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KANG, Chun-Won
Department of Housing Environmental Design, College of Human Ecology, Jeonbuk National University

JANG, Sang-Sik
Department of Bio-based Materials, Chungnam National University

HASHITSUME, Kazuharu
Graduate Schools of Education, Shimane University

JANG, Eun-Suk
Research Institute of Human Ecology, College of Human Ecology, Jeonbuk National University

他

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Light–weight Impact Sound Evaluation of CLT Wooden Building Floors

Chun–Won KANG[1,2], Sang–Sik JANG[3], Kazuharu HASHITSUME[4], Eun–Suk JANG[2,5]* and Junji MATSUMURA

Laboratory of Wood Science, Division of Sustainable Bioresources Science,
Department of Agro–envioronmental Sciences, Faculty of Agriculture,
Kyushu University, Fukuoka 819–0395, Japan
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This study evaluated the lightweight impact sound of CLT (Cross Laminated Timber) made of plywood and square timber produced from domestic small–diameter larch wood. According to KS F 2810–1, the light–weight impact sound blocking performance of the CLT was evaluated by excitation with a tapping machine on the second floor and sound collection with a microphone from the lower floor. As a result, the light impact sound was 85 dB. The light impact sound blocking performance was poor, and additional studies are needed to improve the lightweight impact sound of CLT.

Key words: Cross Laminated Timber, CLT, lightweight impact, floor noise

INTRODUCTION

Today, as interest in carbon neutrality has increased, interest in wooden houses is also increasing (Jang, 2022; Ottelin *et al*., 2021). A wooden house has advantages in insulation, earthquake resistance, and appearance. Still, it is inferior to a concrete building in terms of airtightness, moisture change, flame retardancy and noise between floors (Khidmat and Fukuda, 2022).

Common residential types in Korean cities are common housing types such as apartments (Jo and Jeon, 2019; Moon *et al*., 2014). In an apartment, since the upper and lower houses share the floor and ceiling, the noise and vibration of the upper house affect the lower house, which causes disputes between neighbors (Jo and Jeon, 2019). Disputes caused by noise between floors lead individuals to social problems (Kim *et al*., 2019; Yang and Choi, 2019). Recently, due to the spread of telecommuting and home–based classes due to the COVID–19 outbreak, the number of people staying at home is increasing, and complaints about noise between floors are also on the rise (Jang and Kang, 2022).

Therefore, evaluating inter–floor noise in an apartment is the starting point for resolving these disputes. In the case of wooden construction, since wood, which is easy to generate sound, is used as a wall or floor material, the noise between floors in a wooden house is more vulnerable than in a concrete building. However, the reality is that the noise evaluation between floors in wooden houses built in Korea is not being carried out smoothly.

Korean larch accounts for 12% of the country's forest stock and is the second most supplied species after pine. In addition, domestic larch has a higher specific gravity than pine and cypress, flexural and compressive strength about 1.3 times higher than that of pine. It has a longer lifespan as it receives less damage from pests and diseases than other tree species. Therefore, larch is suitable as a building material (Lee *et al*., 2018).

Domestic wood resource supply stability is at stake due to the prolonged COVID–19. Therefore, domestic larch wood as a wooden building material needs to be reviewed again. However, most of the larch grown in Korea is small in diameter and has many defects, so most are used for fuel (firewood, pallets, etc.). Therefore, we thought that using these as the core material of CLT (Cross Laminated Timber) could be a good example for the use of small–diameter, short–scale domestic wood (Kang *et al*., 2019). In wooden construction, CLT structures is a global trend (Cherry *et al*., 2019), and interest in CLT structure construction is increasing in Korea (Choi *et al*., 2018; Jang and Lee, 2019; Kang *et al*., 2019).

Kang *et al*. (2019) analyzed the acoustic characteristics of CLTs with a thickness of 1,100 mm using Korean larch as a core material, and reported that their sound absorption performance was not good (Noise Reduction Coefficient: 0.2). However, the transmission loss was relatively high (45.12 db at 50–1600 Hz), indicating excellent sound insulation performance.

