Modal Testing of Reinforced Concrete Floor using Reaction Mass Shaker (Direct Method)

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Abstract

Modern structures are becoming more and more slender but with improved stiffness with use of large number of materials in combination, making the predictions of dynamic characteristics of such structures extremely difficult for the analysis using commercially available general purpose finite element softwares. On the other hand, if a building floor is properly excited and the input force and the resulting responses are accurately measured with proper hardware, the dynamic characteristics can be found out without much error. In direct method of analysis, the input force is generated by the load cells provided. The present work is focused on actual physical measurement of input force of a reaction mass shaker to a typical building floor to determine the floor dynamics. A case study on a double storey Laboratory floor establishes the advantages of this kind of combined experimental and numerical methods.

Keywords: FEM – Finite Element Modelling, EMA – Experimental Modal Analysis, Modal Analysis – A method to obtain the modal parameters of any structure, FRF – Frequency Response Function, Stiffness – It is the rigidity of an object, Direct method

I. INTRODUCTION

Modal testing procedure was thought to be practiced on different types of Reinforced Concrete floor systems. The usage of this type of system is actually independent of the size, type and properties of any flooring system. The test structure is the model room floor slab of structures lab in Civil Engineering Department, IIT Kharagpur. Although the floor was little complicated in its geometry, it was chosen as the first test floor because the instruments need not be carried elsewhere and adequate time could be given to get acquainted to the system. This floor was a lively indoor floor with floor finishes. Although the floor had little complex boundary conditions, the fact that it was indoors and posed less logistic problems, it was found to be a better slab to start with direct method of measurement of Modal Parameters.

II. CASE-STUDY

The dimensions of the floor are 20.4m X 9m with 150 mm total depth.

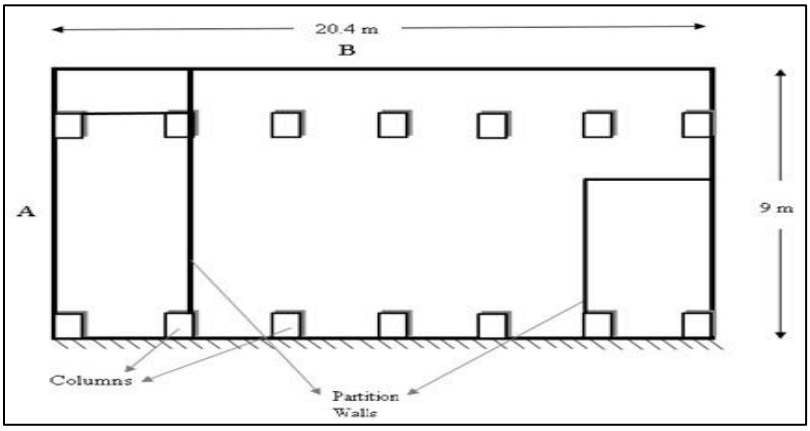

Fig. 1: Plan of test floor slab

- E of floor slab – 2.0 x 10^{10} Pa
- Poisson's ratio – 0.2
- Density of concrete – 2400 Kg/m^3

A. Preparatory Phase (Pre Test Analysis of the Test Floor):

The purpose of a pre-test analysis is to give an indication of likely natural frequencies and mode shapes of the structure prior to testing. A pre test analysis gives an indication of a frequency range to be used for the experiment so that the floor is safely excited. Since the entire structure was not taken for analysis, the supporting columns length were assumed up to 3m for top and bottom and all columns were pinned at the ends. The slabs were allowed rotation about their edges.
The element constants for the beams and Columns are as given below:-

Table – 1:
Element constants for pre test model

Element type	*Parameter*	*Value*
Beam (0.54x0.34)	*TKZ*	*0.54*
	TKY	*0.34*
	Area	*0.1836*
	IZZx10^{-3}	*4.46*
	IYYx10^{-3}	*1.77*
Column(0.4x0.3)	*TKZ*	*0.4*
	TKY	*0.3*
	Area	*0.12*
	IZZx10^{-3}	*1.6*
	IYYx10^{-3}	*0.9*
Slab	*TKI, TKJ, TKK, TKL*	*0.15*

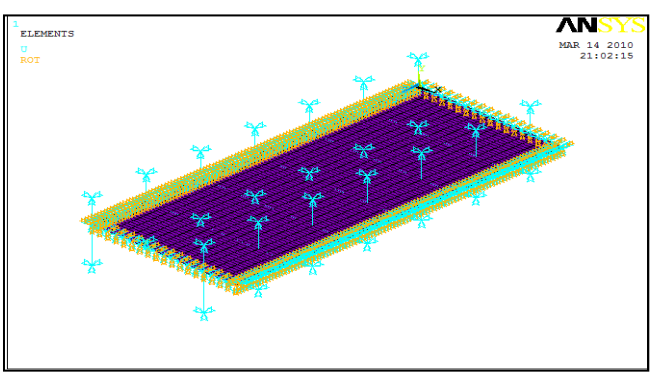

Fig. 2. Pre test FE model

The first 10 natural frequencies were recorded and are as tabulated below:

