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EXPERIMENTAL INVESTIGATION OF VIBRATION PERFORMANCE OF A GLULAM DECK FLOOR SUPPORTED ON GLULAM BEAMS

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ABSTRACT: As mass timber panels gain popularity in mid-rise and high-rise wood structures, ensuring adequate floor vibration performance is crucial for occupancy comfort and work performance. However, current timber floor vibration design methods often assume rigid supports, overlooking the influence of beam flexibility on floor vibrations. Additionally, while concrete topping is commonly used to enhance acoustic and fire performance, its effect on floor vibration remains uncertain. This study examines the dynamic properties, acceleration responses, and vibration performance of a full-scale glulam deck floor through experimental testing, considering the effects of support conditions, non-structural sheathing panels, and concrete topping. The test results were further utilized to evaluate several commonly used floor vibration design methods. The findings highlight the significant influence of support conditions and concrete topping on the vibration performance of mass timber floor systems, emphasizing the need to incorporate these factors into future design approaches. Moreover, the study has revealed limitations in existing vibration design guidelines for such floor systems. The experimental data presented in this research provide valuable insights for the practical design and construction of mass timber floors regarding vibration serviceability performance.

KEYWORDS: vibration performance, mass timber floors, support conditions, concrete topping

1 – INTRODUCTION

Mass timber panels (MTP) are commonly used as primary load-bearing components in mid-rise and high-rise wood structures, including floors, walls, and roofs [1]. However, compared to concrete and steel, MTPs have lower density and bending modulus of elasticity, making them more prone to human-induced vibrations [2], which can affect occupants' comfort and market acceptance. Although ultimate limit state design typically ensures adequate structural capacity, vibration performance often governs the floor span in design [3]. Mass timber floors provide greater design flexibility than conventional concrete and steel floors, allowing for a variety of panel types, material combinations (composite floors), and support configurations [4]. To meet acoustic and fire safety requirements, floating concrete toppings are often applied to mass timber floors. These factors could add complexities in vibration serviceability assessments of mass timber floors, posing challenges in the design process.

Current floor vibration design methods for mass timber floors can be broadly categorized into two types: acceptability-based and perception-based methods [6]. Acceptability-based methods link the floor vibration acceptability to its performance indicators, such as static deflection and fundamental natural frequency, through both physical testing and subjective evaluations, like the vibration-controlled span method in CSA O86-2024 [7]. Perception-based methods are based on human perception of vertical vibrations and empirical response factors with acceleration levels as the sole performance indicator [8]. Examples of such methods include the American steel design method (AISC DG11-2016) [9] and the concrete design method (CCIP-016-2006) [10], which are included in the US Mass Timber Vibration Design Guide [11]. The draft Eurocode 5 (prEurocode5) [12] proposes a modified timber floor vibration design procedure based on fundamental natural frequencies,

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static deflection, and response factors for acceleration, which can be chosen according to the designer's expectations.

However, the rapid development of mass timber floors over the past few decades has made it challenging to account for the variations in structural types and materials within existing design methods. For instance, the applicability of CSA O86-24 [7] is limited to mass timber floors only with rigid simple supports, and the design criteria in perception-based methods are often adapted from research on steel and concrete floors with resonant response [9-10]. As a result, it has been reported that current design methods are inadequate in predicting design parameters and assessing human acceptability of vibration in mass timber floors for different occupancy categories [6,13,14]. Additionally, there is a significant lack of experimental data specific to mass timber floors, hindering the validation of these methods and the development of tailored design criteria. Therefore, more experimental investigations are needed to refine and develop vibration design methods for mass timber floors.

In this study, a full-scale glulam deck floor supported by glulam beams was constructed in the laboratory and tested to evaluate its dynamic properties and vibration performance through testing and subjective evaluations. The study also investigated the effects of sheathing panels and floating concrete toppings on the floor's vibration behavior at different test phases. Additionally, several current mass timber floor vibration design methods were evaluated based on the experimental results and subjective assessments to determine their applicability to beam-supported floor systems. The findings from these tests provided valuable insights for the verification of the floor systems for a 14-storey mass timber building under construction in Toronto, Canada, which is expected to become one of North America's tallest wood buildings.

2 – MATERIALS AND METHODS

2.1 MATERIALS

A full-scale floor mock-up was constructed using glue laminated timber (GLT) deck panels (Fig. 1a) supported by glulam beams (Fig. 1b). The Douglas Fir glulam beams (24f-E), measuring 365 mm × 1026 mm were designed with a fire resistance rating of 2 hours. The GLT deck panel, made from #2 and better grade Spruce-Pine lumber, was 175 mm thick and spanned a distance of 16.3 m.

