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# Brief Introduction to Vibration Measurement and Application to Structural Performance Evaluation of Timber Structures in Japan

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## Short communication

From past experiences, buildings in Japan built before1980 tend to suffer severe damage by earthquake compared to buildings built afterward. The structural performance of building structures in Japan are regulated by the Building Standard Law, enacted in 1950 by the national government. The BSL has gone through many revisions, and the most recent major revision on building structures was operated in 1981. The results of damage investigation by multiple earthquakes have revealed that buildings built before this revision show severe damage by large earthquakes compared to the buildings built afterward [1]. The architectural engineering society together with the government have been trying to promote the application of seismic diagnosis and structural reinforcement on buildings for the past several decades.

The structural systems of buildings in Japan are mainly reinforced concrete, timber and steel constructions. For residential buildings 60% of the existing housing units are of timber construction, mostly detached houses. Also, 90% of the cultural heritage are timber structures. How to secure the safety of these existing private houses and valuable architectural heritage are a major concern and challenge for timber engineers in Japan.

Several evaluation methods for timber structures have been developed, tested and applied. The methodologies range from simple checklist to highly sophisticated calculation accompanied by partial destructive investigation, material/element/joint experiments. The main interest and target has been to clarify the maximum restoring force, ductility and maximum response to probable or artificial input motion. In most cases the discussion is to prevent the structure from collapse. Of course there are examples to minimize the structural damage, preferably within the elastic range, so that the building can be used directly after a large earthquake. In order to realize this, sophisticated technology and device for vibration control have been developed and applied. But these devices require highly specialized knowledge of the engineer and more often larger budget. The balance between the necessary investmentand the value of the existing building is discussed.

The above evaluation methodologies are mainly based on calculation, sometimes accompanied by joint or element tests. There are other approaches to understand the actual structural performance of existing structures based on non-destructive vibration measurement. The most classical method is the ambient vibration test (micro tremor measurement), which has been operated on timber structures In Japan since the 1920's [2]. Structural performance evaluation and health monitoring based on earthquake monitoring has also been operated, mainly after 1995 earthquake in Kobe. Recently due to the development sensors and devices, various studies relating to damage identification based on earthquake monitoring is increasing for all types of structures (several examples are shown in references) [3-10]. The main objective is to determine the change in natural frequency of the structure before, during and after earthquake, in order to evaluate the stiffness degradation of the structure.

Timber structures are strongly non-linear from minor amplitude range. We have proposed a relationship to estimate the natural frequency/stiffness for larger displacement based on the measurement of minute amplitude for several traditional timber structure systems. We have measured the response of the structure for multiple minor earthquakes, the responses within the range of 1/1,000 rad. [10]. We are continuously monitoring earthquakes in several buildings, and by analyzing the natural frequency and displacement relation in the larger amplitude range, we hope to refine our estimation method. However, the maximum restoring force cannot be determined by this relation and this is a much larger topic, which we need to study further.

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