Table – 2
First ten frequencies of Pre test model

Mode	*Natural Frequency(Hz)*
1	*13.660*
2	*14.411*
3	*15.774*
4	*17.847*
5	*20.640*
6	*25.523*
7	*29.101*
8	*33.146*
9	*34.101*
10	*34.517*

The first four frequencies and mode shapes after pretest analysis are:

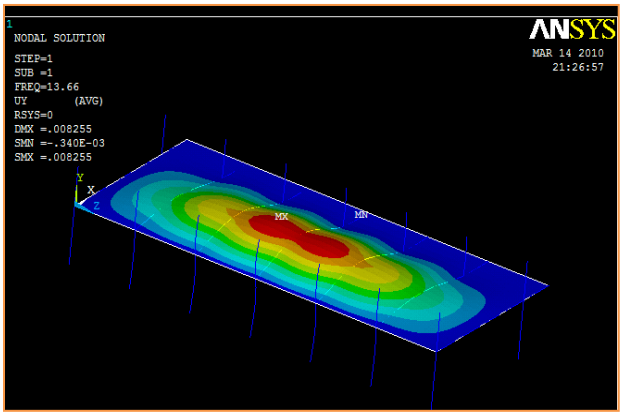

Fig. 3: (a) First Mode

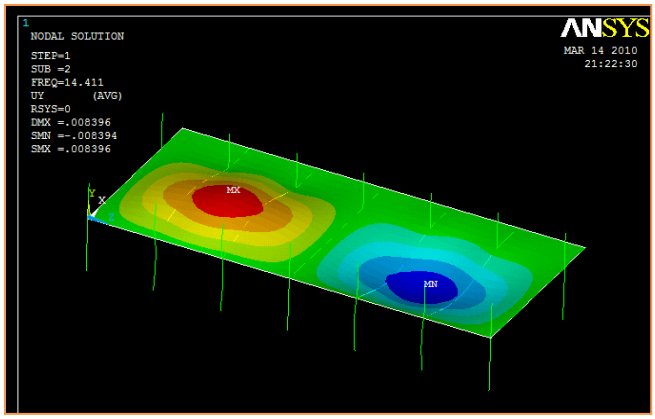

Fig. 3: (b) Second Mode

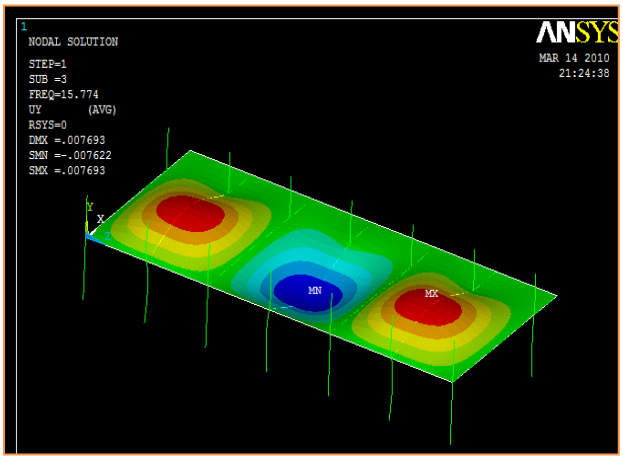

Fig. 3: (c) Third Mode

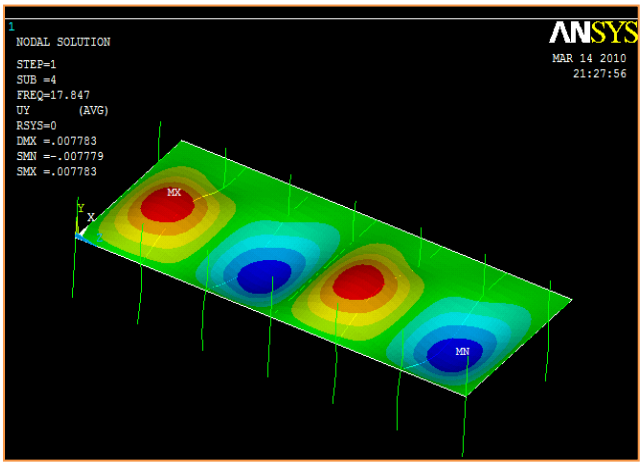

Fig. 3: (d) Fourth Mode

Fig. 3: Pre test analysis of model room floor slab: Mode shapes.

The grid consisted of 50 points which was created seeing the most likely points of excitation and nodes. It was suspected that there would be no movement near the partition walls. However some points were taken to test the response of slab at those points. The response at the walls was almost zero. So the points at the walls were neglected.

B. Measurement and Post Analysis Phase (Direct Method):

After these tests being conducted, FRFs were recorded. The shaker was kept with the load cell. Three accelerometers were roved along the selected points. The FRFs near the partition walls were not of sufficient quality due to the local stiffness provided by them at the points.

