저진동 RC 플로어 구조의 진동특성에 관한 연구

Vibration Characteristics of Low-Vibration RC Floor Structures

김진호*
Kim, Jin-Ho

ABSTRACT

Due to the location of vibration sensitive equipment on the floor, it is necessary for its vibration performance to be maintained within stringent limits, resulting in a design of higher mass and stiffness than would be usual for a floor of this type. Modal testing is conducted on the floor to obtain their dynamic characteristics. A considerable level of vibration transmission is observed by comparing the ratio of simulated transfer and point mobility FRFs of the floor.

1. Introduction

Dynamic loading of a floor can excite vibrations that may adversely affect production or research activities using equipment supported on that floor. These loads may be caused by mechanical systems. Excessive vibration problems may become a governing design criterion in the case of floors in buildings with mix occupancies.

Modal testing is performed on the floor structure before construction. The results from the modal testing are then correlated with the pre-test FE analysis and discrepancies identified. Through this procedure, shortcomings in the original FE model are identified so FE models developed in the future of similar structures may be improved.

2. Pre-Test FE Modeling

Before the modal testing is performed, an FE model of the floor is developed using the ANSYS code. Its main purpose is to serve as the basis for manual FE model updating to match the analytically calculated modal properties with their experimental counterparts. Fairly detailed modeling of the entire floor surface is performed, resulting in the 3D FE model shown in Figure 1.

In this FE model, the supporting columns above and below the slab are introduced to realistically model the boundary conditions of the floor. ANSYS SHELL63 elements, which have both bending and membrane capabilities, are chosen to model the precast concrete slab. Standard BEAM44 elements are used to model the steel beams and columns, making use of the offset

* 정회원, 한국철도기술연구원

option to model the offset of the centroid of the down stand edge beams from the centroid of the slab, in the cases where this is applicable.

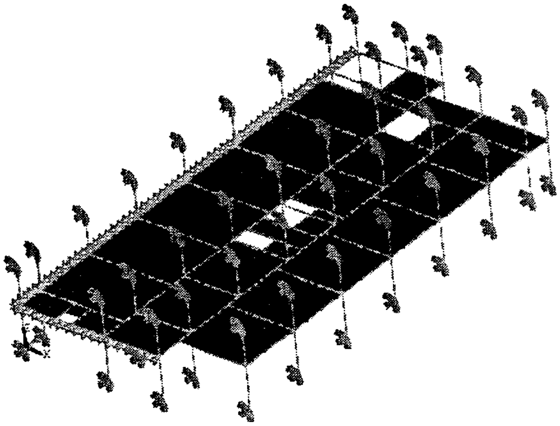


Figure 1 Pre-test FE model

The bending stiffness and material density of the SHELL63 elements in the direction of spanning of the precast beams have to be adjusted to take account of the openings in the hollow-core precast elements. During the modeling a number of fundamental assumptions were made, namely that:

- the dynamic Young's modulus of concrete with a design strength of 55 MPa (grade C55) concrete is 38 GPa, its density is 2400 kg/m^3 and its Poisson's ratio is 0.2,
- the connection between the beams and columns is rigid, which is justifiable for the small displacements associated with walking-induced excitation, and
- restraints are applied to the model by allowing no rotation and no displacement of the columns at ground and second floor.

Table 1. Natural frequencies and modal masses from pre-test FE model

Mode	Frequency (Hz)	Modal Mass (Tonnes)
1	13.65	53.6
2	14.76	64.3
3	15.95	59.7
4	17.82	72.1
5	20.00	58.1

A modal analysis is performed to determine first 50 modes of vibration. The natural frequencies of the first five modes are of interest as they are lower than 20 Hz. They are presented in Table 1 with their modal masses, determined using unity normalized mode shapes. The first main mode of vibration is a single curvature mode in the wider bay, occurring at 13.65 Hz. The second, third and fourth modes of vibration also occurre in the wider bay, with increasing curvature. The fifth main mode of vibration occurred in the 23.8 ft wide bay as a single-curvature mode. Significant modes across the structure do not occur until the seventh analytical mode of vibration, at frequencies in excess of 20Hz.

3. Modal Testing

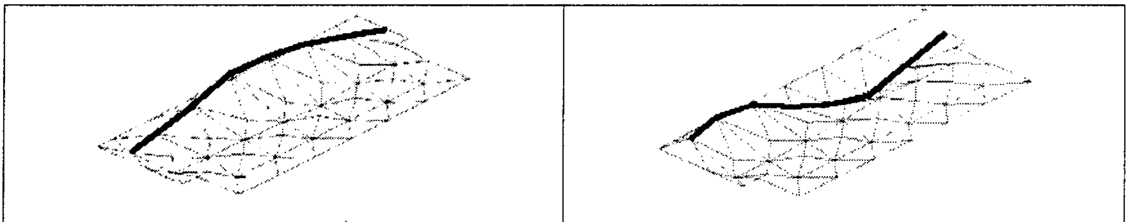
The modal testing methodology used in this work is based on the measurement of frequency response functions (FRFs) due to controlled and measured shaker excitation. The key data acquisition parameters utilized in the FRF measurements are shown in Table 2.

