Dynamic Behavior Analysis of Single Door Cabinet based on Experimental Test Data

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1. Introduction

Recently, earthquakes of magnitudes greater than 5.0 hit Gyeongju in 2016 and Pohang in 2017. The Gyeongju earthquake with many contents in the high frequency range (more than 10Hz) caused substantial damage to not only structural elements, but also non-structural elements [1]. In addition, precedent research studies have revealed that earthquakes that have occurred in Korea contain many high frequency contents [2, 3]. Nuclear power plants are designed from the 2Hz to 10Hz frequency range [4]. This is the time to require a seismic safety evaluation for non-structural elements of critical facilities in areas like Korea with high probability of high frequency earthquakes.

In this study, the time history analysis was performed using the high fidelity finite element (FE) Model developed in previous studies, and the validity of the model was verified by comparing the FE and experimental results.

2. Experimental Test

2.1. Resonant Frequency Search Test

The size and weight of the electrical single door cabinet are 800mm×800mm×2350mm and 480kg, respectively. Using the 6 degrees of freedom shaking table, the resonant frequency search test was performed at a level of 0.07g in the 1Hz~50Hz range. As shown in Fig. 1, accelerometers were attached to the inside and outside of the cabinet to measure the acceleration.

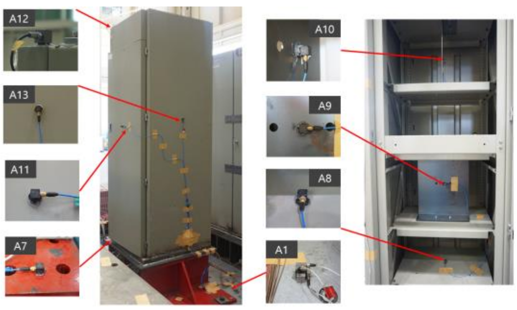


Fig. 1. Accelerometer location

As Fig. 2 displays the experimental results, 16Hz and 24Hz were the frequencies at which amplification occurred in both internal and external accelerometers, and these were judged as the global modes. 30.50Hz, the frequency at which the amplification of A9 attached to the vertical panel on the first floor stood out, was judged as the first local mode, and 37.50Hz, the frequency at which the amplification of A10 attached to the vertical panel on the second floor stood out, was judged as the second local mode.

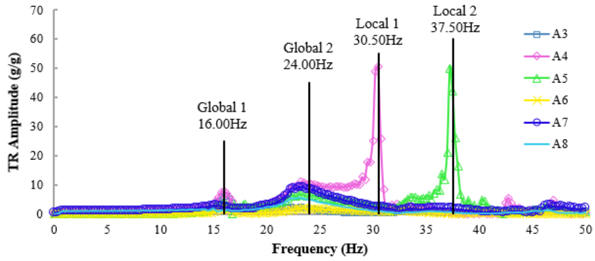


Fig. 2. Resonanat frequency search test result

2.2. Seismic Simulation Test

The input motion used in the shaking table test generated artificial seismic waves using the RG 1.60 required response spectrum (RRS) of Fig. 3. As shown in Fig. 4, the duration of the artificial earthquake wave was 30sec in total, and the duration of the strong earthquake was 20sec.

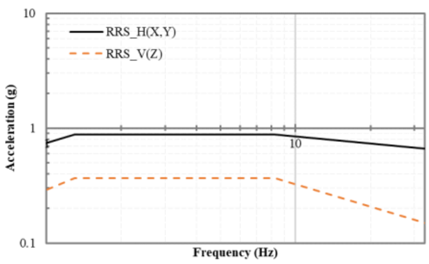


Fig. 3. Required response spectrum by RG 1.60

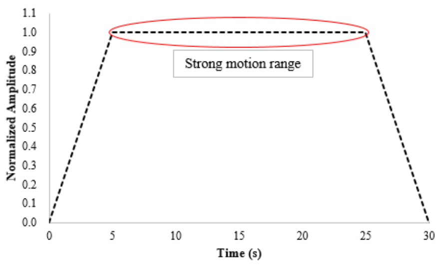


Fig. 4. Artificial earthquake envelop function

Fig. 5 displays the comparison of the acceleration response measured at the top (A12) and RRS. Fig. 6 exhibits the comparison of the acceleration response as measured at the side door (A13) and RRS.

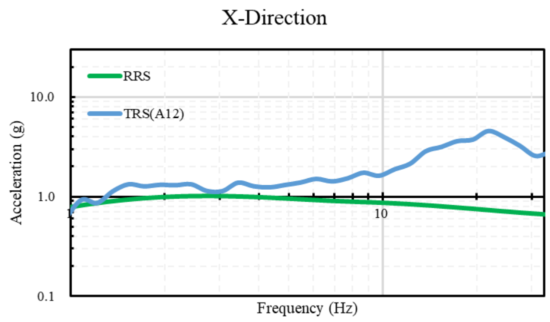


Fig. 5. Front-back(X) direction response in A12

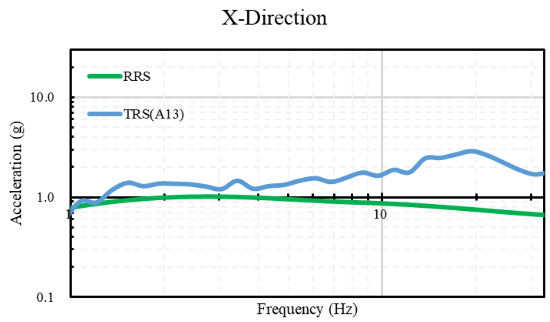


Fig. 6. Front-back(X) direction response in A13

3. Finite Element Analysis

3.1. Finite Element Model

The time history analysis was performed using the FE model developed in the study by Son et al [5]. The elastic modulus E=200,000MPa, density ρ=7.85×10^{-9}t/mm^3, and Poisson's ratio υ=0.28, which are the material properties of general steel materials, were applied for the material model. The 4node shell element (S4R) generally used in the ABAQUS platform [6] was used, and the FE model is depicted in Fig. 7.

