Improvement of floor impact sound insulation in cross laminated timber model building for experiment

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ABSTRACT

The Act for Promotion of Use of Wood in Public Buildings (Law No. 36 of 2010 of Japan) was enforced in 2010. A public building in a low layer is supposed to attempt making to timber construction by this act. Moreover, it is expected that the building such as apartment houses comes to be made from wooden construction. The promotion of the use of wood can contribute to the prevention of global warming. CLT (Cross Laminated Timber), which had been used in Europe, was standardized by JAS (Japanese Agricultural Standard) in 2014. Among the objections and the troubles of houses in Japan, the sound insulation performance is one of the most serious issues, especially floor impact sound. However, we have little knowledge about sound insulation of CLT. Therefore, we built a 3-story CLT model building for experiments and investigated the floor impact sound insulation. This paper presents the effect of ceiling, floor finish (floating floor) and elastic material on the floor impact sound insulation. The results showed that the surface density of the floating floor influences the floor impact sound insulation. Furthermore, the effect of elastic material was confirmed.

Keywords: Floor impact sound, Cross laminated timber
I-INCE Classification of Subjects Number(s): 51.2, 51.5

1. INTRODUCTION

The promotion of the use of wood can contribute to the prevention of global warming. Efforts toward the construction of timber public buildings have been made since the enforcement of the Act for Promotion of Use of Wood in Public Buildings (Law No. 36 of 2010 of Japan). Moreover, cross laminated timber (CLT) was standardized by JAS (Japanese Agricultural Standard) as construction material in 2014. The impact sound insulation is the most serious issue in apartment houses of Japan. Moreover, a timber building usually has inferior performance of floor impact sound insulation than a concrete construction.

Zeitler et al. reported the impact sound insulation of cross laminated timber floors in reference (1). Author reported the effect of floating floor (dry double system floor) on the floor impact sound insulation in wooden building by reference (2). However, we have little knowledge about sound insulation of cross laminated timber building. Therefore, we built a 3-story cross laminated timber model building for experiments and investigated the floor impact sound insulation. This paper presents the effect of damping material, ceiling and floating floor on the floor impact sound insulation of cross laminated timber building.

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2. CROSS LAMINATED TIMBER MODEL BUILDING OVERVIEW

2.1 Building Frame

Figure 1 shows the outside view and Figure 2 shows the cross-sectional view of the cross laminated timber model building. Its one floor measures 3.64 x 3.18 m (10.4 m^2 in a floor area) and the entire building is three-storied. H steels were set on the concrete earth floor and 1st floor was finished the floating floor. The 2nd and 3rd floor were 150 mm thick CLT panel, which had 5 ply. All walls were 90 mm thick CLT panel, which had 3 ply. As for the ceiling height, the 2nd floor was 2.3 m, the 1st floor was 2.7 m. In addition, the floor is Jointed the wall by bolts and angles, it was structure to be proof against earthquakes.

