Abstract:

A newly-developed simulation program, NeEX, enables quick prediction of the nonlinear seismic response of buried distribution networks in gas and water supply systems, which are characterized by geometry in a complex linear form. As a key feature of NeEX, the novel algorithm which is used to simulate the seismic response of the network idealizes the network in segments. Idealization of networks in segments makes it possible to model networks using far fewer elements than in finite element analysis (FEA). While the accuracy of NeEX is on the same level as FEA, computational time is only 1/5 000–10 000 that with FEA. The

figure, the network comprises straight pipes and the various types of fittings, such as bends and junctions, which are used to connect the straight pipes. The figure shows a condition in which the respective parts of the network have deformed as a result of propagation of a seismic wave along the network. In deformation of a network by a seismic wave, axial deformation predominates in the straight pipe sections and bending deformation predomi-

the basic length of the straight pipes is 100 m. The case of a wavelength of 200 m is presented, supposing wave propagation from the left to the right side of the network model.

In a case where the wave motion propagates from left to right in the network model, the network can be modeled by the three segments shown in red, blue, and green. Both boundary elements are bends in Segment ① and junctions in Segment ②; Segment ③ has one bend and one junction as its boundary elements.

Figure 6 shows the node definition of the network model corresponding to the calculation conditions, assuming three wavelengths (200 m, 300 m, 400 m) as the input ground displacement.

4.2 Calculation Assumptions

As assumptions for calculations of the deformation of the network model, the stress-strain curve of the material was set as shown in **Fig. 7**, and the soil springs were set as shown in **Fig. 8**, based on the above-mentioned Seismic Design Codes for High Pressure Gas Pipelines (2000). The nonlinear reaction properties of the boundary elements positioned at the ends of the straight pipes were obtained as shown in **Fig. 9** by finite element analysis, based on the assumed conditions in Figs. 7 and 8.

4.3 Calculation Accuracy

The calculated results for Cases 1–3 are shown in **Tables 1–3**. These results represent the displacement of the two ends of the straight pipes. The numbers in these tables are the node numbers in Figs. 5 and 6.

this calculated result is considered to have sufficient accuracy, as the actual error was small, at only 0.1 cm. Examples of calculations with error on the order of 5–7% can also be seen, but considering the fact that the error was only about 0.3 cm in these cases, this is adequate analytical accuracy for practical purposes.

4.4 Computational Speed

In addition of calculations for the network in Fig. 1, calculations were also performed for a more extensive network, and the computational time was compared. The hardware used was a super computer in the FEA and a personal computer in the NeEX analysis. As a result, the computations in the analysis by NeEX were completed in 1/5 000–1/10 000 of the computational time required for the FEA.

When the response of a network in a 3 km square area was calculated using NeEX, the computational time was approximately 1 min. Calculation of the response of the same network by FEA using a mainframe computer would require 5 000–10 000 min. This means that the computer must be occupied for 3.5–6.9 days, even assuming 24-hour operation.

5. Conclusion

This paper has presented an outline of the newly-developed NeEX program, which enables high efficiency simulation of the nonlinear seismic response of buried pipe networks. The basic performance and distinctive features of NeEX can be summarized as follows.

(1) In calculations of the deformation properties of boundary elements, accuracy equivalent to that in FEA is assured by the development of a database of FEA results. As a result, calculations can be completed more quickly with no reduction in computational accuracy.

(2) As boundary elements, it is possible to consider bends of any desired angle, as well as junctions, cranks, loops free ends, etc. As a result, rapid seismic design, seismic diagnosis, and examination of the seismic integrity of extensive networks is possible.

References

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