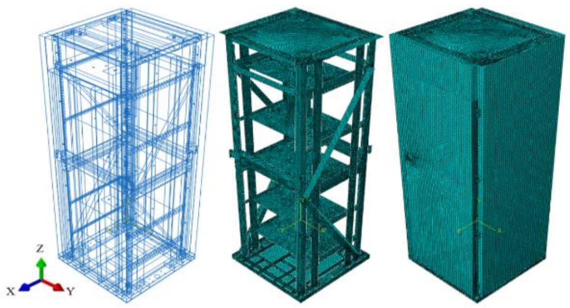


Fig. 7. High fidelity FE model [x]

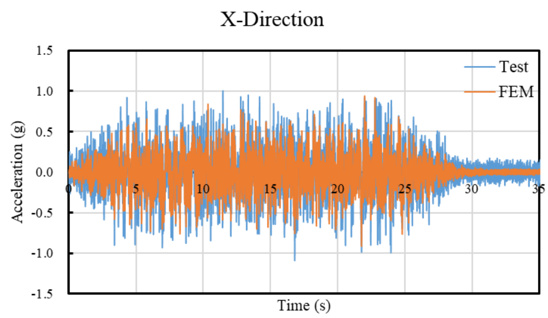
3.2. Compare to Experimental and FEA Results

When comparing the results of the resonant frequency search test, it was seen that error occurrence was about 1% in both global and local modes, and detailed results were compared in Table 1.

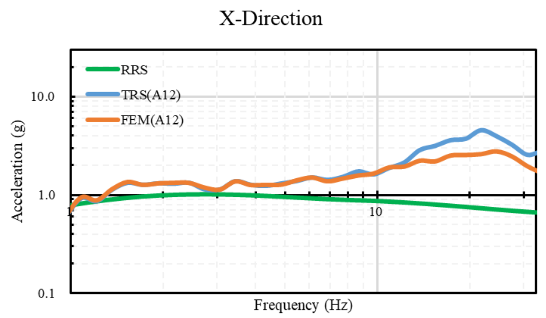
Table 1: Resonant frequency search test compare to FE analysis

Mode	Experimental test	FE analysis
1st global	16.00	16.11
2nd global	24.00	23.86
1st local	30.50	30.81
2nd local	37.50	37.25

Results of the time history analysis and the shaking table test were compared and exhibited in Fig. 8 and Fig. 9. The responses of the top (A12) and the side (A13) were compared, and it was found that both locations matched well with the experimental results. At the spectrum less than 10Hz, front-back direction matched well. At the range greater than 10Hz, the trends of matched well, but the analysis revealed slightly smaller responses.

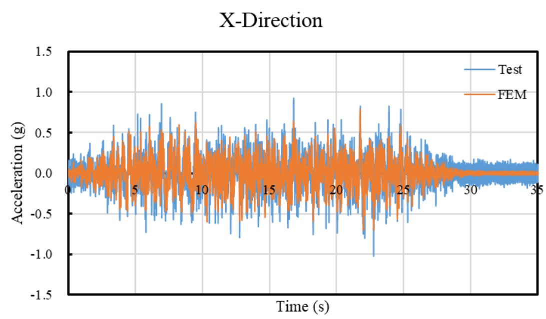


(a) Time domain

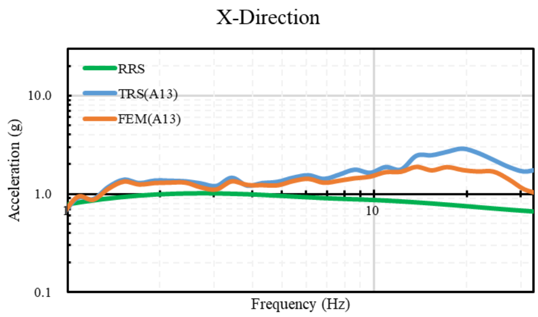


(b) Frequency domain

Fig. 8. Front back direction response compare to test and FE analysis in A12



(a) Time domain



(b) Frequency domain

Fig. 9. Front back direction response compare to test and FE analysis in A13

4. Conclusion

In this study, the Time History Analysis was performed using the High-Fidelity FE Model developed in the previous study. The responses of the top (A12) and side door (A13) measured in the experiment were compared with the analysis results. When the responses were compared in the time domain, it was revealed that the response between 5sec and 25sec, which is the duration of a strong earthquake, was matched well. When compared in the frequency domain, the overall trend was matched well, so it is judged that the developed model can represent the behavior of the cabinet caused by the earthquake. In future studies, the experimental result and analysis result of the accelerometer located inside will be compared.

ACKNOWLEDGEMENT

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[6] ABAQUS ver.2020 Dassault Systems.