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System Identification (SI) of High-Rise Base-Isolated Building through Observed Earthquake Data

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High-rise Base-isolated Building System Identification
Observed Earthquake Natural Frequency Damping Ratio

1. Introduction

In recent years, seismic isolation systems have been widely applied in high-rise buildings. Despite their widespread adoption, research on system identification (SI) for these systems through observed earthquake data remains relatively limited. Huang and Sato [1] estimated the natural frequency of a high-rise base-isolated building using observed earthquake data in one direction; however, other mode parameters were not addressed.

In this paper, the recorded acceleration responses from three earthquakes that occurred in 2023 are utilized to estimate the natural frequency and damping ratio of a high-rise base-isolated building by SI procedures.

2. Monitoring system in high-rise base-isolated building

This paper centers on the J2-3 building [2], located in the Suzukakedai campus, Tokyo Institute of Technology. Fig.1 shows a photo of the J2-3 building. J2-3 building is a 20-floor structure with a height of 91.4 m, comprising of two interconnected buildings J2 and J3. The construction of J2-3 building involves reinforced concrete for its 1st floor, primarily embedded in the subsurface, thereby assumed as a rigid body. Conversely, the 2nd to 20th floors were constructed using a steel framework, and an isolation layer (MF) is positioned between the 1st and 2nd floors.

Fig.1 Photo of J2-3 building

Fig.2 illustrates the locations of accelerometers in J2-3 building. The directional arrows in the figure indicate the specific directions in which acceleration data are captured. For this study, the acceleration records in the X direction are utilized for analysis, and these designated accelerometers are situated on the 20th, 2nd, and 1st floors of the J2 side building, demarcated by red circles. Their corresponding channel numbers are F080, F084, F050, F000, respectively.

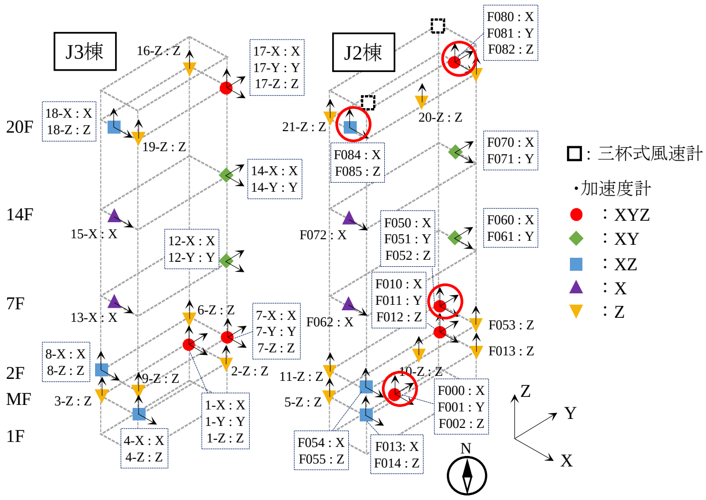

Fig.2 Locations of accelerometers in J2-3 building

3. Observed earthquake records

In accordance with Chapter 2, because the 1st floor of J2-3 building is buried underground, the acceleration data recorded on the 1st floor can be assumed to represent the ground acceleration. Table 1 presents the maximum absolute acceleration values recorded on the 1st floor of the J2 side building during three observed earthquakes in 2023. Each earthquake occurrence is labeled from Case 1 to Case 3, respectively.

Table 1. Maximum ground absolute acceleration

	Occurred time of earthquake	Acceleration[cm/s^2]
Case 1	May 11, 2023, 04:16	5.18
Case 2	September 5, 2023, 13:27	3.42
Case 3	May 10, 2023, 11:21	1.94

4. System identification

System Identification (SI) is the process of approximate modeling for an unknown system based on a set of observed data and prior system knowledge [3]. In this study, the first step of calculation is to modify the acceleration value of the 20th floor to ensure that only translational movement is included using Equation (1).

$$A_{Translation} = \frac{A(F084)+A(F080)}{2} \quad (1)$$

Here, A(F084) and A(F080) respectively represent the acceleration data recorded from channels F084 and F080, whose locations are shown in Fig. 2. Then, the Fourier spectrum of $A_{Translation}$ is divided by the Fourier spectrum of the ground acceleration (F000) to obtain the transfer function of entire building $|H_E|$. Similarly, when divided by that of the 2nd floor's acceleration (F050), the transfer function of superstructure $|H_S|$ is gained. The transfer function results and calculation principles are shown in Fig. 3.