The mock-up floor (Fig. 1c) consisted of twelve 610 mm wide GLT deck panels and four glulam beams, with a total of three spans, each measuring 5.3 m. The moisture content of the materials was measured as approximately 13%. The dimensions of the components and the floor system are provided in Table 1. In the mock-up specimen, the ends of the glulam beams were supported on two deep glulam beams, which were anchored to the warehouse floor using custom-made steel brackets, ASSY self-tapping screws, and post-installed anchor bolts. The GLT deck panels were fastened to the supporting glulam beams using 0.276" × 12" SDWH Timber Hex screws by *Simpson Strong-Tie*, spaced at 203 mm on center (O.C.).

To simulate construction details, the GLT deck was sheathed with 12.7 mm thick, 1.22 m × 2.44 m square-edged plywood panels. The plywood sheathing panels were secured to the GLT deck using WSV Subfloor Screws (#9 × 2.5" by *Simpson Strong-Tie*) at 76 mm O.C. along the plywood edges and 305 mm O.C. along interior lines at 0.61 m intervals. Additionally, 12 mm thick felt mats and a 38 mm thick concrete topping, composed of discreate concrete paver blocks measuring 38 mm × 0.61 m × 0.61 m, were placed on top of the GLT deck panels without screws. A 10 mm gap was maintained around each block to prevent unintentional damping from friction between the blocks. This construction method simplified laboratory setup and allowed for the reuse of the glulam beams and deck panels but resulted in conservative outcomes due to the negligible stiffness contribution from the blocks compared to a continuous concrete topping used in construction.

Table 1. Detailed dimensions of test specimens

Specimen	Thickness (m)	Width (m)	Span (m)	Number
GLT deck panel	0.175	1.216	16.3	12
Glulam beam	1.026	0.365	14.8	4
Floor	/	14.8	15.9 (5.3 per span)	1

2.2 METHODS

2.2.1 Experimental Modal Testing

To determine the modal properties including natural frequencies, mode shapes, and damping ratios of the panels, beams, and floor specimen, instrumented impact hammer tests were conducted. The GLT deck panels were tested with two edges in the minor strength direction simply supported on two glulam beams resting on the

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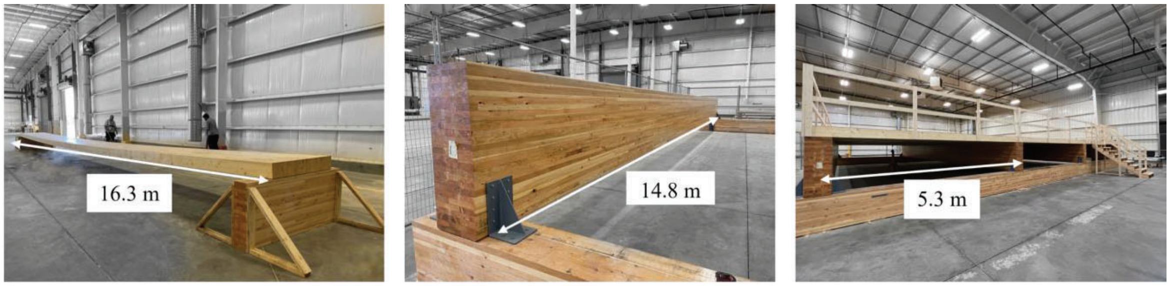

(a) Glulam Deck Floor Panel (b) Glulam Beam (c) Full-scale floor

Figure 1. Photos of test specimens

ground floor, as shown in Fig. 1a. The supporting glulam beams were tested while connected to the deep beams resting on the ground floor, as depicted in Fig. 1b.

Roving hammer tests were performed with accelerometers positioned on the floor, as illustrated in Fig. 2. A total of five accelerometers, each with a nominal sensitivity of 10 mV/g, were mounted on the test specimen surfaces using hot melt glue as the red dots in Fig. 2. The modal analysis was conducted in BK Connect software to determine the dynamic properties of each specimen.

