

論文 / 著書情報
Article / Book Information

論題(和文)	
Title(English)	System Identification of Base-isolated High-rise Building with Lateral Extension by Frequency Domain Decomposition
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出典(和文)	日本建築学会大会学術講演梗概集, 構造 , , pp. 245-246
Citation(English)	, 構造 , , pp. 245-246
発行日 / Pub. date	2025, 9
権利情報	一般社団法人 日本建築学会

System Identification of Base-isolated High-rise Building with Lateral Extension by Frequency Domain Decomposition

Structural Health Monitoring Frequency Domain Decomposition
System Identification Building Extension Ambient Vibration

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1. Introduction

As an effective approach to urban densification, building extension has been widely implemented worldwide in recent years. Research [1] shows that combining building renovation with lateral and vertical extensions yields greater financial returns than energy-efficient renovation alone. However, unlike vertical extension, lateral extension has received little attention, particularly in the studies comparing buildings' dynamic characteristics before and after extension. Moreover, frequency domain decomposition (FDD) is a user-friendly system identification (SI) technique relying only on a system's output [2-3]. Previous studies applying FDD to ambient vibration primarily model excitation as white noise, while actual observed data from structural health monitoring (SHM) systems remain underutilized.

This study performs SI on a real-world base-isolated high-rise building with lateral extension using FDD, utilizing recorded ambient vibration response data from an SHM system.

2. Extension from J2 Building to J2-3 Building

The J2 building [4], located on the Suzukakedai campus, Institute of Science Tokyo, is a base-isolated high-rise structure constructed in 2005. On February 4, 2011, construction began on another side building, the J3 building. Subsequently, on March 17, 2012, the J2 and J3 buildings



(a) J2 building

(b) J2-3 building

Fig.1 On-site photo

were integrated into a single structure, named J2-3 building, marking the completion of the extension project. Fig.1 presents a photo of the J2 building before and after extension.

A long-term dense SHM system was originally installed in J2 building and was later expanded to J3 side building following the extension project. This system incorporates accelerometers positioned on the 1st, 2nd, 7th, 14th, and 20th floors, as well as on the isolation layer (MF). Fig.2 illustrates the locations of the accelerometers.

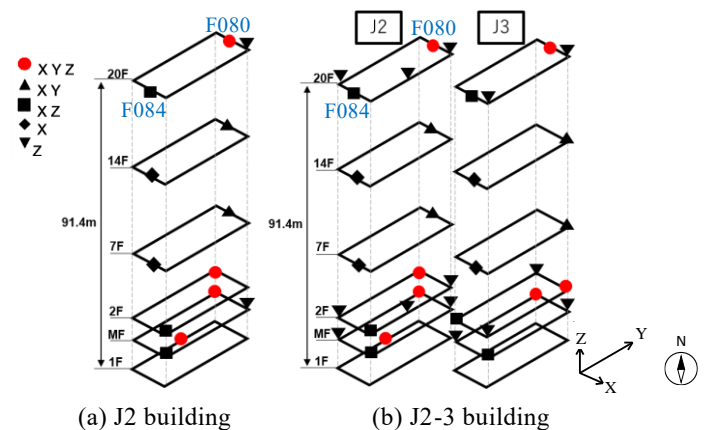


Fig.2 The installation position of accelerometers

3. Data Processing

In this study, the response acceleration in the X direction of the top floor, recorded by accelerometers F080 and F084 (see Fig.2), is used as the output. To avoid other seismic events, the response of ambient vibration collected during midnight (0:00~1:20 AM) is utilized. Furthermore, to analyze translational and torsional movements independently, their accelerations are calculated using the following equations:

