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Dynamic Response of Multi Storey Building Frame under Harmonic Excitation

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Abstract

The strong movement caused by a seismic event causes structural damage to a building. Buildings are designed for gravity, and thus are usually sufficiently designed for vertical movement. Earthquake forces act similarly to sound waves, produced at different frequencies and at different amplitudes. A three storied building frame model subjected to harmonic motions is studied. The frame is rectangular in plan consists of four steel columns and four steel slabs, each attached to the columns at regular interval. The objective is to understand the response behavior of the frame under known input excitation while realizing the occurrence of resonance phenomenon in multi degree-of-freedom systems. Upon completion of the model, free vibration tests are performed to determine the actual properties of the model such as stiffness, damping ratio, and natural frequencies of vibration. Shake table is used for excitations and corresponding response of the physical model is measured in terms of amplitude, natural frequency, resonance frequency, acceleration, mode Shape. The experimental results are compared with Ansys software.

Keywords: Dynamic response of building, S hake table Testing, Stiffness, Damping, Frequency and Mode shape.

1. Introduction

Earthquake has a variety of complex waveforms of various amplitudes and frequencies. Large earthquakes tend to produce larger amplitude, lower frequency seismic waves, whereas small earthquakes tend to have smaller amplitudes but higher frequency waves. Most structural failure is due to buildings not having enough bracing or shear resistance or moment resistance. Seismic waves can move vertically, horizontally, or a combination of both and can come from any direction. Higher frequency earthquakes tend to damage shorter, stiffer structures, and lower frequency earthquakes tend to damage taller, more ductile structures. Buildings with the same period of a seismic event tend to resonate and be more damaged. Buildings have a resonant period of about 0.1 second per story, so a 03-story building would have a resonant period of 0.3 second. Study of the response of structure is very important so little effort is made to study the behavior of a three storied building frame model subjected to harmonic motion. This experiment also enables the understanding of occurrence of resonance phenomenon in multi-degree of freedom system.

2. Objective of Study

1. To find out dynamic properties of the model like damping, natural frequency with free vibration test.
2. To find out dynamic properties of model like acceleration, natural frequency, time period, mode shapes, with shake table testing.
3. Comparison of dynamic responses of model from shake table test with ANSYS software.

3. Instrument Used In Experiment

1. Shake table
2. Accelerometer
3. Four channel vibration analyzer instrument
4. Data acquisition system
5. Shake table speed controller
6. Dewesoft software

4. Description of Model

Three storey frame model of building is rectangular in plan as well as in elevation. The Model is made up with steel bars and plates. Material used to construct model along with its dimensions are given below.

Figure 1: Three storey frame model

Slab dimension = 11 mm x 140 mm x 380 mm
Column dimension = 2.8 mm x 24 mm x 380 mm

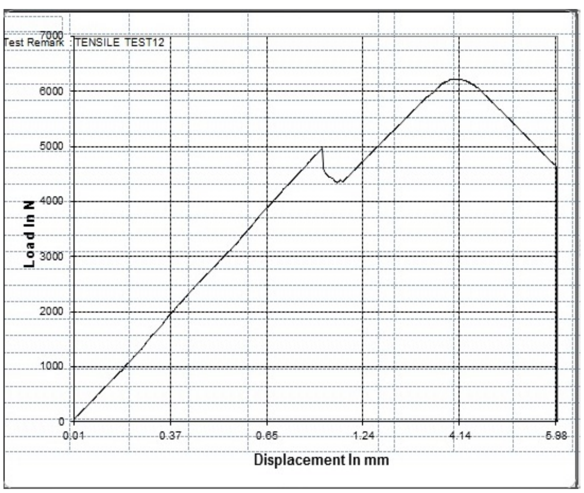

Figure 2: Stress Strain curve of Mild Steel

5. Experimental Setup

Having constructed the prototype model, Place the 3D model on the shake table. Fix the laser sensors on the reference stand, at appropriate positions (at each floor levels). The frame is allowed to free vibration by applying an initial displacement. Then the structure is set to vibrate under the base excitation test at different frequencies. For a given input, the frame was allowed to oscillate for few seconds so that the frame reaches its steady state. The frequency range for experiment is within the natural frequencies of the model.