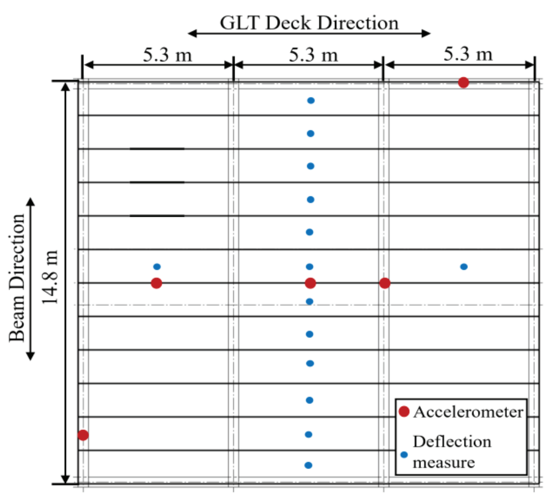

Figure 2. Locations of accelerometers in the modal test and locations of deflection measurements

2.2.2 Floor Vibration Response Tests

After the modal tests, floor vibration response tests were conducted on the full-scale floor system following ISO 10137 [8] and ISO 18324 [15] to evaluate acceleration levels under normal human walking. These acceleration levels are critical indicators of floor vibration performance in many current design standards, including AISC DG11-2016 [9] and Eurocode 5 [12].

The walking tests were performed by a 100-kg male evaluator along six different paths, with walking frequencies of 1.6, 1.8, 2.0, and 2.2 Hz, as shown in Fig. 3. Acceleration responses were measured at specific locations on the floor surface, where the maximum response was expected under the walking path.

It is important to note that ISO 10137 [8] does not provide explicit guidelines for collecting and post-processing acceleration data. Therefore, the time-domain acceleration data for the entire walking path was post - processed following ISO 2631 [16]. To obtain the acceleration values from the frequency-weighted floor acceleration-time response, a weighting curve denoted as W_m, as proposed in ISO 2631, was applied in the calculation process. Equation (1) provides the expression for calculating the frequency-weighted root-mean-square (RMS) acceleration, a_w, of a vibration signal:

$$a_w = \left[\frac{1}{T}\int_0^T a_w^2(t)dt\right]^{\frac{1}{2}} \tag{1}$$

where $a_w(t)$ is the frequency-weighted acceleration as a function of time in m/s^2, and T is the duration of the signal in s. In this study, the duration of the whole walking path was considered for calculating the acceleration values.

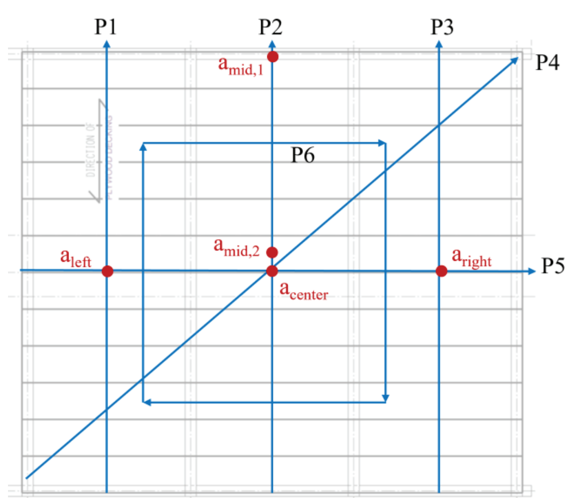

Figure 3. Walking paths and accelerometers' locations

2.2.3 Deflection Measurements

In addition to the vibration tests, static deflection tests were conducted in accordance with ISO 18324 [15]. A 1 kN point load, equivalent to a 100 kg person, was applied at the center of the floor to evaluate its static deflection. The deflection was measured using a single dial gauge with a precision of 0.01 mm, positioned at the midspan directly beneath the loading point.

Since the floor was constructed with 12 individual GLT deck panels, the load was applied at the center of each panel in the middle bay, and the deflection was measured separately for each. Additionally, deflection measurements were taken in the left and right spans under the 6th GLT deck panel. The loading and measurement locations are shown in Fig. 2 as blue dots.

2.2.4 Subjective Evaluation

Subjective evaluations were conducted to assess the acceptance level of the floor specimens based on ISO/TR 21136 [17], which ranks floor acceptance from 1 (definitely unacceptable) to 5 (definitely acceptable). A survey involving approximately 10 evaluators was conducted on the mock-up floor to gather perception and acceptability of floor vibrations.