The estimated modal properties of the first seven modes of vibration of the floor are presented. It can be seen that the seven identified modes with frequencies are lower than 20 Hz. The estimated modal damping ratio are generally low, but quite realistic for a bare floor structures with no cladding and services is the condition of the structure at the time of the testing.

Table 2. Main data acquisition parameters adopted for FRF measurements

Parameter description	Parameter setting/value
Data acquisition time	20s
Frequency resolution	0.05 Hz
Frequency range of interest	Zoom 3 - 24Hz
Number of frequency domain averages	5
Force window duration (% of acquisition)	25%
Exponential window time constant	0.25
Excitation type	Logarithmic burst swept sine
Excitation duration	4s

The estimated modal properties of the first seven modes of vibration of the floor are presented in Figure 2. It can be seen that the seven identified modes with frequencies are lower than 20 Hz. The estimated modal damping ratio are generally low, but quite realistic for a bare floor structures with no cladding and services is the condition of the structure at the time of the testing.



Mode 1f=12.7 Hz ζ=0.6%   Mode 2f=13.8 Hz ζ=0.5%

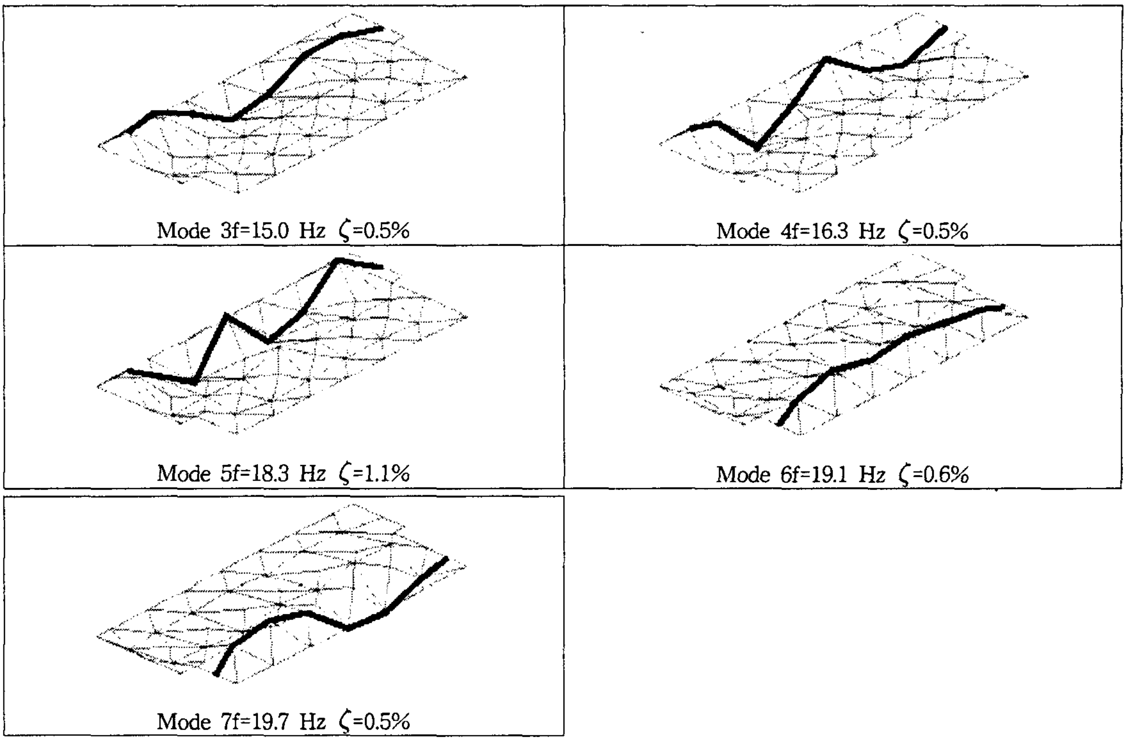


Figure 2. The modal properties of the first seven modes

4. Discussion and Conclusions

This study demonstrates that, in the case of high-frequency bare floors, a good correlation between the experimental and analytical modal properties is possible, when reasonably detailed 3D FE modeling is performed. For this structure, orthotropic shell elements are used to model the floor, with particular attention being given to the accurate estimation of the lateral floor stiffness, which has to be reduced, probably to represent the effects of shrinkage cracking. Supporting columns rigidly connect to the floor and with remote ends fully fixed proved to be a simple but reasonable modeling assumption.

It is clear from a consideration of its modal properties that the as-built structure is performing. This is particularly evident because the dominant frequencies of vibration are lower in the wider office bay. The minimum dominant frequency in the laboratory bay is above 18 Hz

References

1) Lin, R. M. and Lim, M. K. (1997) Modal analysis of close modes using perturbative sensitivity approach, Engineering and Structures, 19(6), 397 - 403.
2) Benaroya, H. (1998) Mechanical vibration: analysis, uncertainties and control, Prentice Hall, Inc., New Jersey, USA.
3) Ewins, D. J. (2000) Modal testing - theory, practice and applications, 2nd Edition, Research Studies.