Following our previous research, the current work evaluated light–weight impact sound by manufacturing a kiosk using CLT vertical diaphragm and horizontal diaphragm using domestic plywood as a right–angle plate and using square timber produced from domestic small–diameter larch wood as a yard. Following KS F 2810–1, the lightweight impact sound blocking performance of the CLT was evaluated by excitation with a tapping machine with a two–story floor and sound pickup with a

[1] Department of Housing Environmental Design, College of Human Ecology, Jeonbuk National University, Jeonju 54896, Korea
[2] Research Institute of Human Ecology, College of Human Ecology, Jeonbuk National University, Jeonju 54896, Korea
[3] Department of Bio–based Materials, Chungnam National University, Daejeon 34134, Korea
[4] Graduate Schools of Education, Shimane University, Shimane 690–8504, Japan
[5] Sambo Scientific Co. Ltd, R&D Center, Seoul, 07258, Korea
* Corresponding author (E–mail: esjang@sambosc.com)

microphone from the lower floor.

MATERIALS AND METHODS

Specimen Preparation

Larch logs with a diameter of 120 mm to 150 mm were sawn and dried, and the cross–section was made of a square material of 80 mm × 80 mm. This square timber was bonded to the sides with an acetylated vinyl–based adhesive to form a 1,200 mm × 2,400 mm panel used as the core of the CLT wall panel. CLT wall panels were then fabricated using 18 mm thick structural plywood panels measuring 1,200 mm × 2,400 mm as cross bands covering the surface and back of a small square wood core. A side view of the CLT panel used in this study is shown in Fig. 1. The average apparent density and moisture content of the CLT specimens were 0.5 g/cm^3 and 8%, respectively. Then, as shown in Fig. 2, a simple wooden building was manufactured to measure light impact sound, and CLT was installed.

Light impact sound measurement

We used a tapping machine (model: Nor277, Norsonic, Norway) to measure light impact sound. Excitation points for light impact sound measurement were installed at a distance of 0.5 m from the peripheral wall by KS F 2810–1 (2015) and KS F 2810–2 (2012), including the central point (Fig. 3–a). The microphone locations for light impact sound measurement were five, including the central point, 0.5 m away from the peripheral wall of the room and installed at the height of 1.2 m from the floor (Fig. 3–b). Table 1 shows the analyzers used for noise analysis for this study.

Analysis of the normalized impact sound pressure level

KS F 2863–1 stipulates a method for evaluating floor impact sound blocking performance with a single index from the measurement result of 1/3 or 1/1 octave band according to KS F 2810–1. Based on the values in Table 1, we draw a and then compare it with the measurement result curve. In this study, a 1/1 octave band was used. First, the reference curve is moved up and down in 1 dB intervals compared to the measurement result curve. In the range of 5–octave bands, the sum of the measured values exceeding the reference curve does not exceed 10.0 dB, and the reference curve is moved as far as possible to the position lower than the measurement curve.

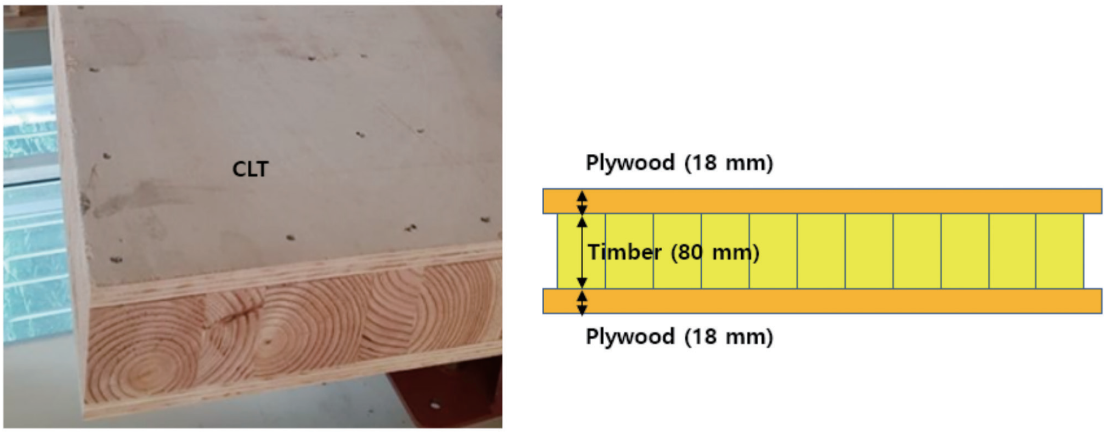


Fig. 1. Schematic diagram of CLT.

