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To cite this article: NH Abd Ghafar and N M Sahban 2017 IOP Conf. Ser.: Mater. Sci. Eng. 271 012096

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Modelling of concrete topping thickness effects on the vibration behaviour for lvl-concrete composite floor (LCC)

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Abstract. This research was conducted on 2 m LVL - concrete composite (LCC) floor consisting of two parts between concrete floor and laminated veneer lumber (LVL) timber joist. The floor system was model using SAP 2000 software package. The aim of this research to study the vibration behaviour of the LCC floor with different concrete topping thickness which 25 mm, 65 mm and from 20 mm until 200 mm in every 20 mm interval. Natural frequency decision produced through SAP 2000 in thickness 25 mm and 65 mm is 57.45 Hz and 57.19 Hz. In thickness from 20 mm until 200 mm interval, optimum value which found is during thickness reach 65 mm. For concrete topping below 65 mm thickness, the mass will be domain the behavior of the floor. When concrete topping increased more than 65 mm, the behavior of the floor will be domain by floor stiffness.

1. Introduction

Floor vibration is an important element that should be consider in a construction structure. Floor vibrations of a building are caused by human activity such as running, dancing, jumping or even walking and mechanical equipment excitation that are affect personal comfort. The force from walking transferred from one location to another with each step. This may create the serviceability issues which human feel annoy and not comfortable.

Traditional timber floor had an issues in vibration serviceability due the flexibility of the timber especially for the long span floor. Thus, the vibrations problem of traditional timber floors can be solved by applying a thin layer of concrete on top of the timber joists. The concrete slab can increases the mass, stiffness and strength of the timber floor. This means that the strength and stiffness are utilized to the greatest advantage giving the timber-concrete composite floor system the potential to improve the dynamic and vibration performance of traditional timber floors [1].

Timber-concrete composite (TCC) floor is a construction technique used to upgrading the traditional timber floor [2]. This system is the combination of timber beam with concrete topping slab using a joist system to transfer the loads between the timber and concrete. TCC floor system offers larger strength and stiffness, higher fire resistance and smaller effect of vibration compare with traditional timber floors [3]. The benefits of TCC systems caused it attractive use for new construction [4]. TCC structure provided more advantages as compared to traditional timber structure in term of strength and durability. TCC has higher

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stiffness and strength, reduces susceptibility to vibration, more resist to fire and seismic and good in thermal mass and acoustic separation. Besides that, the overall weight of a floor can be reduced due to introduce of timber in construction of floor that can reduce the volume of reinforcement concrete usage, which directly can reduce the imposed load act on foundation [5].

In this research, the laminated veneer lumber (LVL) was used as timber joist to increase the strength of the TCC floor. LVL is engineered timber which has almost three times the strength of the sawn timber, more reliable and high modulus of elasticity (Abd Ghafar, 2008). The LCC floor was model using SAP 2000 finite element software package to study the effect of concrete topping thickness and to determine the optimum of concrete topping.

2. Materials and Methods

The material properties for LVL and concrete as illustrated in table 1. The properties of the LVL was adopted from H'ng [6]. The material properties is the first element need to insert in SAP 2000 software package.

Material Properties	LVL		CONCRETE
Grade	SG3		C30
Unit Weight (kN/m ³)	9.0		25.0
Young Modulus, E (N/mm ²)	Mean	Minimum	30000
	11300	499	30000
Poisson's Ratio, U	0.5		0.2
Shear Modulus, G (N/mm ²)	753		12500

Table 1. Material Properties of LVL and Concrete.

The second step in SAP 2000 software package is to insert the element of TCC. Three types of element that been used in this research which (1) beam element, (2) shell element and (3) link element. Beam element represented the 400 mm thickness of LVL joist. While the shell element represented the concrete topping with varies concrete topping thickness were model form 20 mm to 200 m with 20 mm interval, including 25 mm and 65 mm thickness. The selection of 25 mm and 65 mm based on Abd Ghafar [7]. The link element represented the connector of the TCC. The link element was used to connect two beam elements and transfer the loads from concrete topping to the LVL joist. Two types of link were defined in link properties which are shear connector and rigid connector. The finite element modelling and cross-section of LCC as shown in figure 1.



Figure 1. (a) Cross-section of LCC and (b) Finite element modelling of LCC floor.

3. Result and Discussions

The important of the mode shape is to make sure that the natural frequencies of the LCC floor models were correct. Table 2 shows the natural frequencies and mode shapes of 2m LCC floor with 25 mm and 65 mm concrete topping thickness. All floors model had the similar behavior of mode shapes as for models in table 2.

The first mode of LCC floor was presented as half sine curve with the natural frequency of 57.45 Hz and 57.19 Hz for thickness 25 mm and 65 mm. The first mode shape was similar to the deflection shape caused by uniform gravity loading LCC floor system. The highest displacement located in the mid span of LCC floor due to self- weight of span turn into stress focus at the mid-span where it is most far from the support. The second mode shape of LCC floor corresponds to a predicted natural frequency of 121.90 Hz and 121.38 Hz where it presented as full sine curve. The third mode shape of LCC corresponds to a natural frequency of 193.72 Hz and 188.57 Hz which is also not significant for floor vibration. The third mode of LCC floor was presented as one and the half sine curve. The natural frequencies of the floor were a bit higher due to the short span of the LCC floor. The shorter the span of the floor will increased the stiffness and the natural frequency of the floor.

The natural frequencies of different concrete topping thickness were obtained by using SAP 2000 software and theoretical analysis. The natural frequencies between theory and SAP 2000 software results as illustrated in figure 2. The results shown that the natural frequencies were decrease from 20 mm until 60 mm concrete topping thickness. While, the results increased starting from 65 mm concrete topping until 200 mm concrete topping. This behavior present that the natural frequencies of the LCC were dominant by mass for LCC with 65 mm concrete topping or less. LCC with 65 mm concrete topping or more will be dominated by stiffness of the LCC. This is due to the changing of the mass and the stiffness when changing the thickness of concrete topping as mention by Rijal et. Al [7], theoretically the natural frequency depends on the system properties, mass and properties.

Comparison between theoretical and modelling show that the theoretical gave the higher value of natural frequency due to no stiffness of the connector included during the theoretical calculation. The average percent difference between the theoretical calculation and SAP 2000 is in the range of 4.25% to 11.56%. Wherein, the lowest percentage difference is 4.25% when the thickness of the concrete is 200 mm. The highest percentage difference is when the concrete thickness 60 mm where it was 11.56%. While, on the thickness of 25 mm and 65 mm, the percentage difference that occurred was 11.46% and 10.78%.





Figure 2. Comparison of natural frequency between finite element modelling and theoretical analysis.

4. Conclusions

The 2 m span LCC floor was model in Sap 2000 software package with different thickness of concrete topping. This study proof that the thickness of concrete topping influence the natural frequency of the LCC floor. The optimum concrete topping was determined at 65 mm thickness. For concrete topping below 65 mm thickness, the mass will be domain the behavior of the floor. When concrete topping increased more than 65 mm, the behavior of the floor will be domain by floor stiffness.

5. References

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