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Experimental Evaluation of the Anchor Movement Effect on the Dynamic Response of Piping Systems under Seismic Loading

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1. Introduction

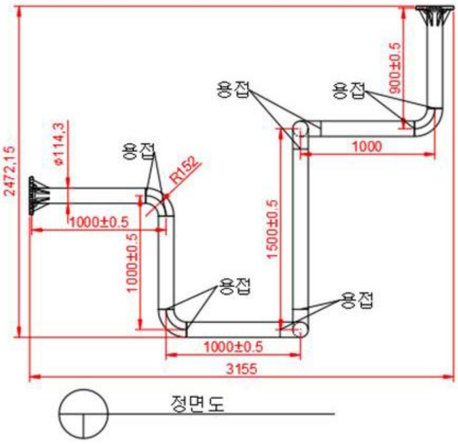
Although the structural integrity of system, structure, and components (SSCs) in nuclear power plants (NPPs) under seismic is evaluated in the design of NPPs, the seismic safety of SSCs is still an important consideration. In particular, recently, the structural integrity of SSCs has become an important issue under large earthquakes exceeding the design basis [1]. Thus, a number of experimental and numerical studies have been conducted and evaluated the safety margin of SSCs under excessive seismic conditions [2-4]. Our previous study also conducted dynamic tests using elbow specimen under unidirectional excitation that simulated the excessive seismic loading [5]. As an extension of the previous study, the present study conducted excitation tests on the simplified piping system under simulated seismic loading. From the results, the effect of anchor movement on the dynamic response of piping system under seismic loading was investigated.

2. Experiment

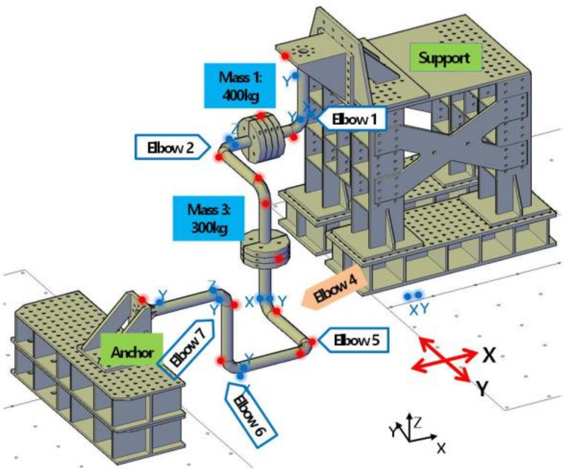
A simplified piping system, consisted of 4-inch, Sch. 40 straight pipes and elbows, was used for the excitation test. The pipe specimens were made of SA106 Gr.B and SA234 WPB carbon steels (PST-S2) and SA312 TP316 and SA403 WP316 stainless steels (PST-C1), respectively. Fig. 1(a) shows dimension of the simplified piping system used for the test.

As shown in Fig. 1(b), one end of the piping specimen was connected to the support set on the shaking table and the other end was fixed with an anchor. To simulate the valves in the piping system and to enhance the dynamic load on the piping system during the excitation, weights of 300 and 400 kg were attached at two locations, respectively All specimens were pressurized to 4.8 MPa by injecting water.

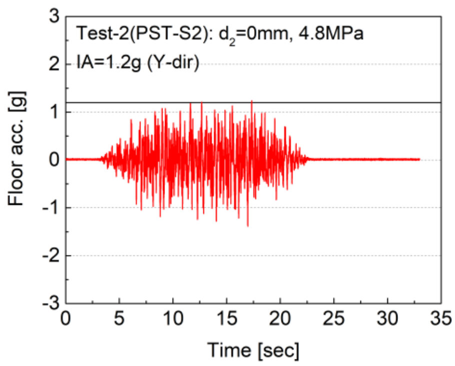
The piping system was excited by excitation of the shaking table in the Y-direction with an acceleration of the waveform shown in Fig. 1(c). In the test, two different anchor displacement conditions were regarded; fixed condition (d_2=0mm) and moved condition (d_2=-250mm in X-direction). Acceleration, displacement, and strain were measured at several locations during the excitation. Fig. 1(b) shows the locations of the accelerometers.



(a) Dimensions of simplified piping system



(b) Configuration of excitation test and locations of accelerometer



(c) Floor acceleration

Fig.1 Excitation test on simplified ping system

3. Results and Discussion

Under fixed anchor condition (d_2=0mm), the natural frequencies of the simplified piping system were 4.602Hz for the PST-S2 specimen and 4.802Hz for the PST-C1 specimen. When an input acceleration with a peak of 1.2g was applied while the anchor was fixed, the top of the support to which the piping system was connected was excited to 2.08g. Elbows 4 and 5 were excited to approximately 7.5g for the PST-S2 specimen and to approximately 10g for the PST-C1 specimen. The higher acceleration of the PST-C1 specimen under the same excitation level is related to the higher natural frequency. Also, the maximum amplitudes of displacement and strain were found at Elbows 2 and 4.

When the anchor statically moved d_2=-250mm in X-direction, the strains at Elbows 4 and 5 increased to approximately 0.25～0.5%, which indicated occurrence of local deformation. Under this anchor moved condition (d_2=-250mm), the natural frequencies of both simplified piping systems were almost the same as those at the fixed anchor condition (d_2=0mm). Also, when an input acceleration with a peak of 1.2g was applied, the locations where the maximum of acceleration, displacement, and strain appeared were not changed by anchor movement of -250mm. Under the anchor movement condition, however, the acceleration increase of Elbows 4 and 5 was more pronounced and the accumulations of displacement and strains appeared during the initial excitation.

4. Conclusions

This study conducted excitation tests on a simplified piping system using a shaking table at two different anchor conditions. The effect of anchor movement on the dynamic response of the piping system subjected to excessive seismic load was investigated from the experimental results.

Acknowledgements

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