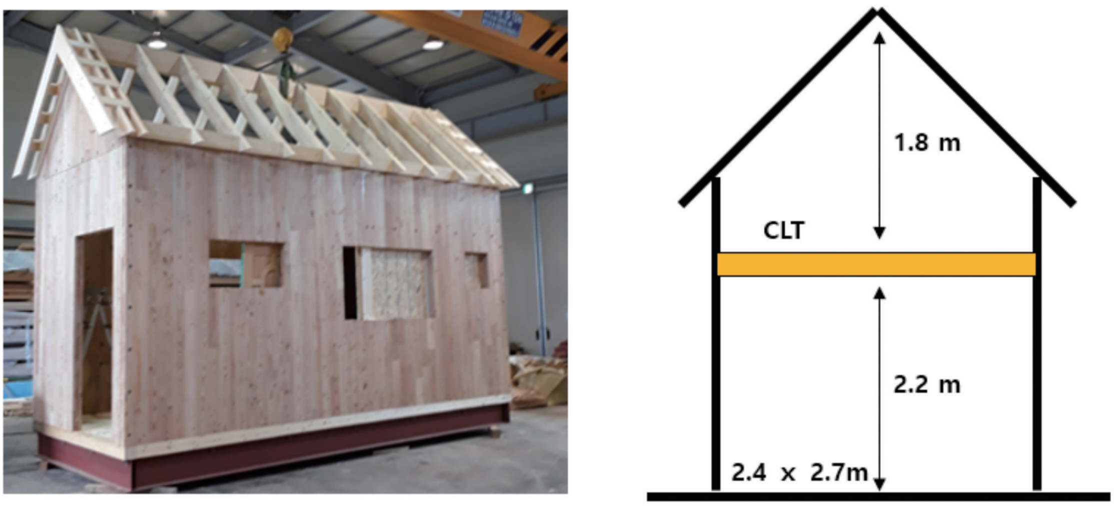
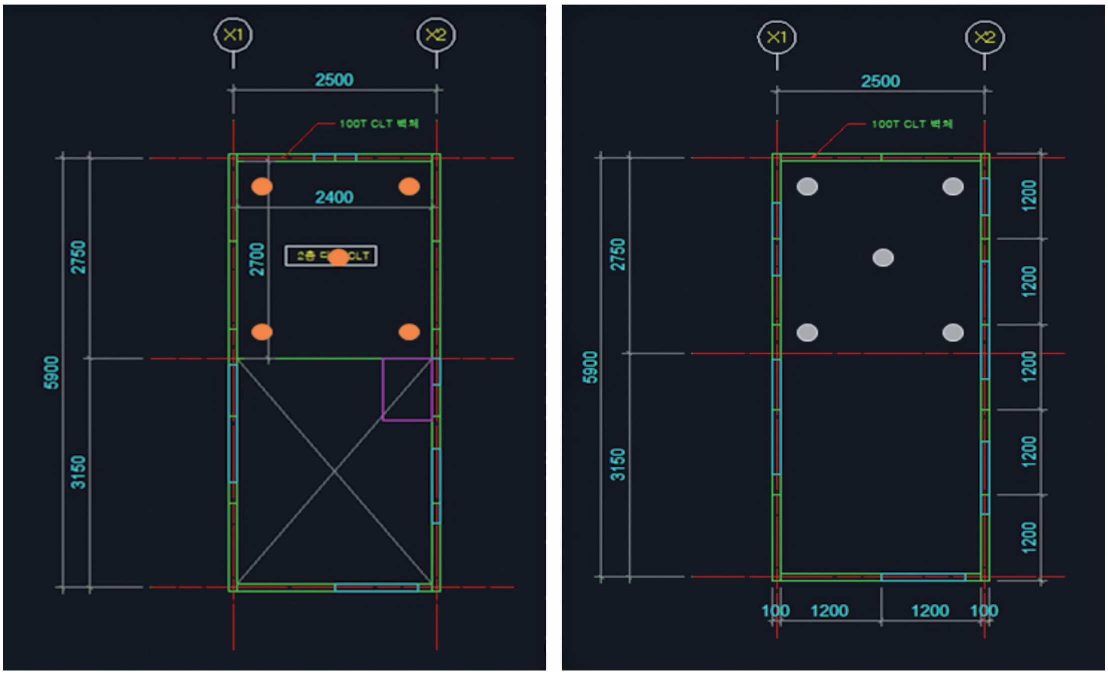


Fig. 2. Temporary wooden building with CLT applied.