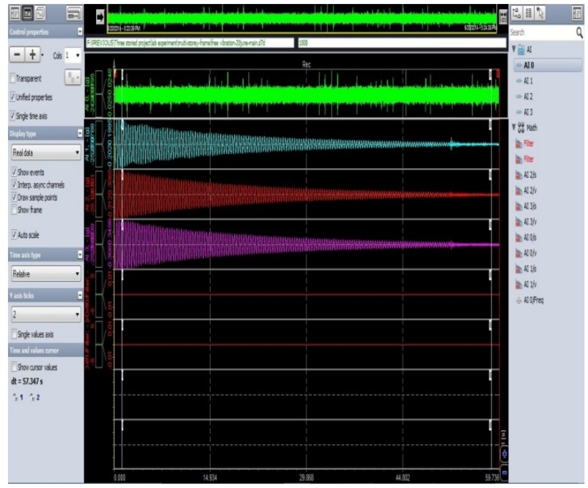

Figure 3: Free vibration test using Dewesoft

6. Results of Experiment

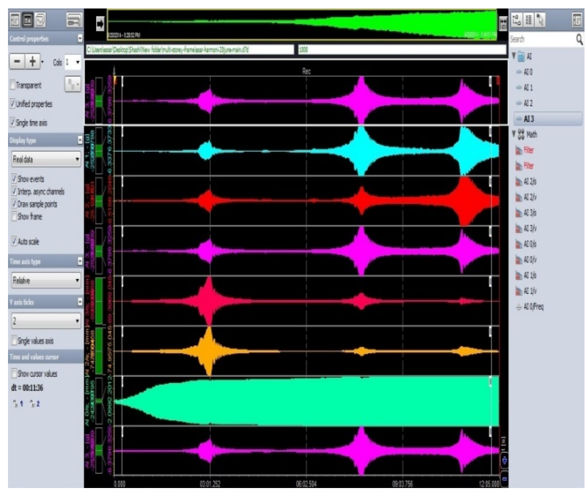

Figure 4: First three mode shape

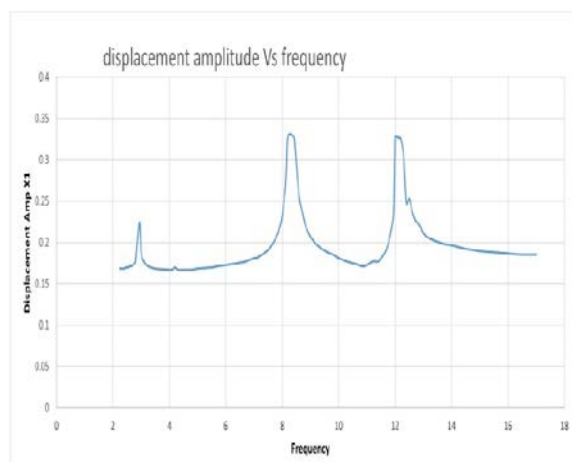

Figure 5: Displacement verses frequency at first floor

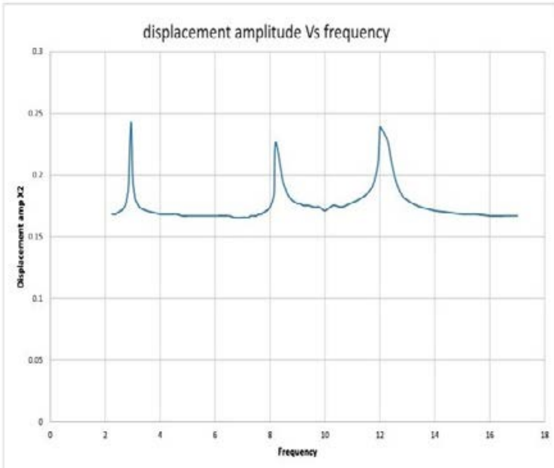

Figure 6: Displacement verses frequency at second floor

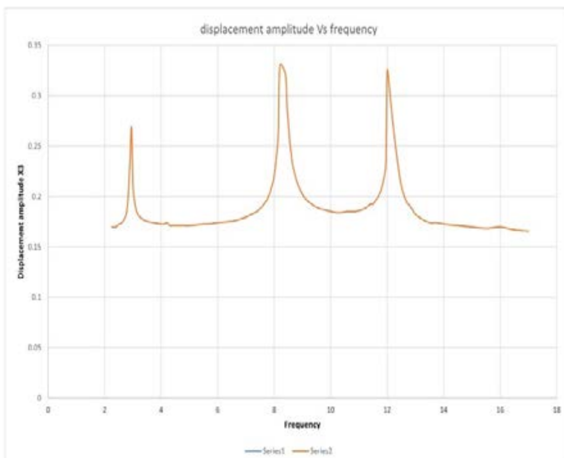

Figure 7: Displacement verses frequency at third floor

$$\begin{matrix} 1.6065 & 0 & 0 \\ 0 & 1.6065 & 0 \\ 0 & 0 & 1.5338 \end{matrix}$$

Mass Matrix (kg)

$$\begin{matrix} 5.8474 & -2.9237 & 0 \\ -2.9237 & 5.8474 & -2.9237 \\ 0 & -2.9237 & 2.9237 \end{matrix}$$

Stiffness Matrix (N/m)

$$\begin{matrix} 0.0243 & 0 & 0 \\ 0 & 0.0093 & 0 \\ 0 & 0 & 0.0067 \end{matrix}$$

Damping ratio

17.8936 49.7469 71.1188

Natural frequency (radian/sec)

Table 1: Mode Shape at respective frequencies

S No	Mode	Experimental **Frequency (Hz)**	ansys **Frequency (Hz)**
1	**I**	**2.8**	3.0186
2	**II**	**7.9**	8.6962
3	**III**	**11.5**	12.659

Table 2: Amplitude at each floor at respective frequencies

S No	**Frequency (Hz)**	**Amplitude (S1)**	**Amplitude (S2)**	**Amplitude (S3)**
1	**2.8**	1.25	1.29	1.34
2	**7.9**	1.54	1.21	1.48
3	**11.5**	1.28	1.3	1.36

Table 3 displacement amplitude at respective frequencies

S No	**Frequency (Hz)**	**Displacement Amplitude X1**	**Displacement Amplitude X2**	**Displacement Amplitude X3**
1	2.8	0.17677669 5	0.1824335 5	0.1895046 17
2	7.9	0.21778888 9	0.1711198 41	0.2093036 07
3	11.5	0.18101933 6	0.1838477 63	0.1923330 44

7. CONCLUSION

Frequency & natural period calculated experimentally & Ansys are very close.
Mode shape experimentally & Ansys are also very close.
Resonance was visible with bare eyes.

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