Figure 1 – Outside View of the cross laminated timber model building

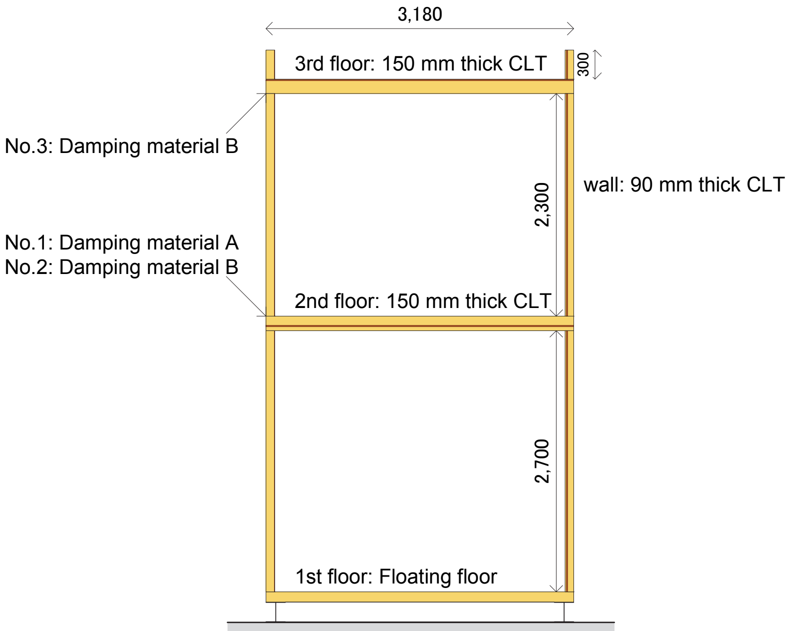


Figure 2 – Cross-sectional view of the cross laminated timber model building

2.2 Specifications of Floor Sections

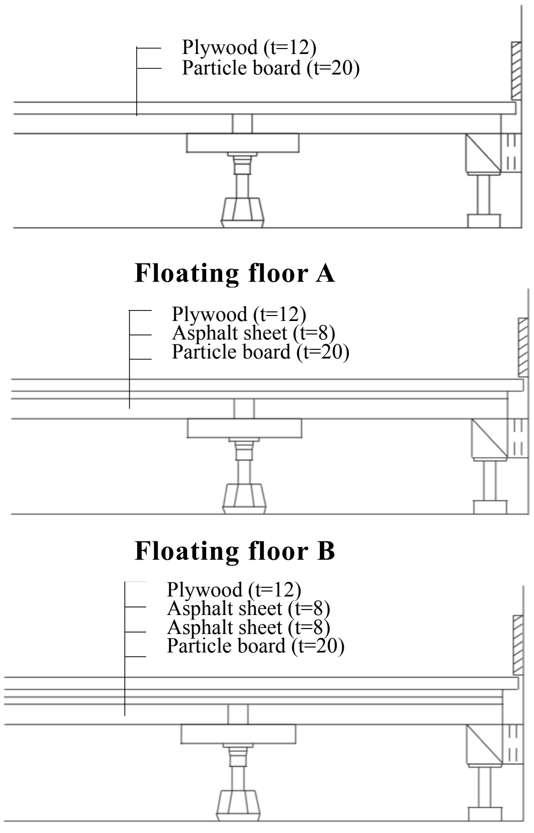
In order to investigate the effects of damping material, ceiling and floating floor on floor impact sound insulation for cross laminated timber building, the specifications of the specimen were determined. Table 1 shows the outline of section specifications of 11 specimens. Specimen No. 1 as reference specimen was only building frame.

Specimens No. 1, 2 and 3 were No. 0 with damping material. The damping material is polyurethane elastomer foam of thickness 12.5 mm. As for each Young's modulus of static load, in damping material A, approximately is 8.0 N/mm^2, damping B is approximately 1.8 N/mm^2. Specimen No. 1 was No. 0 with damping material A between 2nd floor wall and 2nd floor, Specimen No. 2 was No. 0 with damping material B between 2nd floor wall and 2nd floor, and Specimen No. 3 was No. 0 with damping material B between 3rd floor and 2nd wall.

Specimens No. 4 was No. 0 with ceiling, specimens No. 5, 6, 7 were No. 0 with floating floor, and specimens No. 8, 9 and 10 were No. 4 with floating floor. The celling was constructed in 9.5 mm thick gypsum board with substrate light gauge steel. Figure 3 shows the cross-sectional view of floating floors. The topping of floating floors was changed with and without 8 mm thick asphalt sheet.

Table 1 – Outline of section specifications of specimen

No.	Damping material	Ceiling	Floor topping
0	None		
1	Damping material A (between 2nd floor wall and 2nd floor)		
2	Damping material B (between 2nd floor wall and 3rd floor)	None	None
3	Damping material B (between 3rd floor and 2nd floor wall)		
4		Gypsum board, t=9.5 mm	
5			Floating floor A
6		None	Floating floor B
7	None		Floating floor C
8			Floating floor A
9		Gypsum board, t=9.5 mm	Floating floor B
10			Floating floor C



Floating floor C

Figure 3 – Cross-sectional view of floating floors

3. MEASURMENTS

The floor impact sound insulation was measured in accordance with JIS A 1418-2 by reference (3) and JIS A 1418-1 by reference (4). The impact positions were five positions, and the sound-receiving positions were five positions. The floor impact sources for measurement of the heavy-weight floor impact sound insulation ware a car-tire source (bang machine) and a rubber ball source, and of the light-weight floor impact sound insulation was a tapping machine. The rubber ball source was dropped from a height of 100 cm according to JIS. The floor impact sound insulations were evaluated with JIS A 1419-2 by reference (5).

4. RESUILTS AND DISCUSSINS

4.1 Floor Impact Sound Insulation

Figure 4 shows the measurement results of the floor impact sound insulation on the 3rd floor for the sound-source room and the 2nd floor for the sound-receiving room. Concerning specimen No. 0, the heavy-weight floor impact sound insulation using the car-tire source was L_r-90, the heavy-weight floor impact sound insulation using the rubber ball was L_r-80 and the light-weight floor impact sound insulation was L_r-105. These floor impact sound insulations were exceedingly low performance for actual buildings by applicable grades of sound insulation of Architectural Institute of Japan in reference (6). Specimen No. 10 yielded high performance, showing L_r-75 in the heavy-weight floor impact sound insulation using car-tire source, L_r-65 in the heavy-weight floor impact sound insulation using rubber ball and L_r-70 in the light-weight floor impact sound insulation.

