

NOISE AND VIBRATION CONTROL OF LIGHT FRAME WOOD JOIST FLOORS TOPPED WITH CONCRETE

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ABSTRACT: Light frame wood joist floors have poor sound insulation because of their lightweight nature. The popular solution to the noise transmission problem is to float a 38mm or thicker cementitious topping over them. Although this solution efficiently improves sound insulation of light frame floors, it makes normal walk-induced vibrations more perceivable than with the floors without the topping. Currently, more than half of the housing market in Canada is multi-family buildings. As more multi-family light frame wood buildings are being built, we have been receiving more complaints about excessive feelable vibrations through concrete topped wood joist floors. This paper explains the myths behind this phenomenon, and more importantly sheds light on available solutions.

KEYWORDS: Light frame, multi-family building, wood joist floor, concrete topping, noise control, vibration control

1 INTRODUCTION

Wood joist floors have poor sound insulation. Solutions have been developed to address noise transmission issues in the wood joist floors. The well adopted solution is to float a 38mm or thicker concrete topping on wood joist floors. On other hand, there is an increased number of complains about excessive feelable vibrations in wood joist floors topped with concrete have been received. Conventional design methods in codes and literatures attempt to control wood joist floor vibration through controlling stiffness of a wood joist floor. However, they have failed to control vibrations of concrete topped wood joist floors. It indicates that using stiffness alone to control the vibration of light frame wood floors topped with a heavy topping is not adequate. Considering the additional significant mass of the heavy topping, a new design methodology should include stiffness and mass, and is needed to control the vibrations of wood joist floors topped with heavy topping. This paper first briefly summarizes the noise control methods for wood joist floors, and then describes the new design method to control vibrations of wood joist floors topped with heavy topping.

2 WOOD JOIST FLOORS

Conventional North American wood joist floors are built with wood joists at a spacing of 400, 500 or 600 mm. The

joists are connected to a 15mm-18mm thick wood composite panels using nails or screws; or nails or screws along with glue. They are light. The mass of the base floor ranges between 15-20 kg/m². Various types of toppings and ceilings are used in multi-family wood joist floors.

3 NOISE CONTROL

Numerous studies have been conducted around the world to develop solutions to control noise transmission through light frame floors. The Institute for Research in Construction (IRC) tested many hundreds of such floors and the results were implemented into National Building Code of Canada (NBCC) [1]. It has been found that lack of sufficient mass is the major cause for the poor sound insulation of light frame floors. Logically, mass has to be added to the light frame floors to achieve satisfactory sound insulation of light frame floors. Therefore, adding a 38mm or thicker floating concrete topping to light frame wood floors has become a popular practice.

4 VIBRATION CONTROL

A number of complaints about excessive vibrations in wood joist floors with concrete topping were received. Investigation found that adding a heavy topping such as a 38mm concrete topping around 80kg/m² significantly reduced the floor's fundamental natural frequency, which made the floor vibration more perceivable than that of the floors before the topping was added. A series of tests and subjective evaluations conducted by Taylor and Hua [2] proved these observations. They found that heavy topping mass significantly affected the vibration of the light frame

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wood floors, reduced the vibration performance, and recommended to reduce the spans when the wood joist floor was topped with a heavy topping. More than 10 years of floor research at FPInnovations further concluded that besides stiffness, mass is also a significant parameter that should be involved in floor vibration controlled design [3]. These findings explained why the current design methods for controlling vibrations of light frame wood floors have failed to control vibrations of light frame wood floors with heavy topping.

A research project was conducted at FPInnovations to develop vibration controlled design method for wood joist floors with heavy topping. Across Canada field surveys and measurements were conducted on hundreds of wood joist floors with and without various toppings. A simple design method was developed using stiffness and mass as the design parameters for controlling vibrations of wood joist floors with a broad range of construction details including various toppings.

The design method consists of a design criterion and a series of equations to calculate the criterion parameters.

The design criterion uses frequency and static deflection of a T-beam as parameters. The T-beam includes the joist, sub-floor and topping strip with the width of the joist spacing. The criterion can be expressed by Equation 1 below:

$$\frac{f}{d_{1kN}^{0.46}} \geq 20.00 \quad (1)$$

where: f = calculated frequency of simply supported T-beam (Hz);
 d_{1kN} = calculated mid-span deflection of the simply supported T-beam under a 1kN-point load at the centre of the T-beam (mm), see reference [4] for the calculations.

The equations to calculate the T-beam fundamental natural frequency and the mid-span deflection can be found in FPInnovations report [4].

A simple equation to calculate the vibration controlled spans, l of wood joist floors was derived from the design method and is given below.

$$l \leq \frac{1}{8.22} \frac{(EI_{eff})^{0.284}}{F_{scl}^{0.14} m_L^{0.15}} \quad (2)$$

where: EI_{eff} = effective composite bending stiffness of the T-beam ($N \cdot m^2$)
 m_L = mass per length of the T-beam (kg/m),
 F_{scl} = factor related to lateral stiffness contribution from subfloor and topping, see reference [4] for their calculations.

The design method was verified using 102 wood joist floors with and without toppings including field floors and full-scale floors built in various laboratories.

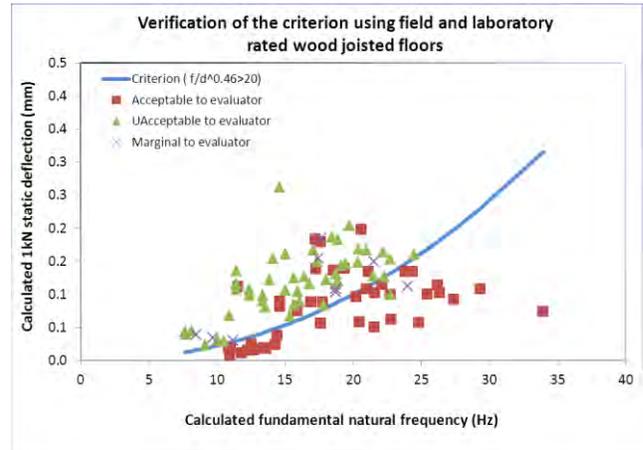


Figure 1: Predicted vibration performance of floors using proposed design method vs. subjective rating by the evaluators.

In Figure 1 above, each symbol represents a floor that was rated by the evaluator. The curve represents the design criterion defined by Equation 1. If the symbol is located below the curve, it means that the floor vibration performance is satisfactory according to the criterion and vice versa. The plot clearly demonstrates the reliability of the proposed design method for the joisted floors based on the field tests.

5 CONCLUSION

Through proper design and construction, the noise transmission and vibration problems of light frame wood floors can be solved efficiently.

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