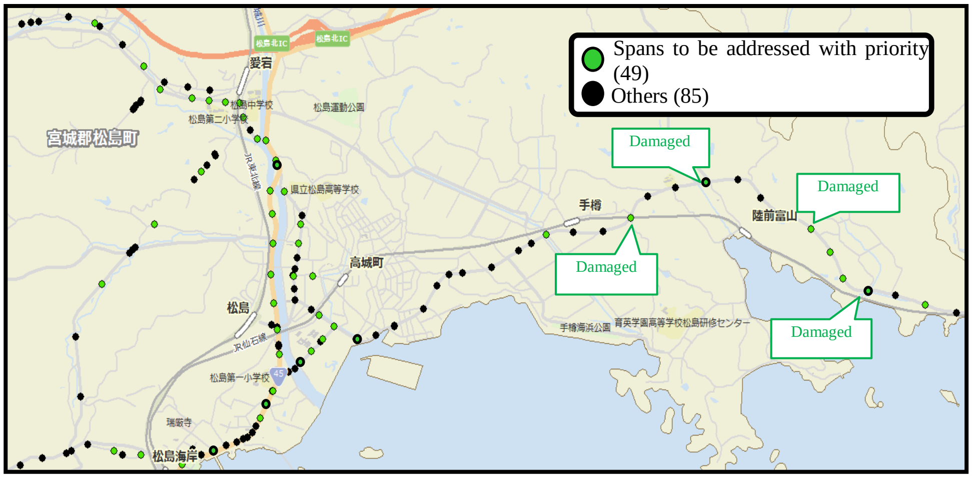

Fig-3: Conduits with different priorities

An example of one conduit with protection concrete and tight curves will be shown to explain the numerical calculation process as follows. The initial strength is 165kN which has been obtained from experiments. The corrected strength is calculated by equation (1) and (2),

$$z' = Ac \tag{1}$$

$$z = z' - A(\upsilon T) \tag{2}$$

where, z is the final strength to be used in the assessment, z' is the strength after correction, A is the initial strength, c is the reciprocal of amplification ratio considering the characteristics of environment, υ is strength-reduction ratio considering corrosion degradation, T is the time of duration since installation. In this case, A equals to 165kN, c equals to 1/1.5, so z'=165× (1/1.5) =110kN; υ equals to 0.0022, this conduit was constructed on the year of 1976, so T equals 2011-1976=35. As a result, z=110-165× (0.0022×35) ≈97.3kN.

According to numerical calculation considering ground condition, seismic intensity scale, the required strength to against the earthquake is 100kN. As a result, 100kN=110-165× (0.0022×T), T≈27.5year, which means the strength is not enough to against earthquake after 27.5years since installation. However, the strength of the example conduit is 97.3kN and the duration already past 35years, therefore it can be considered to be damaged during the earthquake. The procedure for the estimation is shown as Fig4.

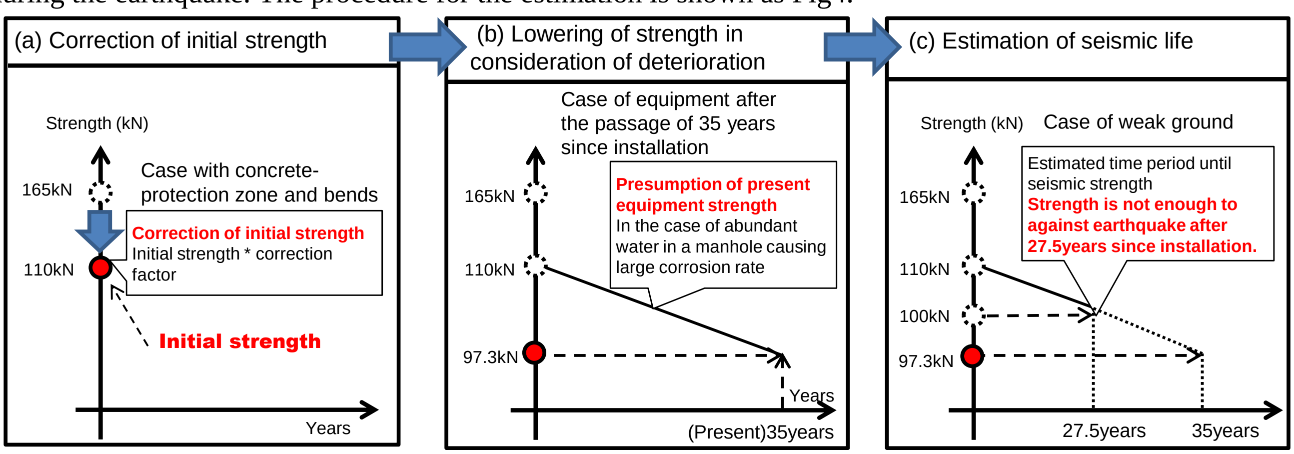

Fig-4: Procedure for estimating remaining strength of existing conduit

By repeating the procedure discussed above, the estimation can be done of each conduit in M area. The result of is shown in Figure-5. There were four damaged spans actually, and two of these damaged spans are estimated as vulnerable spans. According to the proposed screening method, 20% conduits need to be strengthened, and this percentage decreased to be 2% using the developed individual evaluation method. The developed method can be considered to be efficient and effective when applying countermeasure to conduits.

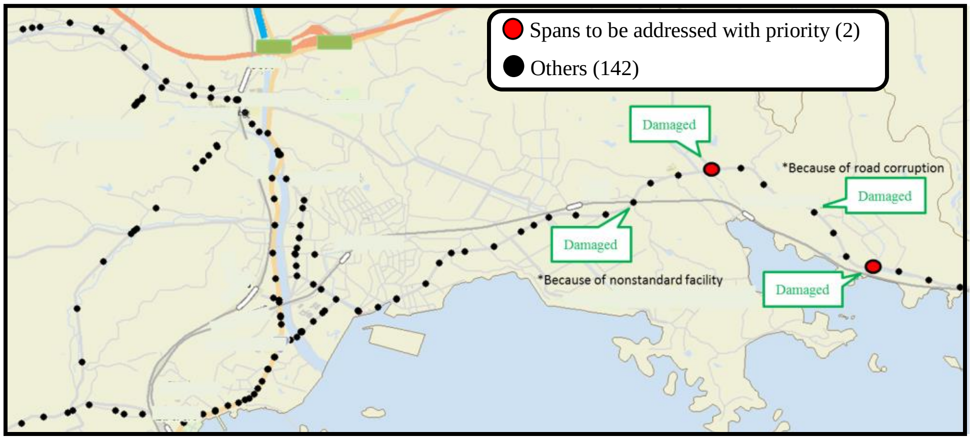

Fig-5: A result of application

5. Conclusions and future plans

A method for simply prioritizing the order of performing seismic strengthening (in terms of when and where to strengthen a huge amount of existing conduit) was proposed. From now onwards, while verifying the precision of evaluation by simulation of disaster areas afflicted by past earthquakes (such as the Great East Japan Earthquake) and correcting the evaluation parameters, we will perform seismic assessments by using data concerning actual equipment and facilities. After that, we plan to apply the proposed method to select appropriate places for implementing seismic-strengthening measures.

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