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Fast Simulation Method "NeEX™" for Seismic Diagnosis of Gas Distribution Networks†

1. Introduction

A fast, accurate algorithm, "NeEX™," which was developed by the JFE Group as a program and makes it possible to analyze stress and strain in buried pipes regardless of their shape [1, 2], is introduced.

In this report, an imaginary network based on a road map of a coastal area was used as an example to demonstrate the high-speed analysis performance of "NeEX™".

"NeEX™" is a powerful tool for seismic design and preventive measures in pipeline industries such as city gas companies.

2. Simulation Method

The general method for seismic diagnosis is evaluation by finite element analysis (FEA) using shell elements or beam elements, considering the nonlinear pipe-soil interaction. However, that method requires excessive calculation time when applied to widespread pipeline networks.

A fast simulation program for seismic diagnosis is deformation analysis of a distribution network against seismic waves and comparison with the strength of each pipe. This method enables rapid analysis of pipeline deformation while maintaining accuracy and taking into account not only the stress-strain relationship of the pipes but also the shape of the network and differences in soil conditions around buried pipes. A distribution network can be idealized with many segments which are each composed of one straight line and two boundary elements (**Fig. 1**).

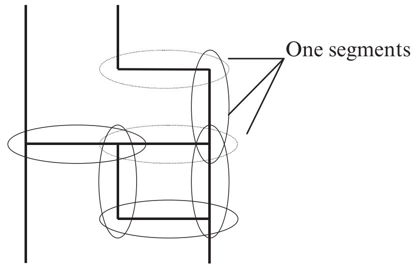

Fig.1 Image of a network and segments

3. Seismic Diagnosis of Networks

3.1 Segments to Idealize Distribution Network

In this study, the network is not the same shape as an actual buried pipeline network in an urban area, but

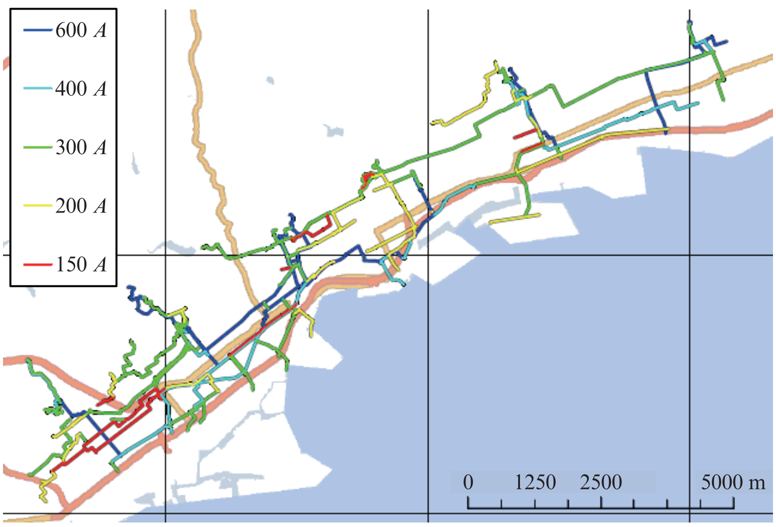

Fig. 2 Hypothetical distribution network

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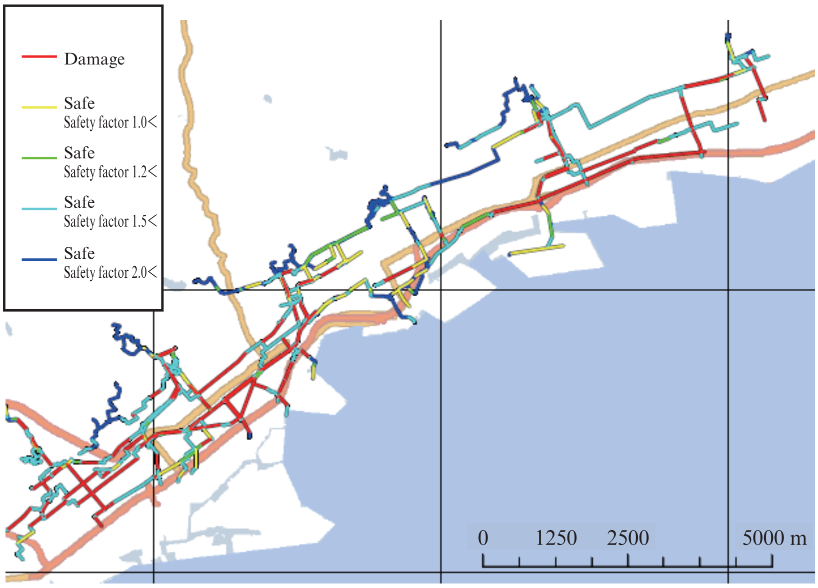