Each evaluator first walked along the centerline of the floor in the length direction. They were then instructed to stand stationary and sit on a chair at the center of the floor while a 100-kg walker, identical to the one used in the vibration response test, moved along designated walking paths. An example of the evaluation process is shown in Fig. 4. The evaluators completed a questionnaire based on ISO/TR 21136, addressing their perception and acceptability of vibration levels. The key questions focused on whether the evaluators felt excessive vibrations while walking, sitting, or standing and whether they found the vibrations acceptable. Additionally, they were asked to rate the overall performance of the floor for residential and office use. The individual ratings from each evaluator were averaged to determine the final acceptance level of the floor specimens.

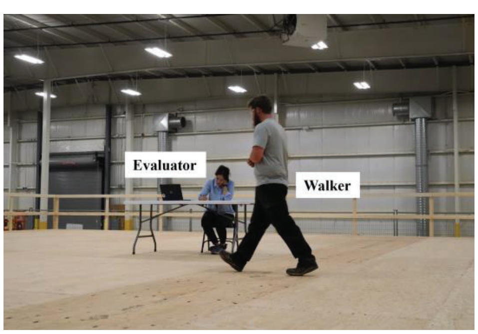

Figure 4. Subjective evaluation

2.3 TEST PHASES

Table 2 summarizes all the sequential testing phases of this study.

Table 2. Experimental test phases

Test Phase	Specimens
Preliminary	Component test (GTL deck panel, Glulam beam)
1	GTL deck floor + Glulam beams
2	GTL deck floor + Glulam beams + Plywood sheathing
3	GTL deck floor + Glulam beams + Plywood sheathing + Acoustic mat + Concrete blocks topping

The preliminary step involved conducting modal tests on the components separately. In Phase 1, modal tests were performed on the floor constructed with the GLT deck and glulam beams, along with deflection measurements. In Phases 2 and 3, as plywood sheathing panels and concrete topping were added, modal tests and deflection measurements were repeated. Additionally, subjective evaluations and performance tests for acceleration levels were conducted.

3 – RESULTS AND DISCUSSION

3.1 DYNAMIC PROPERTIES

The dynamic properties, including selected natural frequencies and average damping ratios, are summarized in Table 3 for the GLT deck panels, glulam beams, and the floor system with different assemblies.

The fundamental natural frequency is a critical vibration performance indicator and is incorporated into nearly all current floor vibration design methods. The measured natural frequencies of the components can be used to determine their elastic constants based on the method proposed by Zhou et al. [18]. Some vibration design standards, such as AISC DG11-2016 and Eurocode 5, recommend using the individual fundamental frequencies of the floor panels and supporting beams to estimate the fundamental frequency of the whole beam-supported floor system. However, the applicability of these approaches has not been extensively validated experimentally and was found to be insufficient in previous research [19].

For the full-scale floor system, modal testing was performed in all phases to assess changes in dynamic properties. Since no tests were conducted on the floor with rigid supports for reference, the fundamental natural frequency was estimated using a commonly adopted

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equation for simply supported floors. This calculation was based on the measured modulus of elasticity and density of the deck panels, the equation is shown in the following:

$$f = \frac{\pi}{2l^2}\sqrt{\frac{EI}{m}} \tag{2}$$

where l is the span, m; EI is the bending stiffness, N·m^2; and m is the mass per unit length, kg/m.

Based on the theoretical calculation, the glulam deck floor panel with a single span of 5.3 m and rigid simple supports is expected to have a fundamental natural frequency of approximately 13.7 Hz. However, experimental measurements in Phase 1 indicated a significantly lower frequency of 6.3 Hz for the bare floor. The addition of plywood sheathing, which provided lateral connectivity between individual GLT deck panels, resulted in a slight increase to 6.5 Hz. The transition from rigid supports to beam supports led to a substantial 50% reduction in the fundamental natural frequency. When concrete blocks were installed, the fundamental natural frequency dropped to 5.1 Hz. The placement of the discrete concrete blocks introduced additional mass to the floor system but negligible stiffness, leading to the decrease on the fundamental natural frequency.

Table 3. Dynamic properties of test specimens

Specimen	f_1 (Hz)	f_2 (Hz)	f_3 (Hz)	Damping (%)
Deck panel[1]	1.5	8.6	86.7	4.0
Beam	10.8	35.1	61.3	3.4
Phase 1	6.3	7.1	8.7	4.1
Phase 2	6.5	7.4	9.1	4.3
Phase 3	5.1	5.7	7.2	4.7

[1] The three frequencies showed for the deck panels are f_{20}, f_{21} and f_{22}
[2] The fundamental natural frequency of the floor with rigid supports was calculated as 13.7 Hz by Eq.2, assuming floor span=5.3 m

The damping ratios indicate the system's ability to dissipate energy and were determined by averaging the individual damping ratios from the three selected modes. Across all phases, the damping ratios ranged from 4.1% to 4.7%.

