Shake Table Test on Laboratory Model – (G+1)

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Abstract— ***This paper introduced the practical aspects of the shake table testing on the scaled model and taking its interference in the actual model. Readings are taking at the each floor by the FFT analyzer. The main objective of this project is to study the behavior of various structural models on shake tables available in the department of Applied Mechanics, by making shake table systems operational. The study is reported in different scaled models of buildings of various plans and materials like aluminum and steel. The acceleration of different responses of the structural models is measured with sinusoidal base excitation of different amplitudes and frequencies. It is observed that the study also involves comparison of shake table (experimental) responses with the corresponding area time history analysis results obtained using the structural analysis package SAP2000.***

Keywords—*Shake Table Testing, scaled model, FFT analyser, SAP2000.*

1. INTRODUCTION

The exact simulation of the earthquake motion has been a serious challenge to researchers and engineers. Shake table testing is being increasingly used in earthquake engineering research centres worldwide, as it is the only means of nearly truly reproducing the dynamic effects that earthquake impose on structure. To enhance the dynamic testing facility, a uniaxial shake table has been installed which is servo-hydraulically operated and supported on low-friction line friction bearings. A relatively simple system has been installed at structural dynamic laboratory to ensure adequate replication of input motion by earthquake. Shaking table test provides important experimental data about critical issue such as the effect of component damage on the system response, collapse mechanisms, residual deformation, and post-earthquake capacity. Even with this facility, most structural system is too large to test at or near full scale. Even with these recent advantages, structural testing has typically been conducted using customized software that is dependent on the configuration and computation procedure for the test method. Investigation on the dynamic behaviour of the large scale civil engineering structures such as buildings and bridges by performing full scale test is very difficult or often practically impossible to be realize due to the size, weight, and cost etc. therefore the behaviour of the whole structure is estimated generally based on the test results obtained by using scaled down model.

1.1 VIBRATIONS THEORY

Most structures are subjected to vibrations. Vibration means to mechanical oscillations about an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road. Vibration is occasionally "desirable". For example, the vibration motions of engines, electric motors, or any mechanical device in operation are typically unwanted. There are two types of the vibrations in the structural dynamics;

A) Free vibrations.

B) Forced vibrations.

These terms are described below.

Free Vibrations:

Free vibration occurs when a mechanical system is set off with an initial input and then allowed to vibrate freely. Examples of this type of vibration are pulling a child back on a swing and then letting go or hitting a tuning fork and letting it ring. The mechanical system will then vibrate at one or more of its “natural frequency" and damp down to zero.

Forced Vibrations:

In forced vibration the frequency of the vibration is the frequency of the force or motion applied, with order of magnitude being dependent on the actual mechanical system. Types of the structural vibration of the system are shown in Figure 1.

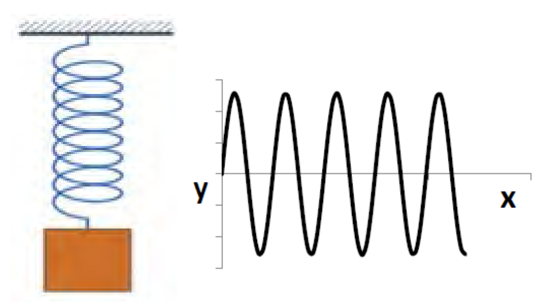


Fig. 1.1 Simple harmonic motion of the mass–spring system

It occurs when an alternating force or motion is applied to a mechanical system. Examples of this type of vibration include a shaking washing machine due to an imbalance, transportation vibration (caused by truck engine, springs, road, etc.), or the vibration of a building during an Some following Points are: earthquake.

These vibrations may arise from wind forces, earthquake excitations, machine vibrations, or many other sources. In some cases, especially under strong earthquake excitations,

1.2. SHAKE TABLE DESCRIPTION

A. Electro-dynamic 30 Kg-f Shake Table

The driven unit is having motor which is connected to eccentric cam unit through the coupling; the inner cam is connected to motor shaft and over which flywheel is mounted. A flywheel is having radial scale to adjust the amplitude; the outer cam is supported in the bearing block. The bearing block is connected to shake table. The shake table is having a platform over which rotary table is mounted and this table can be rotated in 360 degree with respect to fixed bottom circular plate. This unit is mounted on bearing and guided in horizontal direction with precious shaft. The shake table shown in Fig 2.1.

Fig. 1.2. Electro-dynamic 30Kg-f shake table.

Where, 1= Control Panel of Shake Table
2= Fly Wheel
3= Mounting Table

The models are tested on the 30 kg-f shake table for this study but in laboratory there are again two different shake table. One is 50 kg-f shake table and another one is 5000 kg-f shake table. In this paper results were taken from the 30 kg-f shake table. The properties of the electro dynamic shake table held at department of applied mechanics structural dynamic laboratory is given in the table 1.

