MODELLING AND MEASUREMENT OF THE DYNAMIC PERFORMANCE OF A TIMBER CONCRETE COMPOSITE FLOOR

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ABSTRACT: A 3 bay x 5 bay timber concrete composite floor was tested in situ for footfall induced vibration. The same floor was modelled using finite elements and a weighted RMS method that has worked well for predicting the dynamic performance of light steel concrete composite floors. Correlation between site results and model predictions was good, based on a range of stated assumptions for input to the theoretical model.

KEYWORDS: Dynamics, vibration, serviceability, timber concrete composite floors.

1 BACKGROUND

Vibration performance of timber floors continues to be a challenge for designers and a source of risk for owners / tenants. Whole-floor modelling is usually necessary to simulate response to footfall induced vibration. This is because floor stiffness at very low displacement amplitudes depends on assumptions about bay-to-bay, floor-to-column, and floor-to-wall continuity. Floor mass called into participation by a local footfall also depends on whole-floor behaviour. Codified methods are often over-simplified or else over-qualified, as they try to predict overall performance from the behaviour of a single beam or bay. Whole floor modelling still relies on input assumptions for stiffness, continuity and damping. The best way to improve confidence in such modelling is to back-analyse test results from tests on real floors. This paper reports on such a back-analysis, for the case of a 3 bay x 5 bay timber concrete composite floor in the Arts and Media building of the Nelson and Marlborough Institute of Technology, Nelson, New Zealand.

The building comprises three storeys of timber construction, with columns and primary beams of solid LVL sections, and a secondary floor system comprising ‘Potius’ panels with LVL webs and flange. A 75mm concrete topping was applied in situ to the LVL panel floor, but was separated from the timber by a plastic membrane. This was taken into account in the model by shear decoupling of the topping slab and LVL panel. The membrane did not extend over the width of the primary beams however, where screws were used to provide some shear transfer concrete to LVL. The primary beams were therefore modelled as fully composite.

2 METHOD

Vibration test were carried out on Level 2 and Level 3 of the building, including impact tests (heeldrop) to identify frequencies and damping of the natural modes of vibration of the floor, and walking tests (single person) at 1.5, 2.0 and 2.5 steps/second at several locations to identify the peak acceleration response of the floor. Natural frequencies were estimated from FFT (Fast Fourier Transforms) of the impact test data.

A logarithmic decrement procedure was used to estimate damping from each impact test. Vibration response (acceleration) from the single person walking tests was processed using the weighted RMS method described in Steel Construction Institute (UK) Publication P354, ‘Design of Floors for Vibration: A New Approach’, Smith, Hicks, Devine, 2007.

Response factors were deduced from these accelerations, normalised for a 76 kg standard walker mass. For theoretical modelling, a FE model of the floor plate was created using Oasys GSA³ software, to calculate modeshape and frequency. For response factor prediction, assumptions were made about damping, degree of composite action, stiffness of beam / column connections, stiffness of floor / facade connection, and additional mass from superimposed loading.

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Figure 1: TCC floor in the subject building.

Figure 2: Mode 2, predicted 10.9Hz.

Figure 3: Typical heel drop test vibration records.

Figure 4: Example of predicted vibration performance.

3 RESULTS

Regarding frequencies of the dominant modes, good correlation was found between measured and predicted values. (Figures will be quoted in final paper). Regarding response factors, correlation was also good. Enquiries were also made of the building Facilities Manager. Reports of user satisfaction were generally consistent with comfort levels corresponding to the response factors measured and modelled.

4 CONCLUSIONS

A number of deductions were made from the back-analysis, and they will be reported in the final paper. They include comments on the material properties of individual structural elements (timber and concrete elastic moduli); damping relative to the extent of fitout in the spaces tested; vertical restraint offered by the floor-to-facade connection; rotational restraint offered by the bolt-and-bearing primary beam-to-column connection; degree of composite action; and potential cracking of the concrete topping to secondary beams where it passes across primary beams.

Regarding composite action between LVL secondary floor panels and concrete topping, and between LVL primary beams and concrete topping, the modelling assumptions noted above appear to have been valid. Regarding cracking of the concrete topping, good frequency correlation between field test results and modelling results was obtained for Level 2 assuming no cracking. For Level 3, lower frequencies were observed on site, implying lower stiffness for the floor at that level. This may have been attributable to a greater degree of cracking in the topping across primary beams, affecting the stiffness of the secondary beams.

Based on the modelling assumptions adopted, predicted / measured correlation was good. This gives confidence in the use of the whole-floor FE and weighted RMS modelling method for predicting the dynamic performance of floors of this type.