The first three corresponding mode shapes for the floor system in Phases 1–3 are shown in Fig. 5. In all phases, the floor exhibited the first bending mode along the glulam beam direction and then second and third bending modes along the GLT deck panel direction. The addition of plywood sheathing and concrete topping did not alter the mode shapes but resulted in a more uniform vibration response. These non-structural components helped integrate the individual GLT deck panels into a single surface, reducing localized vibrations.

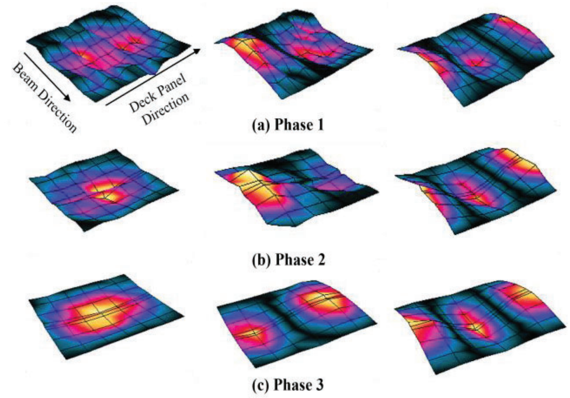

Figure 5. First three mode shapes for the floor system in different phases

3.2 DEFLECTION

Deflection under a 1 kN point load is often used as an important indicator in vibration design of timber floors, as specified in standards such as CSA 086 [7] and Eurocode 5 [12], as it relates directly to the stiffness of the floor system. The deflection of the floor system under a 1 kN point load was measured in all phases, with various measurement locations. The results are summarized in Fig. 6.

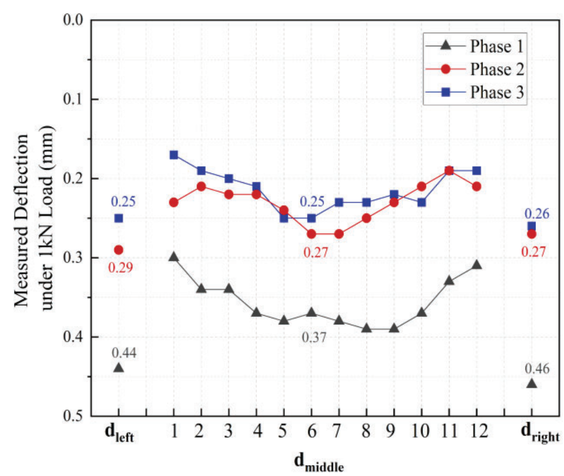

Figure 6. Measured 1kN deflection in different locations

It can be observed that the measured deflections varied in this beam-supported floor system due to the different locations of the deck panels on the supporting beams, which led to slightly different results. Specifically, the 6th and 7th panels exhibited the highest deflection under the same load, as they were positioned at the midspan of the supporting beam, where deflection is greatest. Additionally, in this multi-span floor, the left and right spans tended to exhibit higher deflection values compared to the middle span. The addition of plywood sheathing in Phase 2 reduced the deflection by 30%, as it connected the deck panels, facilitating panel-to-panel load sharing between adjacent panels. While the addition of the concrete blocks had a minor effect on the deflection, as they were not connected to the floor panel but simply placed on top, contributing little stiffness to the floor system.

3.3 ACCELERATION RESPONSES

Acceleration responses are the most commonly used vibration performance indicator in steel and concrete floor vibration design guides [9,10]. These guides typically provide equations for calculating acceleration as a design parameter and specify different limits based on floor occupancy, which are then compared with the calculated values. In both Phases 2 and 3, the floor system's acceleration responses under normal human walking were recorded and processed. The weighted RMS and peak acceleration values for both phases, measured at different walking frequencies, are summarized in Table 4, with the maximum values selected from all walking paths.

In this study, the measured RMS and peak acceleration values for Phase 2 were largely unaffected by the varying walking frequencies, with the RMS acceleration values remaining similar. However, for Phase 3, where the system's fundamental natural frequency was 5.1 Hz, increasing the walking frequency from 1.6 to 2.2 Hz appeared to enhance the resonance of the floor, leading to an increase in acceleration values. The peak acceleration can be significantly influenced by factors such as the walker's weight, walking path, floor boundary conditions, and random disturbances from a single excitation. These variables highlight the challenges in accurately predicting or measuring acceleration and using these values to assess the floor's vibration performance.