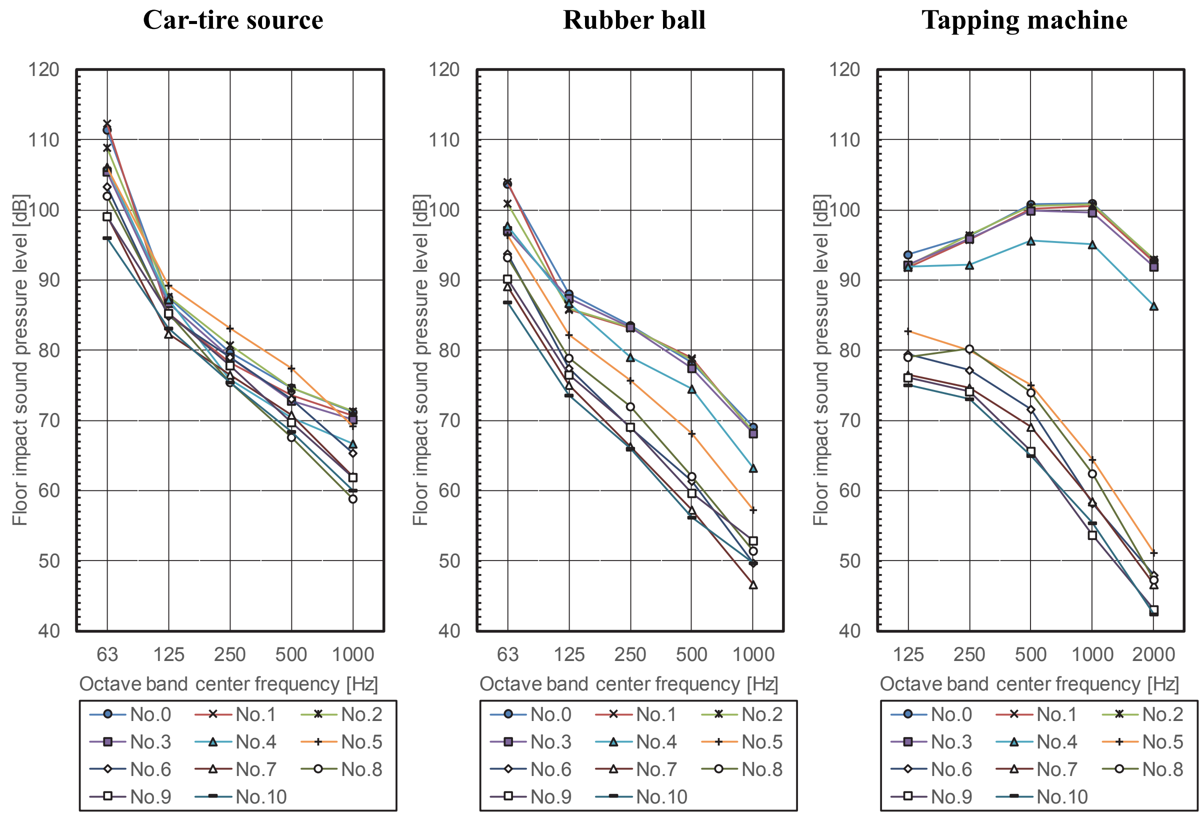


Figure 4 – Measurement results of the floor impact sound insulation of the CLT model building

(Sound-source room: 3rd floor, Sound-receiving room: 2nd floor)

4.2 Influences of Damping Material, Ceiling and Floating Floor

To confirm the effects of the damping material, ceiling and floating floor on the floor impact sound insulation, the differences in floor impact sound pressure levels from specimen No. 0 were calculated. Figure 5 shows the improvements of floor impact sound pressure levels relative to that of No. 0. A positive value in these Figures indicates that the room has a higher floor impact sound insulation than No. 0.