Fig. 4 Safty factor and conduit network diagram

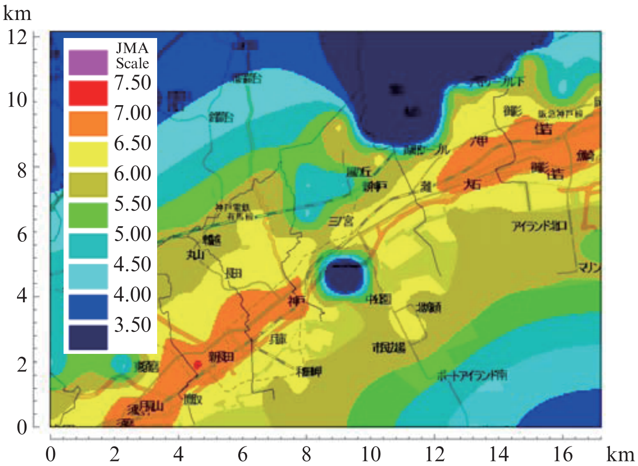

Fig. 3 Distribution of JMA scale in 1995 Kobe Earthquake (JMA: Japan Meteorological Agency)

rather, an imaginary shape based on a road map. However, in the supposed network, the diameters of each pipe are decided considering the typical distribution in actual networks (**Fig. 2**).

3.2 Seismic Waves and Evaluation Method

The seismic waves in this diagnosis was the seismic intensity distribution in the 1995 Kobe Earthquake (January 17, 1995) (Magnitude, M = 7.3, **Fig. 3**)[3], which was an inland earthquake. The estimated maximum intensity of 7 on the JMA scale (JMA: Japan Meteorological Agency).

For evaluation, a safety factor is used for diagnosis in this report. The safety factor equals the ratio of strain on the focus and that at the critical state, which are calculated from the tensile strength of straight pipes.

Table 1 Analysis time

Method	NeEX™	Finite element analysis (FEA)
Number of analysis units	1 658 (Number of segments)	9 948 000 (Number of elements)
Analysis time	8 minutes and 32 seconds (Intel® Xeon® 3.47 GHz)	55.26 hours (2.3 days) (Intel® Xeon® 3.60 GHz)

4. Results and Computation Time

As an example of the calculation results, **Fig. 4** shows the strain of pipes in Kobe City. The red lines represent where the strain exceeds the tensile strength determined in advance.

Table 1 shows the running time in the analysis in the previous section. This time corresponds to 0.3 seconds per segment, and the analysis speed is much faster than that in FEA. In FEA, one segment model with a length of 150 meters is usually divided into about 6 000 elements. "NeEX™" requires a database that contains deformation properties of the boundary elements obtained by finite element analysis. Static equilibrium at both ends of a straight section can be solved using the database in terms of the boundary element that contains the nonlinear load-displacement relationship.

5. Conclusions

The fast, accurate algorithm "NeEX™" is effective for seismic diagnosis of large-scale distribution networks. This study clarified the following facts:

(1) A comparison of calculation times showed that the "NeEX™" method is much faster than the conventional FEA.

(2) The "NeEX™" method is effective for grasping quantitatively the weak points in a widespread distribution network.

References

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3) Yamaguchi, N.; Yamazaki, F. Estimation of strong ground motion in the 1995 Hyogoken-Nanbu Earthquake based on building damage data. Journal of Structural Mechanics and Earthquake Engineering. 1999, no. 612:I-46, p. 325–336.

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