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CHANGE OF VIBRATION CHARACTERISTICS OF WOODEN BUILDINGS UNDER CONSTRUCTION BASED ON MICRO-TREMOR MEASUREMENTS

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It is important to accurately determine the vibration characteristics of wooden buildings to evaluate their seismic performance. This study aims to determine the vibration characteristics of a wooden house at each construction stage and to clarify the factors in their change based on the micro-tremor measurements. The construction process of the wooden house is divided into four stages. In the first stage, the wooden house consists of only columns and beams. In the second stage, the lattice bearing walls are installed in the first stage structure. In the third stage, roofing is added. In the fourth stage, the exterior and interior finishes for the lattice bearing walls are conducted and the entire construction work is completed. Therefore, we conducted micro-tremor measurements a total of four times. Based on the results of the micro-tremor measurements, the stiffness ratio of each element of the wooden house was estimated. The exterior and interior finishes for the lattice load-bearing walls occupy approximately 50–70 % of the overall stiffness and their effect on the stiffness of the wooden house is very large.

Keywords: Construction stages, Natural frequency, Stiffness, Finishes, Lattice bearing walls, Wooden frame.

1 INTRODUCTION

Many large earthquakes have occurred in Japan since the Southern Hyōgo Prefecture earthquake in 1995 that greatly damaged many wooden buildings. Powerful earthquakes have a high probability of occurrence in Japan. Previous examples include the Nankai, Tōnankai, and Tōkai earthquakes. Many Japanese live in wooden buildings that are vulnerable to large earthquakes. Therefore, ensuring their seismic resilience is crucial. It is essential to accurately determine the vibration characteristics of wooden buildings in order to evaluate their seismic performance and promote their seismic reinforcement. However, few studies have focused on the change in their vibration characteristics during construction.

This study aims to determine the vibration characteristics of a wooden house at each stage of construction and to clarify the factors in the change of its vibration characteristics based on micro-tremor measurements. Based on the results of the micro-tremor measurements, the stiffness ratio of each element of the wooden house is estimated.

2 MICRO-TREMOR MEASUREMENTS

2.1 Outline of a Wooden House

The subject of this study is a two-story wooden house at Kumakogen Town in Ehime Prefecture. The wooden house consists of wooden frames such as columns and beams and lattice bearing walls. The length and width of the house are approximately 9.5 m and 7.6 m, respectively. The heights of the first and second story are approximately 3.0 m and 2.5 m, respectively. The first and second story exterior finishes are made of

(a) Stage 1

(b) Stage 2

(c) Stage 3

(d) Stage 4

Figure 1. Overview of the wooden house at each stage.

Table 1. Summary of each stage.

Date of micro-tremor measurement	Construction stage	Description	Natural frequency (Hz)	
			Longitudinal direction	Transverse direction
2011/10/11	Stage 1	Wooden frame	3.11	2.94
2011/10/27	Stage 2	After installation of load-bearing walls	6.86	8.42
2012/01/07	Stage 3	After installation of roofing	6.28	7.64
2012/07/04	Stage 4	After completion	7.89	8.72

plaster and wooden plate, respectively. The interior finish consists of plaster board, and the roof is composed of galvalume steel plate.

2.2 Measurement Method

To estimate the vibration properties of the wooden house at each construction stage, we carried out micro-tremor measurements. The construction process of the wooden house is divided into four construction stages that are shown in Figure 1 and Table 1. In the first stage, the wooden house consisted of only columns and beams. In the second stage, the lattice load-bearing walls were installed on the first stage structure. In the third stage, the roofing was installed. In the fourth stage, the exterior and interior finishes for the lattice bearing walls were conducted and the entire construction work was completed. We conducted micro-tremor measurements in both the longitudinal and transverse directions a total of four times (Table 1).