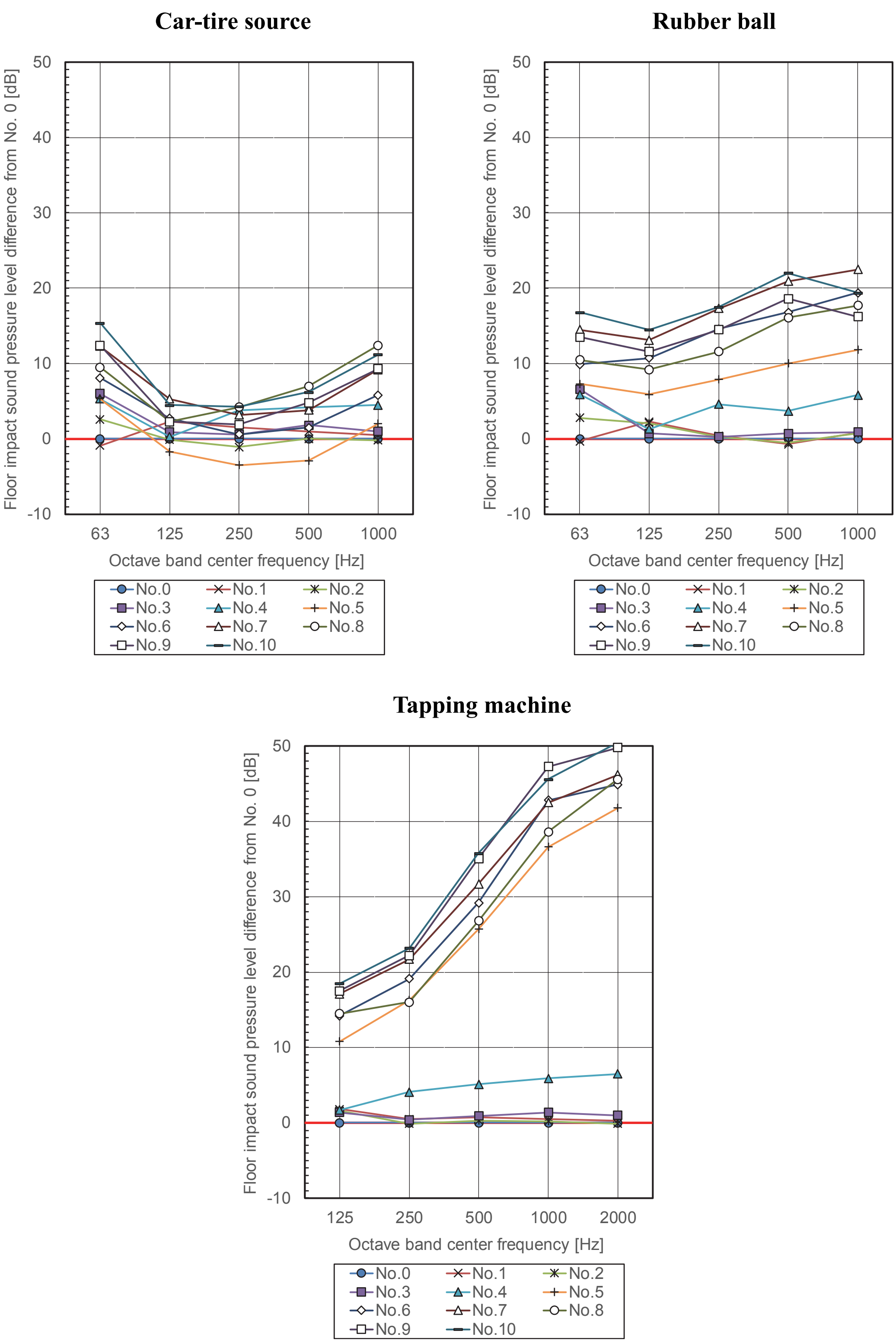


Figure 5 – Improvements of floor impact sound pressure levels from specimen No. 0

In the heavy-weight floor impact sound insulation, we found that there were few level differences in the 63 Hz octave band between car-tire source and rubber ball. In contact, the level differences of the rubber ball were higher than of the car-tire source in the 125 Hz octave band or higher frequency.

There are few changes of the level difference by the damping material (specimen No. 1,2 and 3) in the 125 Hz octave band or high frequency regardless of the floor impact source. The floor impact sound insulations were increased by damping material in the 63 Hz octave band. In addition, an effect of damping material was the highest in specimen No. 3. The differences were 6.0 dB in the case of the car-tire source, and 6.6 dB in the case of the rubber ball.

The value of the effect of the ceiling (specimen No. 4) in all octave bands were approximately 5 dB regardless of the floor impact source. From the above results, the ceiling has the effect on heavy-weight and light-weight floor impact sound insulation of cross laminated timber building.

We found that the effect of the floating floor (specimen No. 5, 6, 7, 8, 9 and 10) on the heavy-weight and the light-weight floor impact sound insulation. Furthermore, the floor impact sound insulation was high by mass on the surface of the floating floor. It was a performance gain of approximately 3 dB a layer in the asphalt sheet in the floor impact sound insulation.

5. CONCLUSIONS

This paper presents the floor impact sound insulation of the 3-story cross laminated timber building for experiments. The results of the floor impact sound insulation suggest the influences of the damping material, ceiling and floating on the floor impact sound insulation of cross laminated timber building. We conclude that the effects on heavy-weight and light-weight floor impact sound insulation by using floating floors for cross laminated timber building. Furthermore, we find that the effect on the floor impact sound insulation due to the topping parts of the floating floor.

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