FINITE-ELEMENT UPDATING OF THE UNIVERSITY OF EXETER FORUM WALKWAY

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SUMMARY

This paper presents the finite element (FE) updating of a walkway, part of the University of Exeter's Forum building. The walkway is a relatively slender structure with natural frequencies in the range that can be excited by human induced vibrations.

It is often difficult for designers to model and predict as-built modal properties of such structures with an adequate degree of precision. Thus updating of their FE models is highly instructive for situations like this one. The aim of this paper is to assess the ability to predict accurately the modal properties of this particular structure and to correlate and update the initial FE model with experimental results. The initial model is made based on technical drawings and on best engineering judgement. However, comparing the natural frequencies and mode shapes of the FE model with experimental results, it was seen that the model needs to be updated to match the real structural properties (natural frequencies and mode shapes) as accurately as possible. After the updating, an FE model was obtained where the first five vibration modes were updated. The obtained properties are by no means a unique solution. However, they lead to a reasonable model of the walkway which more accurately represents its modal properties.

1: Footbridge Description

The walkway is a composite steel-concrete bridge approximately 15 m long and 2.7 m wide as seen in Figure 1(a). The composite deck spans along the length of the bridge between secondary beams which in turn are supported by the primary (side) beams. On the right side of Figure 1(a), the bridge is supported by two circular steel columns. On the left side the bridge is connected to an adjacent floor slab with cast-in threaded bars. This detailing, along with the section 1-1 are also shown in Figure 1.

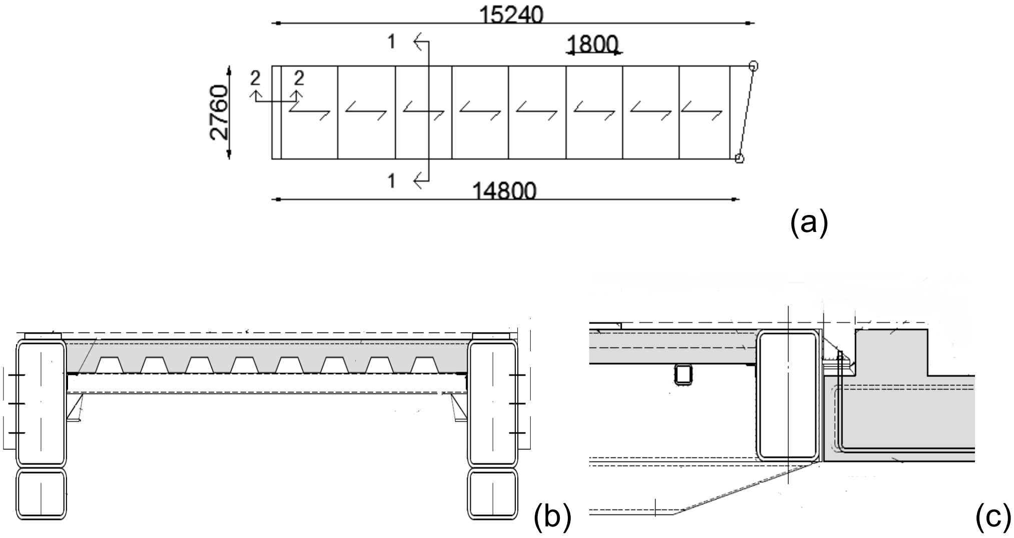


Figure 1: (a) Plan view, (b) Section 1-1, (c) Section 2-2

2: Preliminary FE Modelling

The FE model was developed based on best engineering judgement. Information available from construction drawings were used to properly model the geometry and the various section properties. For the material properties for dynamic situations and the modelling of the composite deck, the recommendations in SCI publication P354 were used. The effects of uneven mass distribution and non-uniform structural properties (e.g. thickness of slab deck) were neglected. Finally, all beam-beam and beam-column connections were modelled to be rigid, since the friction cannot be overcome from human induced vibrations.

3: Modal Testing

A test grid of 39 test points was used (13 x 3 rows). An input force was provided to the structure by an APS Dynamics model 400 shaker and the acceleration response was monitored by 13 QA750 accelerometers. Frequency response functions (FRFs) were acquired and used to determine the modal properties of the structure.