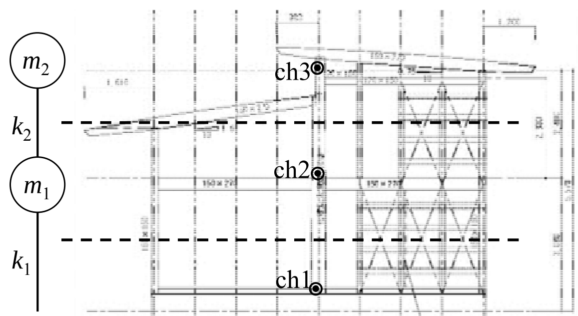
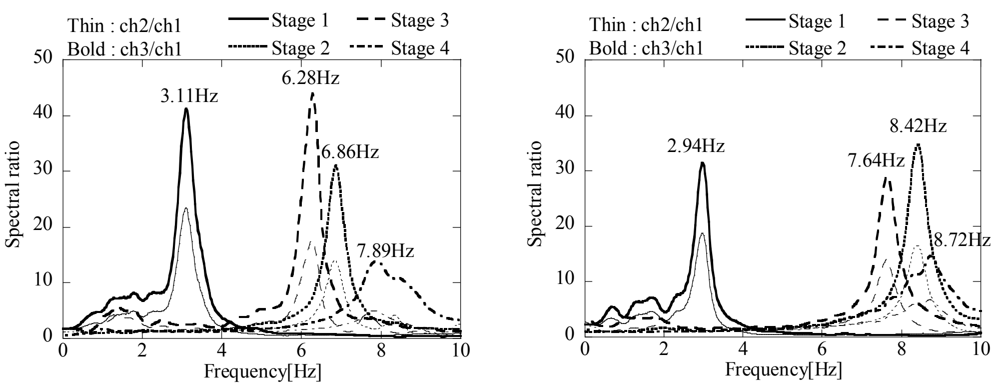


Figure 2. Location of sensors.



(a) Longitudinal direction (b) Transverse direction

Figure 3. Results of micro-tremor measurements.

Figure 2 shows the locations of each sensor. Ch1 was set on the ground level, ch2 was on the second floor level, and ch3 was on the roof level. Micro-tremors were measured five times over 200 min at each stage at a sampling frequency of 100 Hz. The measured values were divided by 40.96 s. The portion that had less noise such as traffic vibrations were subjected to ensemble-averaging and smoothing (Hanning

Window: 50). The obtained records were Fourier-transformed and from the ratio of Fourier spectra to the ground surface at each measurement point inside the wooden house, the natural frequency, and vibration mode of the wooden house were estimated.

2.3 Measurement Results

Table 1 and Figure 3 show the measurement results at each construction stage. From Stage 1 to 2, installing the lattice bearing walls increases the natural frequency of the wooden house by approximately 2.2 times in the longitudinal direction and 2.9 times in the transverse direction. From Stage 2 to 3, installing the roofing decreases the natural frequency of the wooden house by approximately 0.9 times in both directions. From Stage 3 to 4, once the house is completed, the natural frequency increases by approximately 1.3 times in the longitudinal direction and 1.1 times in the transverse direction.

3 ESTIMATION OF STIFFNESS

We estimated the stiffness of each element of the wooden house from micro-tremor measurements at each construction stage. The wooden house was modeled using a multi-degree-of-freedom model (Figure 2). Figure 4 shows the weight of each story calculated from the volume of wood. Figure 5 shows the change of the stiffness ratio at each construction stage calculated from the natural frequency, vibration mode, and the weight. From Stage 1 to 2, the effect of the lattice load-bearing walls on the stiffness is very large because the change in weight is very small. From Stage 2 to 3, the weight of the second story increases slightly although the stiffness of each story remains the same. The natural frequency of the wooden house decreases slightly. From Stage 3 to 4, the weight and natural frequency of the wooden house increase and the stiffness ratio of the lattice load-bearing walls decreases from approximately 70–80% to 20%. The finishes comprise 50–70% of the stiffness ratio of the wooden house. Therefore, the effect of the exterior and interior finishes for the lattice load-bearing walls on the stiffness of the wooden house is very large.