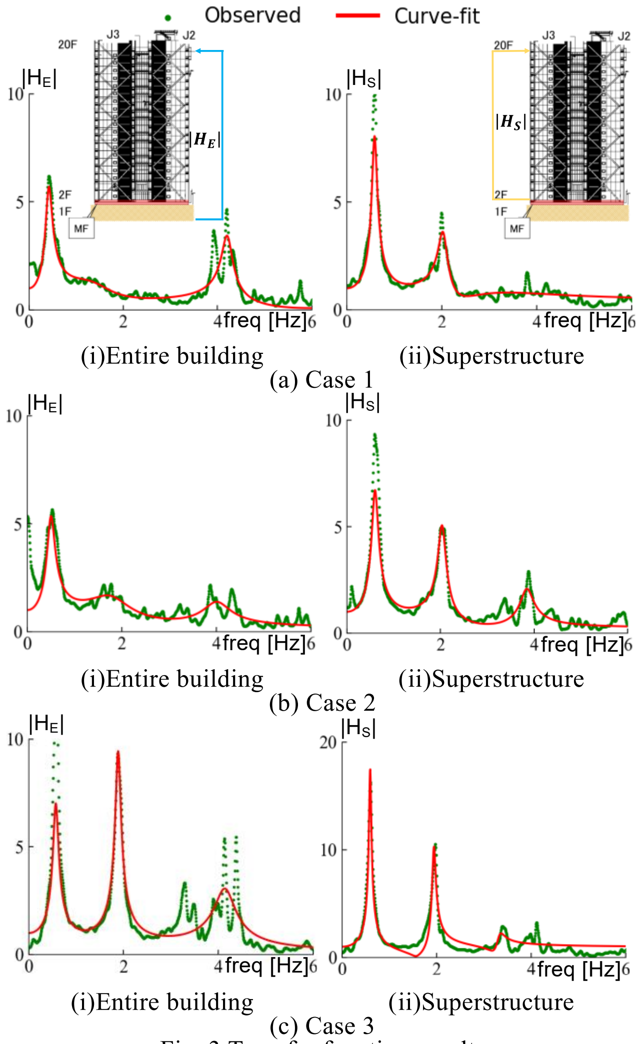

Fig. 3 Transfer function results

Fig. 4 shows the relationship between the maximum ground acceleration and natural frequency f or damping ratio ξ, based on the results obtained from the SI procedures for the three cases analyzed. The natural frequency of the superstructure in the 1st and 2nd modes exceed those of the entire building, and the percentage difference increases as the seismic intensity increases, consistent with the findings from the study conducted by Huang and Sato [1]. However, for the 3rd mode, the natural frequency of superstructure is lower than that of the entire building. In addition, the damping ratios of superstructure are consistently lower than those of entire building for the first three modes.

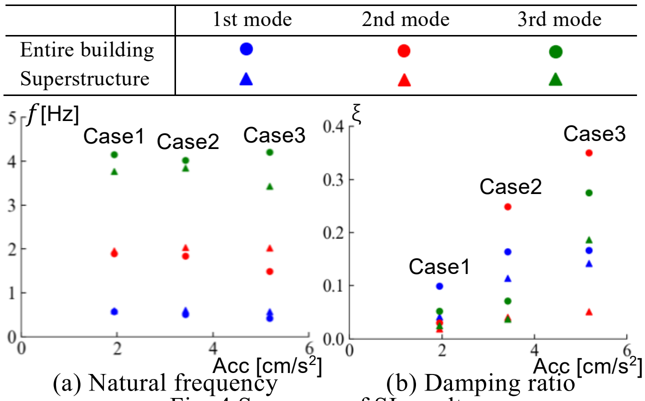

Fig. 4 Summary of SI results

5. Conclusion

This study employs SI procedures to estimate the natural frequency and damping ratio of a high-rise base-isolated building using observed earthquake data. Compared with the findings of previous study, two results are gained:

1) Natural frequencies of the 1st and 2nd modes increase due to presence of the isolation layer, while that of the 3rd mode decreases.
2) The damping ratio of superstructure is consistently lower than that of the entire building, indicating the effect of isolation layer in reducing damping ratio.

In summary, this study shows an application of SI to analyze the influences of the isolation layer on a high-rise base-isolated building under seismic conditions.

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