4: Manual Updating

Comparing the experimental results to the initial FE model it is clear that there are considerable differences. Even though the mode shapes are fairly similar, the frequencies of all modes of the FE model are much higher. This suggests that FE model updating is necessary in this situation.

As mentioned by Pavic et al. (2007), there are two stages in manual updating: model refinement, where new elements are added to more accurately represent the real structure, and parameter adjustment. As far as the former is concerned, the only change of the model that was considered necessary was to add vertical springs at both ends of the footbridge to represent better the boundary conditions. On one side the springs were placed on the base of the columns and on the other side 5 springs were placed on the transverse beam.

For the manual updating, sensitivity analysis was performed to find which parameters affect the response the most. The following parameters were considered for the updating: spring constants for the columns and the transverse beam supports (K1 and K2, respectively), mass per m length of the side beams to account for the mass of the handrail system (Mpl), mass per m^2 of the deck to account for any superimposed dead load (e.g. finishes, services etc.) apart from the weight of the deck (Md) and the offset of the transverse and side beams from the deck (offs and offs2, respectively to account for the composite action between them and the deck.

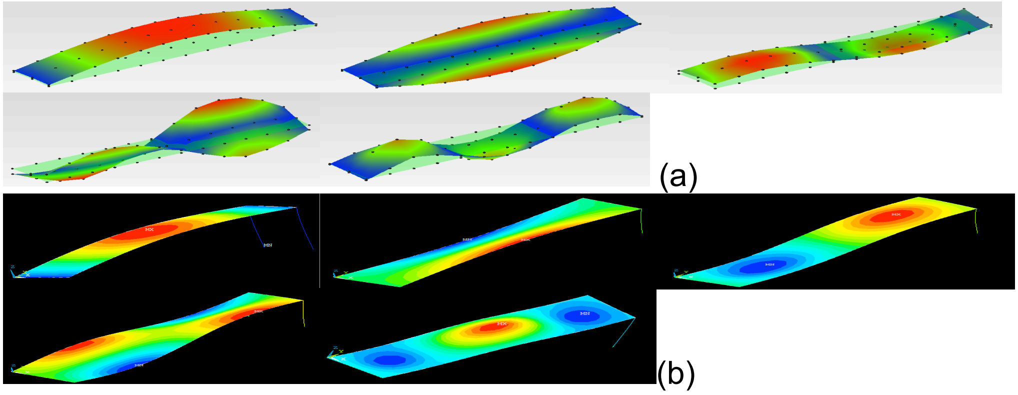
In Table 1 below the modal frequencies and modal masses of the initial and updated model are given along with the measured ones from the experiments. A considerable improvement is observed after the updating. The updated parameters are given in Table 2 and the mode shapes from the experiment and the updated model are shown in Figure 2.

Modal Parameters	Experimental	Initial	Updated
Freq1 (Hz)	6.4	7.1	6.06
Freq2 (Hz)	10.5	13	11.46
Freq3 (Hz)	20.5	23.9	19.87
Freq4 (Hz)	26.9	33.3	28.6
Freq5 (Hz)	34	38.5	32.75
Modal Mass1 (kg)	13000	14566	13560
Modal Mass2 (kg)	10800	9218	9045
Modal Mass3 (kg)	10400	8358	8455
Modal Mass4 (kg)	19800	14318	12800

Table 1: Modal frequencies and modal masses from experiment, initial and updated FE model.

Updated Parameter	K1(N/m)	K2 (N/m)	Mpl (kg)	Md (kg/m^2)	Offs (mm)	Offs2 (mm)
Value	17E7	10E7	65	100.5	92	200

Table 2: Updated parameters from manual updating.



(a) (b)

Figure 2: Mode shapes of (a) Experimental and (b) updated FE model

5: Conclusions

This paper has presented the model updating of the University of Exeter's Forum Walkway. It was demonstrated that a FE model developed on the basis of best engineering judgement can yield natural frequencies well above or below their measured counterparts.

The updated model shows a considerable improvement. The bending natural frequencies (1^{st}, 3^{rd} and 5^{th}) are less than 5% different from their measured counterparts. The correlation of the torsional modes however (2^{nd} and 4^{th}) is not as good.

To further increase the accuracy the model should be improved by means of a more detailed modelling of the boundary conditions. A more sophisticated automatic updating procedure could also be used adding MAC values and FRFs as objectives of the updating.

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