Table.1 Properties of shaking table30Kg-f

Motion	Horizontal
Load Capacity	30 Kg
Operating Frequency	0-25 Hz
Frequency Control	‘+/-‘ 3%
Amplitude	0-10 mm
Resolution	1 mm
Table Size	400 x 400 mm
Rotating Table Diameter	390

B. FFT Analyzer:

The FFT (Fast Fourier Transformer) analyser is the one of the small handy equipment used in this experiment for transforming the sin wave/ vibrations into the numeric value. The diagram of the FFT anallyzer is shown in the Fig.3.

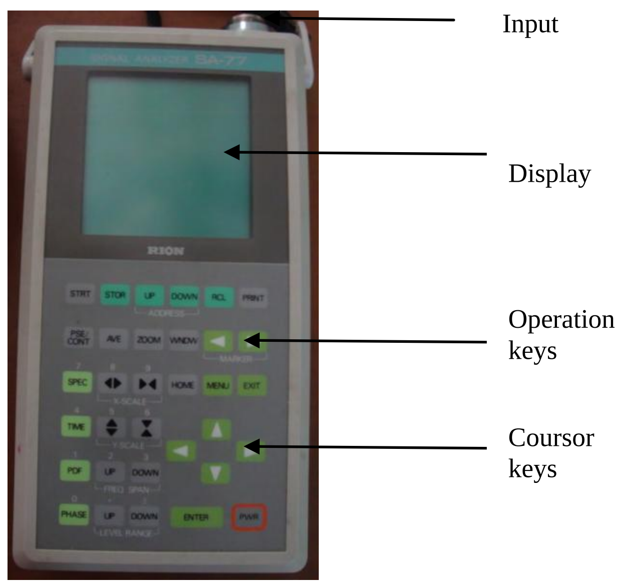


Fig 1.3. FFT Analyser.

The FFT (Fast Fourier Transform) is a faster version of the Discrete Fourier Transform (DFT). The FFT utilizes some clever algorithms to do the same thing as the DTF, but in much less time. Fourier's theorem states that any waveform in the time domain can be represented by the weighted sum of sines and cosines. The FFT spectrum analyzer samples the input signal, computes the magnitude of its sine and cosine components, and displays the spectrum of these measured frequency components. The advantage of this technique is its speed. Because FFT spectrum analyzers measure all frequency components at the same time, the technique offers the possibility of being hundreds of times faster than traditional analogue spectrum analyzers.

C. CONVERSION FACTOR FOR FFT:

As the FFT analyser taking the all vibrations in electrical wave format, so for converting the electrical signals into the amplitude readable format the following conversion is needed. The experimental results are as follows;

- *Calculation for Amplitude*

As we know the amplitude of the given electro-dynamic shake table used to perform the experiments. The amplitude of the shake table is 0.4 mm. It can be confirmed by using the FFT analyzer i.e. SA77 is used. And also having accelerometer PV 42 having sensitivity 5.39 mV/ (m/s2). The calculations are as follows; 1 m/s2 = 5.39 mV

V = 5.39 x10-2 Vr

V = 0.038 Vr

2. EXPERIMENTAL SETUPS

The frame in figure 4 can be approximately modeled as a three degree of freedom; the frame consists of four aluminum columns and two aluminum slabs each attached to the four columns. The entire structure assembly is placed on a shake table driven by an electric motor. The frequency of the shake table can be varied to achieve harmonic base motions at different frequencies. The parameters of the following model can be arrived at by the following usual assumptions made in construction of shear beam model.

Sr No.	Part	Dimensions in mm		
		Depth (D) mm	Width (W) / Thickness (t) mm	Length
1	Column	27	3	460
2	Slab	150	18	300

$$K_c = \frac{12EI}{L^3{}_A}; I = \frac{B_A D_A^3}{12}$$

$$K_1 = K_2 = K_3 = 4K_c$$

Here, E = Young's Modulus
I = Moment of Inertia
B_A = Breath of Column cross-section
D_A = Depth of Column cross-section
L_A = Length of column

As a part of this work we have electro-mechanical shake tables. Two of these provide horizontal base motions. Both these tables have the capabilities for applying harmonic base motions. The frame is rectangular in plan with stiffness and mass properties distributed uniformly in plan as well as in elevation. The model however is an idealized demonstration of this phenomenon since the building can only be subjected to harmonic base motions. The frequency of the base motion can be varied by changing the frequency of the control panel; it is also possible to vary the amplitude of the base motion by adjusting the flywheel this adjustment, however, requires somewhat involved manipulations. By changing the frequency it would be possible to set the frame into resonant motions, which would enable you to visualize the first three normal modes of the frame.

Fig. 2.1. Experimental setup for two-story building frame.

2.1. MODEL DESCRIPTION:

Description of model is shown in Table 2. Also in Table 3 material properties are shown.