Table 4. Frequency weighted acceleration levels under different walking frequencies

Test Phase	Acceleration	Walking Frequency (Hz)			
		1.6	1.8	2.0	2.2
Phase 2	a_w (m/s^2)	0.039	0.039	0.034	0.036
	$a_{w,Peak}$ (m/s^2)	0.146	0.194	0.160	0.203
Phase 3	a_w (m/s^2)	0.021	0.036	0.040	0.047
	$a_{w,Peak}$ (m/s^2)	0.148	0.195	0.240	0.318

The time history of the acceleration measured at the geometric center and its corresponding frequency spectrum for both Phases 2 and 3 are shown in Fig. 7. It can be observed that in both phases, the floor exhibited a response closer to resonance. From the frequency spectrum, similar fundamental natural frequency values were identified, which align with those obtained from the modal tests. In both phases, the fundamental natural frequency values were found to be lower than 8 Hz, which is often considered the cut-off point for distinguishing between resonant and transient floor vibrations.

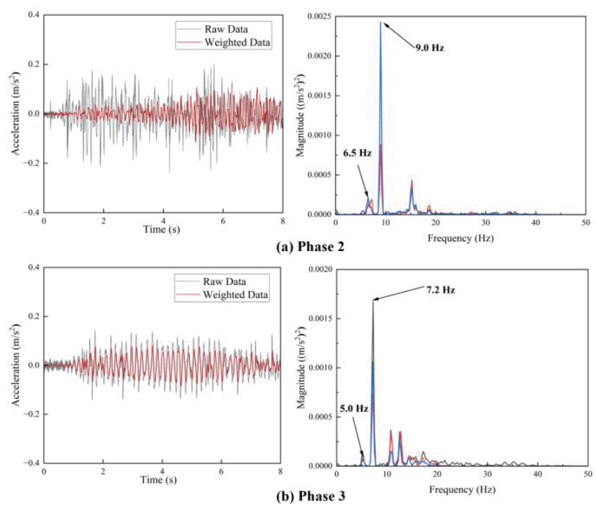

Figure 7. Time history of acceleration and frequency spectrum for the floor in each phase

3.4 VIBRATION SERVICEABILITY PERFORMANCE

The subjective evaluations for Phases 2 and 3 are summarized in Table 5. For the floor in Phase 2 (bare floor with plywood sheathing), evaluators reported not feeling any vibration while walking on the floor by themselves. However, most reported a high level of vibration when standing or sitting on the floor while others were walking, with some evaluators unable to accept the vibration for use in residential or office buildings. The average rating for the floor in Phase 2 was classified as marginal. In Phase 3 (with concrete topping), evaluators did not feel any vibration either while walking on the floor or when others were walking, and all evaluators rated it as acceptable.

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Table 5. Subjective evaluation results

Test Phase	Mean	Minimum	Maximum	COV
Phase 2	3.2 (Marginal)	2	5	30.0%
Phase 3	4.6 (Acceptable)	4	5	9.1%

The subjective evaluation results indicate that the addition of concrete toppings improved the floor system's vibration performance from marginal to definitely acceptable. In this study, although the deflection under a 1 kN load and the RMS and peak acceleration values remained similar between the phases 2 and 3, the fundamental natural frequency of the floor system decreased by 22%. Since the floor exhibited resonant behavior in both phases, the added concrete blocks contributed additional mass and damping, significantly improving the vibration performance of this floor system.

Additionally, the effect of the support conditions on the floor's vibration performance remains uncertain, as no tests were conducted on the floor with rigid wall supports in this research. Previous research by the authors [19] suggests that supporting beams, when adhering to design requirements, may still have a significantly negative impact on the floor's vibration performance compared to the same floor with rigid wall supports.

4 – ASSESSMENT OF CURRENT DESIGN METHODS

To assess the applicability of current design methods, this section presented the comparison between design results according to selected methods with the results obtained from experimental tests and subjective evaluations.

4.1 CSA O86-24

According to CSA O86-24 [7], vibration-controlled span equations are used for vibration design of wood floors. The vibration-controlled span method was originally developed based on the logistic regression using fundamental natural frequency and 1-kN deflection as performance parameters for light frame wood joist floors. For a simply supported CLT floor without any topping, the vibration-controlled span can be determined as

$$l_v \leq 0.11 \frac{\left(\frac{(EI_{1m})}{10^6}\right)^{0.29}}{m^{0.12}} \tag{3}$$

where l is the floor span, m; EI_{1m} is the bending stiffness of the 1-meter-wide floor, N·mm^2; l_v = vibration-controlled span limit, m; m = linear mass of CLT for a 1-meter-wide panel, kg/m.