(a) Excitation point (b) Measuring point

Fig. 3. Locations of excitation and measurement points.

Table 1. Measuring Equipment for noise analysis

Analyzer	Model	Manufacture	Country
Frequency analyzer	SA–02M	Roin	Japan
Calibrator	Cal 02	01dB	France
1/2“ condenser Microphone	40AF	G.R.A.S	Denmark
1/2“ preamplifier	MA220	NTIM	U.S.A
Power Amplifier	PA1000	FALM	Germany
Non director speaker	DO12	FALM	Germany

Table 2. Reference value of floor impact sound insulation performance (KS F 2863–1)

Frequency (Hz)	Reference value (db)	
	1/3 octave band	1/1 octave band
100	62	
125	62	67
160	62	
200	62	
250	62	67
315	62	
400	61	
500	60	65
630	59	
800	58	
1000	57	62
1250	54	
1600	54	
2000	48	49
2500	45	
3150	42	

Then, the level value (dB) at the 500 Hz band of the reference curve is called the weighted normalized floor impact sound level.

RESULTS AND DISCUSSION

The results of Light impact sound measurement

In this study, after excluding the effect of background noise as much as possible, the evaluation of inter–floor noise by light impact sound was performed. Table 3 shows the results of light impact sound measured with microphones at five locations on the first floor after excitation of the second floor of the simple structure with a light impact sound device.

The floor impact sound level shows 86.5, 91.7, 98.3, 96.3, and 87.0 dB at the octave band's center frequencies of 125, 250, 500, 1000, and 2000 Hz. The power value was comparatively high. This is due to the vibration characteristics of light and strong wood, and it can be understood that sound is easily generated by hitting. The noise generated from the surface layer is transmitted to the lower layer according to the material characteristics. The thicker the slab or, the heavier the weight, the lower the noise transmission to the lower layer. In the case of wood, the lightweight and the thickness of the CLT flooring used in this experiment was relatively thin, about 11.6 cm, so it is thought that the inter–floor noise level due to the light impact sound is significant.

To reduce such noise, it is necessary to use wood species with a low elastic modulus compared to specific gravity and high internal friction. It can also be expedient to use a damping agent to reduce vibration when using CLT as a flooring material. The normalized floor impact sound level was 81.1, 85.1, 90.9, 88.8, and

Table 3. The results of floor impact sound level

Frequency (Hz)	Floor impact sound level (dB)	Normalized floor impact sound level (dB)	Inverse–A (dB)	Upper value of reference curve (dB)
125	86.5	81.1	100	–
250	91.7	85.1	93	–
500	98.3	90.9	87	3.9
1000	96.3	88.8	84	4.8
2000	87	80.4	83	–

80.4 dB at octave band center frequencies of 125, 250, 500, 1000, and 2000 Hz, respectively. Comparing this with the inverse A characteristic screed curve, it fell short of the screed curve at 125, 250, and 2000 Hz but exceeded 3.9 and 4.8 dB at 500 and 1000 Hz, respectively. Indicated. On the other hand, *L*'n, AW = 87 dB, exceeding the recommended value of 58 dB for light impact sound suggested by the Ministry of Construction and Transportation (Seo *et al*., 2019).

CONCLUSIONS

This study was an essential investigation to evaluate the light impact sound level of CLT used in wooden houses. As a result of this experiment, the level of sound insulation improvement for light impact sources of CLT was not good. In the future, we need improvements to absorb light impact sound, such as introducing CLT's core material like wood with a higher specific gravity or installing a vibration damper on the underside of the flooring.

AUTHOR CONTRIBUTIONS

CW Kang: Conceptualization, methodology, experiment, data analysis, SS Jang: Experiment, data analysis, Kazuharu Hashitsume: data analysis, ES Jang: Data analysis, writing original draft, review, and editing, Junji Matsumura: data analysis, and editing. All authors read and approved the final manuscript.

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