Table – 3:
Data acquisition parameters

Parameter	*Setting value*
Acquisition Bandwidth	*Zoom 5 - 25 Hz*
Acquisition Duration	*20 s*
No. of Frequency Domain Averages	*7*
Force Window Duration (% of Acquisition)	*45%*
Exponential Window Time Constant	*0.35*
Excitation Type	*Chirp*
Excitation Duration	*8 s*
Excitation Frequency Limits	*5 - 30 Hz*

The available FRFs were exported to MEScope for modal parameter estimation. The values obtained from MEScope are given in table below. The comparison of frequencies of the pre test model and the experiment shows some variation.

Table – 4:
Modal parameters extracted using MEScope

Mode	Frequency(Hz)	Damping ratio(ζ)(%)
1	16	2.77
2	19.60	2.32
3	22.50	2.22
4	24.10	1.68

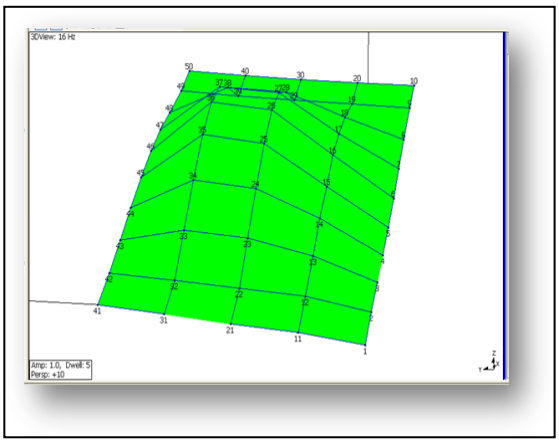

Fig. 4: (a) First mode

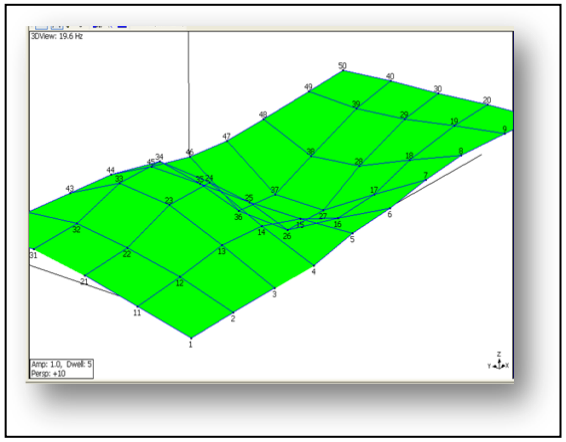

Fig. 4: (b) Second mode

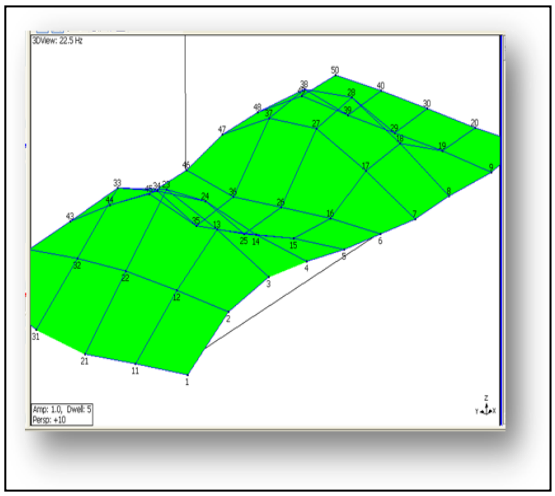

Fig. 4: (c) Third mode

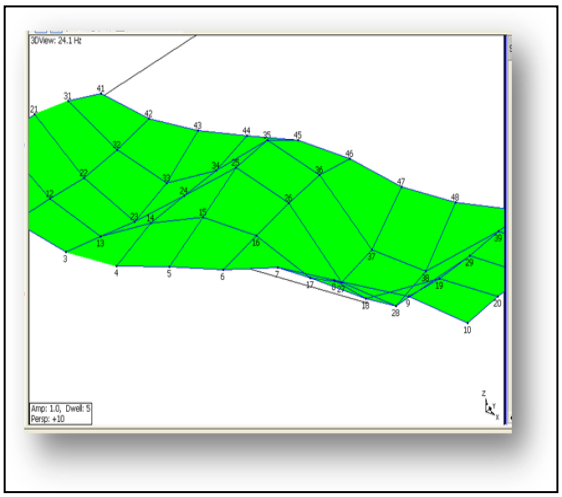

Fig. 4: (d) Fourth mode

Fig. 4: Experimental mode shapes of slab

Table – 5
Comparison of Frequencies (Hz)

Mode	*ANSYS*	*Experimental*
1	*13.660*	*16*
2	*14.411*	*19.60*
3	*15.774*	*22.50*
4	*17.847*	*24.10*

III. CONCLUSION

The comparison of frequencies shows that the stiffness of the slab in pre test modeling was low.

REFERENCES

[1] Shashi Shekhar Singh, "Modal testing of Reinforced Concrete Building Floors using Reaction Mass Shaker", M.Tech. Thesis, Department of Civil Engineering, IIT Kharagpur, India, May, 2011.