Table 2. Geometric data of the structure

The models are shown in the Table 3. In which the whole specification is given. For the testing purpose different types of models were used and the geometry also to be different. Model 1 is made up of the composite material like aluminium column and the aluminium slab but the Model 3 is made up of the aluminium columns and the wooden slab with some weight on the slab. The FFT analyser is attach with the accelerometer and the accelerometer is attach at the middle of the slab for the input signals. The acceleration responses are displayed in volts in the FFT analyzer a sample calculation to convert volt into acceleration is given below

Sample calculation:

$\ddot{x} = 1.965E^{-05} V$

$\ddot{x} = \underline{(1.965EE^{-05}\ V \text{ x } 1m/s^2)}$

$(5.39E^{-03}\ V)$

$\ddot{x}\ (accl) = 3.66\ E^{-03}\ m/s^2$

$accl = amplitude \times \omega^2$

$$Amplitude = \frac{accl}{\omega^2}$$

$$\mathbf{A} = \frac{3.66\ E^{-03}}{(2 \times \Pi \times 5)^2}$$

$A = 3.7\ E^{-06}\ m$

$A = 0.0037\ mm$

$A = 0.0037 \times 25$

A = 0.09 mm

Table 3. Description of the model.

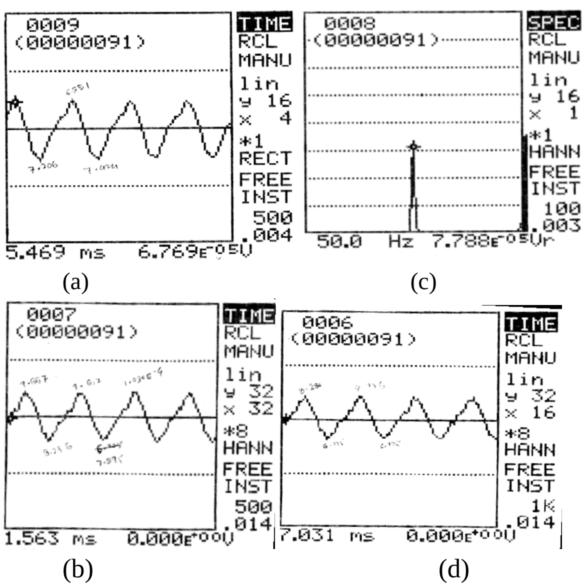


Fig.2.2. FFT Analyzer results for (a) & (b) for 1Hz frequency, (c) & (d) for 5Hz frequency.

3. RESULTS AND DISCUSSION

3.1. Time History Analysis:

Dynamic analysis can be performed either as time history analysis or by response spectrum analysis. Time history analysis is more sophisticated method and is rarely use for the design of ordinary structures. Time history analysis can be performed by the modal superposition method or by using direct integration of equations of motion. Experimental results are taken and compared with the analytical results obtained from SAP2000V14. Results are taking on electrodynamics shake table along with FFT analyzer. The graphs and results which compared also shown in tabulated form below.

3.2. Results of 30 Kg-F Shake Table

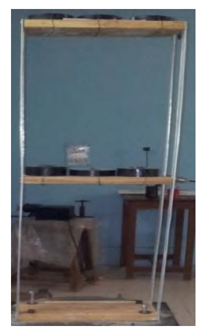
Results as shown in Table 3 and Fig2.2, Table 4. Results of 30Kg-f shake table platform. For the Model 1 and similarly for different model perform the test and finding the results.

Table 4. Results of 30 kg-f shake table.

File no	Frequency	Amplitude (mm) p-p		
		Table	FFT	Graph
6	1	10.05	7.79	10
7	1	10.05	9.36	10
8	5	10	7.32	10
9	5	10	6.36	10

4. CONCLUSIONS

- As here in this paper discuss only one result on the basis

Sr. No	Type & Material	Model	Geometry
3	G+1 Slab- wood Column Aluminium		L= 0.3 m B= 0.15 m H = 0.44 m T= 0.011 m

of different frequency. Here it seems that for the low frequency which is applied for the base excitation giving the results which is in the form of the volts 'V' and later on it converted into the 'mm'. The experimental results of various structural models were measured and compared with the analytical results from SAP2000V4.
- The experimental and analytical results were found to be in good agreement. The results are matching. For ground motion simulation, the displacement time history was observed to have an excellent match without any phase lag or peak-to-peak mismatch for larger displacement amplitudes associated with the typical real ground acceleration used for simulation.
- Further, acceleration time-histories also match well and both peaks and phases have been reasonably reproduced considering the simplicity of displacement as the only control variable.

- The construction and geometry of the shake table platform make it significantly rigid, as its fundamental frequency of vibrations is well above the frequency range in which the table has been designed to operate.
- The tests using harmonic signals show that the displacement time-histories of the commands and table response matched nearly perfectly for low frequencies.

7. FUTURE SCOPES

- However, some error was notices for high frequencies. Significant distortion was notices in the acceleration time histories, especially at the peaks, which is primarily due to relatively low-cost support bearings.
- For more study apply higher frequencies for different models and take results for the amplitude and the displacement and check for it with SAPV2000.
- The ground history for the acceleration study of the model will do which gives more accurate.
- Comparison between the acceleration ground history and the FFT acceleration graphs gives the brief idea about the motion and damages on the building by avoiding the log -log graphs study.

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