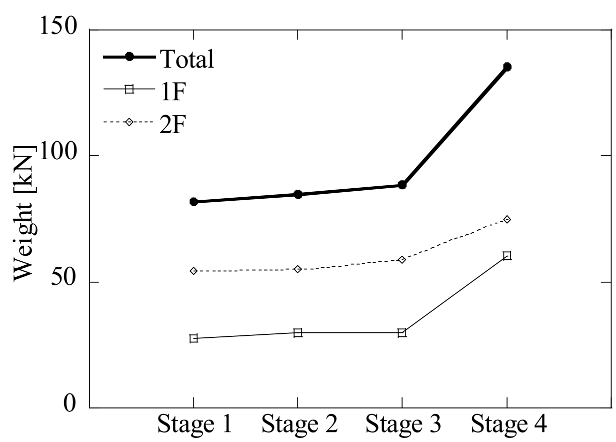
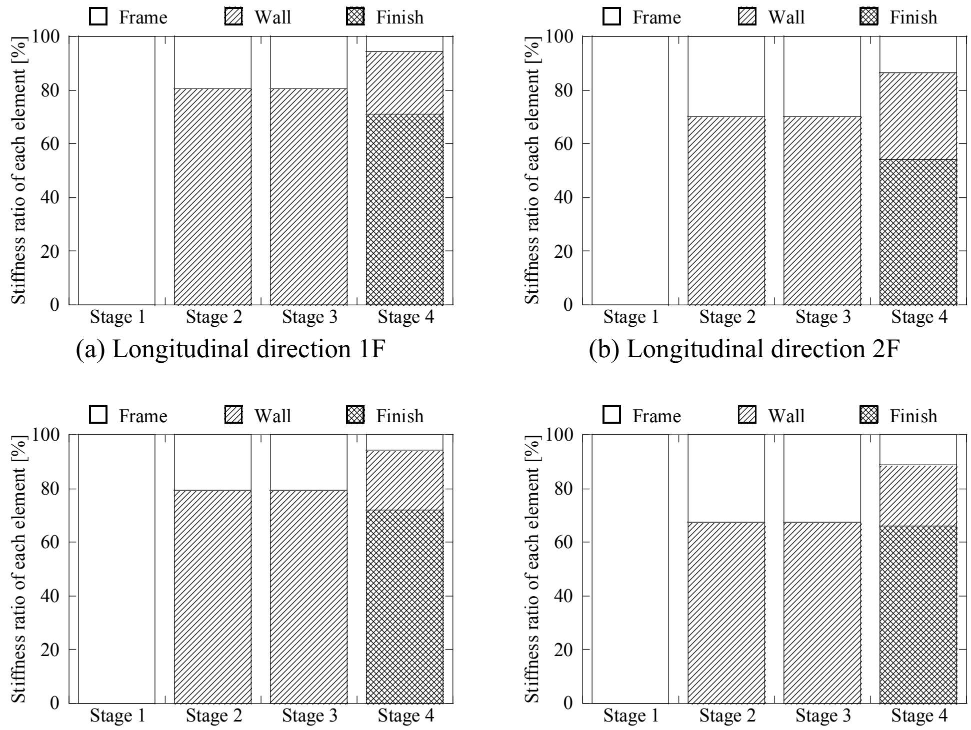


Figure 4. Change of weight.



(a) Longitudinal direction 1F
(b) Longitudinal direction 2F
(c) Transverse direction 1F
(d) Transverse direction 2F

Figure 5. Change of stiffness ratio.

4 CONCLUSIONS

Micro-tremor measurements were carried out to determine the vibration characteristics of a wooden house at every construction stage and to clarify the factors involved in the change of its vibration characteristics. The stiffness ratio of each element of the wooden house was estimated. The exterior and interior finishes for the lattice bearing walls comprise approximately 50-70% of the stiffness and their effect on the stiffness of the wooden house is very large.

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