It should be noted that Equation (3) cannot be applied to the vibration design of the beam-supported floor system with a concrete topping investigated in this study. If applying (3), the floor system in this study would have a maximum allowable span of 5.6 m, which could further increase by 20% for a multi-span configuration. However, the observed vibration performance in Phase 2, where the bare floor with a shorter span of 5.3 m, demonstrated only marginal acceptability.

Experimental test results and analytical calculations indicate that the beam-supported condition significantly influences the fundamental natural frequencies of the floor system. Furthermore, the flexibility of the supporting beams negatively impacts the panel's deflection. These findings suggest that the application of the current vibration-controlled span equation in CSA O86 for such floor systems requires further investigation.

4.2 AISC DG11-16

The second method selected for evaluation is the AISC DG11-16 [9] design guide, as recommended by the US Mass Timber Floor Vibration Design Guide [11]. This method provides a peak acceleration criterion derived from the ISO 10137 [8] baseline curve for RMS acceleration and employs 9.0 Hz as a cut-off point for the fundamental natural frequency. For floors with low frequencies, the peak acceleration is calculated as Equation (4), while for high-frequency floors, the equivalent sinusoidal peak acceleration is derived and calculated following Equation (5). The resulting peak acceleration value is then compared with the specified acceleration limitation.

$$a_p = \frac{P_0 e^{-0.35 f_n}}{\beta W} g \tag{4}$$

$$a_{ESPA} = g\left(\frac{154}{W}\right)\left(\frac{f_{step}^{1.43}}{f_n^{0.3}}\right)\sqrt{\frac{1 - e^{-4\pi h_{step}\beta}}{h_{step}\pi\beta}} \tag{5}$$

where P_0 is the amplitude of the driving force, constant force of 65 lb (29.5 kg) for floors; β is the damping ratio; f_n is the floor's fundamental natural frequency, Hz; f_{step} is the step frequency, Hz; W is the effective weight of the floor, kg; h_{step} is the step frequency harmonic matching the natural frequency.

The calculated natural frequencies and accelerations are summarized in Table 6. The calculated fundamental natural frequency of this beam-supported floor is 8.6 Hz and decreases to 7.2 Hz with the addition of concrete blocks (assuming they contribute only additional mass), which falls below the 9.0 Hz cut-off point. Consequently, the peak accelerations were calculated using Equation (4), yielding values of 0.086 m/s² and 0.081 m/s², respectively, compared to the 0.05 m/s² limitation specified for quite areas in offices and residences in the design guide. This comparison suggests that the floor would not meet the required acceptable vibration performance in both the bare floor and concrete topping phases. However, experimental tests demonstrated that the floor exhibited marginal performance in the bare floor condition and acceptable vibration performance once the concrete topping was applied.

The measured peak accelerations were also included in Table 6. In both Phase 2 and Phase 3, the measured peak acceleration was three to four times higher than the suggested limitation, yet the floor still exhibited marginal to acceptable vibration performance. Additionally, it was observed that the calculated accelerations for both phases were two to three times lower than the measured data, and the calculated fundamental natural frequencies following the design guide were approximately 30% higher than the actual test data. These discrepancies indicate that the equations in AISC DG11 for predicting the required design parameters may not be fully sufficient and require further refinement to improve accuracy.

Table 6. Design parameters calculated by AISC DG11-2016

Phase	Results	f_1 (Hz)	a_{Peak} (m/s²)
2	Calculation	8.6	0.086
	Experimental Results	6.5	0.160
3	Calculation	7.2	0.081
	Experimental Results	5.1	0.240

4.3 prEurocode 5

The prEurocode 5 [12] method involves checking three main parameters for timber floor vibration design. First, the floor must meet a stiffness criterion, which includes checking the deflection under a 1 kN point load. Next, the floor's fundamental natural frequency is calculated, and it should exceed 4.5 Hz. The third step involves classifying the floor into two categories based on its fundamental natural frequency, with a threshold of 8 Hz. For floors with a frequency less than 8 Hz, the RMS acceleration must be greater than 0.005R, where R is the response factor. For floors with a fundamental frequency equal to or greater than 8 Hz, the RMS velocity should exceed 0.0001R. Different response factors are provided in this method to account for various building use categories and performance levels. The flowchart depicting this design guide is illustrated in Fig.8.

