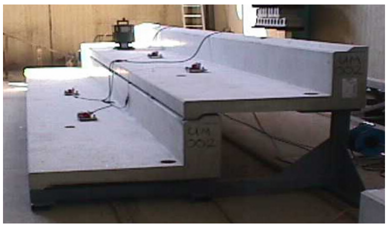
8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

GRANDSTAND TERRACES. EXPERIMENTAL AND COMPUTATIONAL MODAL ANALYSIS.



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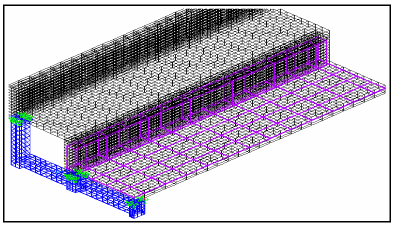

Key Words: *Grandstands, Mode Shapes, Natural Frequencies, Supports, Reinforcement*

ABSTRACT

Experimental, and Finite Element (FE) Modal Analyses were used to determine the natural frequencies and mode shapes of a single and a double precast concrete terrace unit under laboratory conditions. The units were simply supported on steel '*stools'* at the four corners with polychloroprene (neoprene) pads inserted at their interface, between steel and concrete. The stools were part of a specially manufactured steel frame of rectangular hollow section (RHS), firmly resting on the strong laboratory concrete floor.
The laboratory equipment consisted of a Shaker, (vibrator, or exciter), an Amplifier, a Signal Generator, a Spectrum Analyser and a series of Accelerometers. Two sets of modal testing results identifying modes of vibration in the vertical plane for single and double terrace units were obtained. The results from the excitation of the single unit indicated that the lowest mode, Mode 1, was a predominantly bending mode, whereas Modes 2 and 3 were most likely representing twisting of the L-shaped unit (successfully depicted in the FE analysis later) and, perhaps to a lesser extent, the result of not perfectly rigid and symmetric support conditions. Modes 4 and 5 could be regarded as the second and third 'beam-like' modes of bending vibration in the vertical plane.

Modal parameter results of the double terrace unit for the first six vertical modes of vibration were also obtained. As it was noted from the mode shapes, the first mode of vibration excited only the lower unit, which moved in a 'rigid-body' manner and engaged only one support. This indicated that the first mode was actually caused by a relatively 'elastic' (*tuneful*) support under the lower unit. The second mode was principally a 'flexural' mode where the units behaved like simply supported beams undergoing bending. Both units moved in-phase and no moving was detected over the supports this time. The dynamic behaviour in general, and the frequencies of the higher modes seemed to be as expected and compared well with the corresponding behaviour of the single terrace unit. However, bearing in mind that all accelerometers were positioned vertically and that the structure under test was only represented by a series of lumped masses in a straight line (that is, approximated as one dimensional structure), it is probably reasonable to assume that the particular testing procedure missed certain complex modes of vibration. These were depicted in the finite element analysis.

The dynamic model was in effect an extension of the existing static model, developed earlier. The Block Lanczos eigenvalue extraction method for large, symmetric problems was utilised. This method is especially powerful when searching for eigen-frequencies in a specific part of an eigenvalue spectrum of a system. It performs particularly well when the model consists of a

combination of 3D and 2D or 1D elements, using the sparse matrix solver and overriding any other solver specified previously. The adoption of the Block Lanczos method has significantly reduced the CPU-time in this study and has added to the accuracy of the results over the initial choice of the subspace method.

The steel reinforcement was introduced to the model in stages and a modal analysis was performed every time, in order to study its effect on the natural frequencies of the unit. Previous studies at MSc level have revealed no specific or conventional pattern. The same studies have demonstrated the change in dynamic behaviour of a simply supported, singly reinforced concrete beam of rectangular section, undergoing vibrations. Briefly, it was shown that an increase in the amount of reinforcement is likely to increase certain modal frequencies and decrease others. For example, introducing the tension reinforcement, resulted in marginally increasing the first two natural frequencies associated with bending modes but had no effect on the next two modes associated with predominantly torsional vibrations. In fact, reinforcing and therefore increasing the specific stiffness of a particular structural element or structure could result in “forcing” this structure into a different mode of vibration and somehow introducing lower corresponding frequencies.

Initially, a number of degrees of freedom, (DOF) both translational and rotational were restrained at the appropriate directions in an effort to depict realistic support conditions. Plane symmetry was used very consciously, due to its effect on the mode shapes, to reduce the number of elements in the FE-model and minimise effort and CPU-time. The FE-model was set to free vibration. Two important properties, its natural frequencies and the corresponding mode shapes were recorded and compared with those obtained experimentally. It was found that both natural frequencies and mode shapes are extremely sensitive to support conditions. It was also concluded that support conditions ‘built-in’ the FE-program were not adequate to model the behaviour of the real supports satisfactorily. Correlation between experimental and computer predicted natural frequencies and mode shapes improved with the introduction of more complex (advanced) modelling techniques and gradual lifting of the limitations of the model. Best results were achieved when the stiffness of the supports was modelled using the ANSYS dedicated stiffness matrix element (MATRIX27).

Finally, it may be reasonable to conclude that predicted natural frequencies and mode shapes may be more accurate and “realistic” than those obtained in the laboratory. This is more evident in complex modes (eg: coupled, bending + torsion) as, among other (structural) parameters, they greatly depend on the number, position, direction and quality of the transducers and data logging equipment used. Also, it is well known that the higher the mode shape number the more difficult it is to be accurately captured.

The paper includes a discussion of the results aided by a number of tables, figures, graphs diagrams and sketches. Emphasis is given to the experience built up in interpreting modal analysis results in order to be used for similar, or further work.

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