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

$$\theta_{tor} = \frac{A(F080) - A(F084)}{\frac{L}{2}} \quad (2)$$

where, $A(F080)$ and $A(F084)$ are the response acceleration

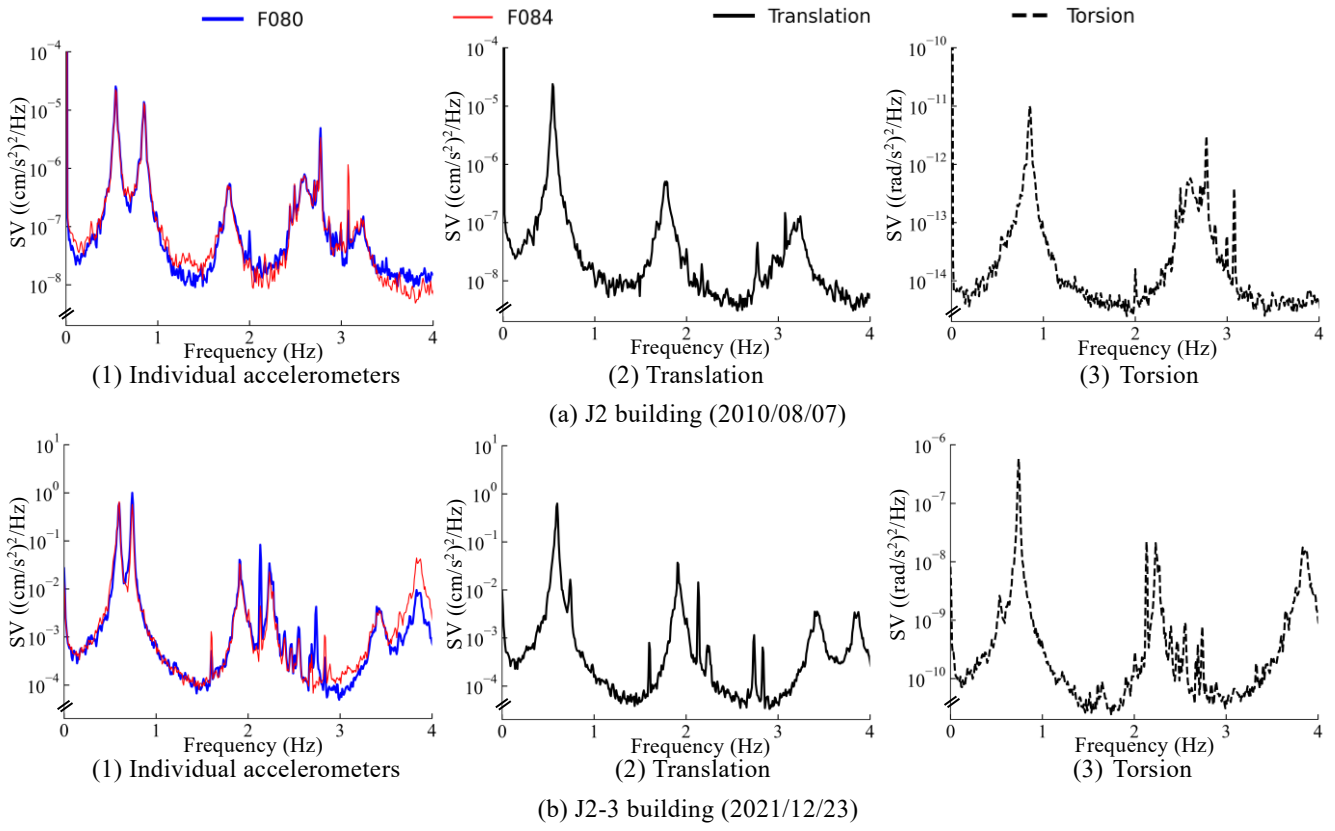


Fig.3 The SV results

from two accelerometers F080 and F084, L is the distant between these two accelerometers. Fig.3 shows singular value (SV) results of each case calculated by FDD.

modes in the J2 building were initially close to each other. After the extension, both damping ratios decrease; however, the 1st mode damping ratio shows greater reduction.

4. Discussion

5. Conclusion

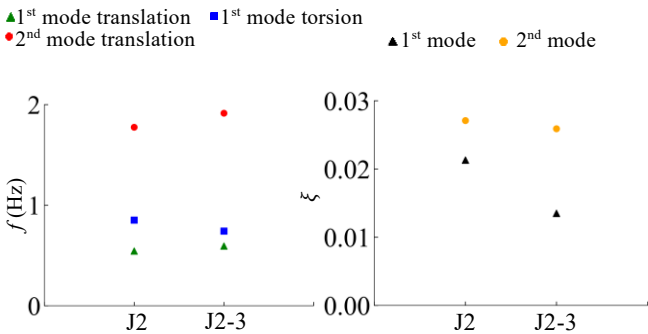


Fig.4 The comparison of the SI results

Fig.4 presents a comparison of the SI results between the J2 and J2-3 buildings. In Fig.4(a), the natural frequencies of the 1st and 2nd modes of translational movement increased after the extension, whereas that of torsional movement decreased. Consequently, the natural frequencies of the 1st mode translational and torsional movements became more similar.

This study applied SI using FDD to investigate the dynamic characteristics of a real-world building before and after its lateral extension. As a result, the natural frequencies of translational modes increased, while that of the torsional mode decreased, leading to a greater interaction between these movements. Additionally, the damping ratios showed reduction after the extension, which was more prominent in the 1st mode.

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