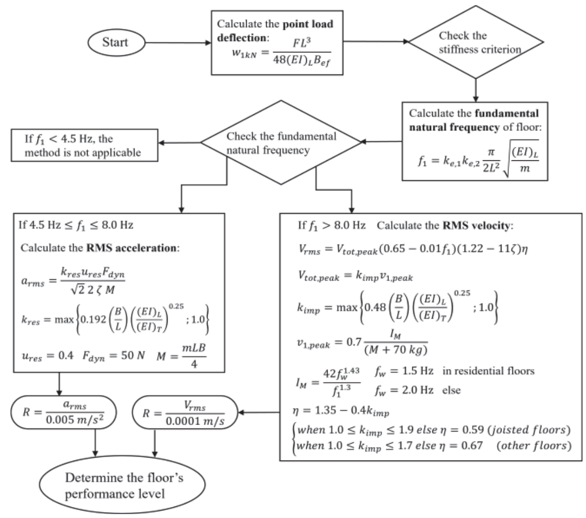

Figure 8. Flow chart of the floor vibration design guide in prEurocode 5

According to this procedure, the required design parameters for the floor in both phases were calculated, and the results are summarized in Table 7. The bare floor was estimated to have a fundamental natural frequency of 9.6 Hz, classifying it as a high-frequency floor, and the RMS velocity was then computed. Based on these parameters, this floor was categorized as a Level 5 floor, which corresponds to the economy choice (lowest performance level) for multi-family residential or office buildings, based on the provided criteria. With the addition of a concrete topping in Phase 3, the floor was calculated to be a Level 3 floor, which typically corresponds to the quality choice (highest performance level) for all occupancies, based on the same criteria. Experimental results, as presented in Table 7, indicate that using the measured data, the floor can be classified as a Level 3 floor in both phases. This classification suggests that the floor meets the quality choice standards for all types of occupancy.

Table 7. Design parameters calculated by prEurocode 5

Phase	Results	d_{1kN} (mm)	f_1 (Hz)	a_{RMS} (m/s²)	R	Level
2	Calculation	0.36	9.6	0.002[1]	22.0	5
	Experimental Results	0.27	6.5	0.034	6.8	3
3	Calculation	0.36	7.8	0.049	9.9	3
	Experimental Results	0.25	5.1	0.040	8.0	3

[1] This value is V_{RMS} (m/s) since the it's a high-frequency floor based on calculation

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The floor showed marginal and acceptable vibration performance in Phase 2 and Phase 3 in the subjective evaluation, suggesting that this design guide appears to be effective in predicting vibration performance. However, it is important to note that the calculated fundamental natural frequencies using the equations in this design guide were approximately 50% higher than the measured values. This discrepancy could lead to different classifications of the floor, highlighting the limitations of this design guide.

5 – CONCLUSION

In this study, modal tests, vibration response tests, and subjective evaluations were conducted on a full-scale glulam deck floor supported by glulam beams. The effects of support conditions, plywood sheathing, and concrete toppings on the floor's vibration performance were systematically examined. Additionally, the applicability of several floor vibration design methods was assessed. Based on the findings, the following conclusions can be drawn:

1. The support conditions have a significant effect on the floor system's fundamental natural frequency, which can decrease by 50% when transitioning from rigid supports to beam supports. This change alters the floor's behavior from a transient floor to a resonant floor.
2. The concrete topping had a slight effect on the measured static deflection and acceleration levels but reduced the floor's fundamental natural frequency by 20%. Additionally, it significantly improved the floor's vibration performance from marginal to acceptable.
3. The current commonly used mass timber floor vibration design methods were found to be insufficient for designing beam-supported mass timber floors. These methods either proved to be not applicable to such floor systems or were too conservative in their design approach. Additionally, the predicted design parameters showed significant discrepancies when compared to the measured results.

This research has provided experimental data for beam-supported mass timber floors and examines the effects of support conditions and non-structural components on their vibration performance, highlighting inconsistencies in current design methods. To further understand the dynamic properties and vibration behavior of mass timber floors, it is essential to gather data from field tests and occupant surveys to create an international database for researchers and practitioners. Additionally, there is an urgent need to improve or develop floor vibration design methods that can account for the variations affecting mass timber floor vibrations, as well as establish criteria specifically tailored to these floors.

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