Experimental Study of Bare Frame Model with Friction Pendulum System

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Abstract— In order to control the vibration of building during seismic events, base isolators is most commonly used for energy absorption. It dissipates the energy by its own characteristics and also changes the dynamic behaviour of the building. Today there are number of types of isolators available in the market, which uses a variety of materials and designs to obtain various levels of stiffness and damping. They are usually provided at the bottom of the building. In present study an attempt is made to compare seismic parameters of bare frame model and bare frame with friction pendulum system (FPS). Inherent Damping, stiffness, acceleration, velocity and storey displacement are calculated and compared. Results and conclusions are prepared on the basis of experimental study.

Key words: Friction Pendulum System, FFT Graph, Shake Table, Sixteen Channel Vibration Analyser

I. INTRODUCTION

Base isolation is a widely used earthquake protection technology and research has demonstrated its viability which has led to its implementation in many applications. The base isolation system separates the structure from its foundation and primarily moves the natural frequency of the structure away from the dominant frequency range of the excitation. The philosophy behind the installation of base isolators is

- To lengthen the period of vibration of structure, so as to reduce the base shear and inertia forces.
- To providing additional damping for reducing the relative displacements across the isolators.

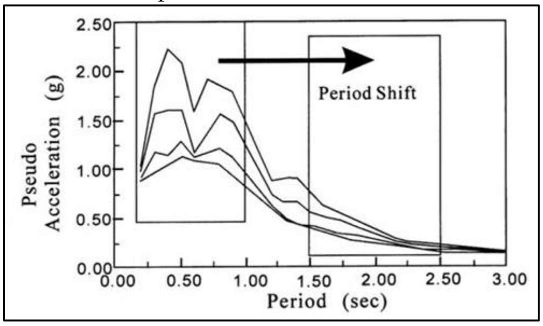

Fig. 1: Period Shift Effect

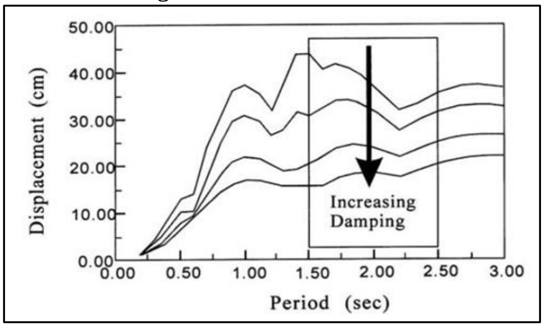

Fig. 2: Energy Dissipating Effect

II. MODEL SPECIFICATION

A three story building model is fabricated. The frame of model is square in plan as well as in elevation. Model is made up with steel bars and plates, there dimensions of model are as below.

A. Materials:

- All plates - 450 mm x 450 mm of 4.2mm thick (Mild steel)
- Columns -6 mm diameter rod (Stainless steel)
- Friction Pendulum System with top & bottom plates.

Two different models were considered for experimental study.

Fig. 3: Bare frame model

Fig. 4: Bare frame model with FPS

Element	Dimensions in mm		
	Thickness (T)	Width (B)	Length (L)
Column	Dia. of column = 6 mm		L = 300
Slab	T = 4.2	B = 450	L = 450

Table 1: Geometry of Bare Frame

III. FRICTION PENDULUM SYSTEM

Sliding friction pendulum isolation system is one type of flexible isolation system suitable for small to large-scale buildings. It combines a sliding action and a restoring force by geometry. The isolation system consists of FPS bearing which has an articulated slider and a concave surface. The resisting forces on the FPS are the sum of the restoring force due to the rise of the mass and the friction force between the slider and concave surface.

A-part of the bearing is the concave surface for the B-part on which articulated slider slides. Friction coefficient of that concave surface is 0.02 to 0.08. Friction coefficient of the concave surface is mostly very much important for the smoothness of the bearing. The coefficient of friction is dependent on the contact pressure between the Teflon-coated slider and the stainless steel surface.

Fig. 5: A-part of FPS

B-part of the bearing is connected with the part A & C. This part of the bearing is one type ball bearing.

C-part is connected with the part B & top plate.

Fig. 6: B-part & C-part of FPS

IV. EXPERIMENTAL TESTS

Different types of tests were conducted and analysis was done on the bases of experimental results.

Instruments used during testing of models

1) Sixteen Channel Vibration Analyser
2) Shake Table
3) Uniaxial & Triaxial sensors with cables

Various Tests Conducted on Models

A. *Stiffness Test:*

Stiffness was calculated for bare frame model with the assembly arranged as shown below. Load was increased on one side and displacement was calculated with the help of dial gauge. For calculating stiffness of 3rd story, 1st and 2nd story were locked with the help of hook.

Fig. 7: Stiffness Calculation of Third Storey

	3rd Story	2nd Story	1st Story
Experimental Stiffness (N/m)	20990.46	20679.48	21490.77
Analytical Stiffness (N/m)	22619.47	22619.47	22619.47

Table 2: Stiffness Test Results

$$\xi = \frac{1}{j * 2\pi} \ln \frac{\ddot{u}_i}{\ddot{u}_{i+j}}$$

B. *Free Vibration Test:*

Bare frame model was tested for free vibration and damping was calculated from free vibration test.

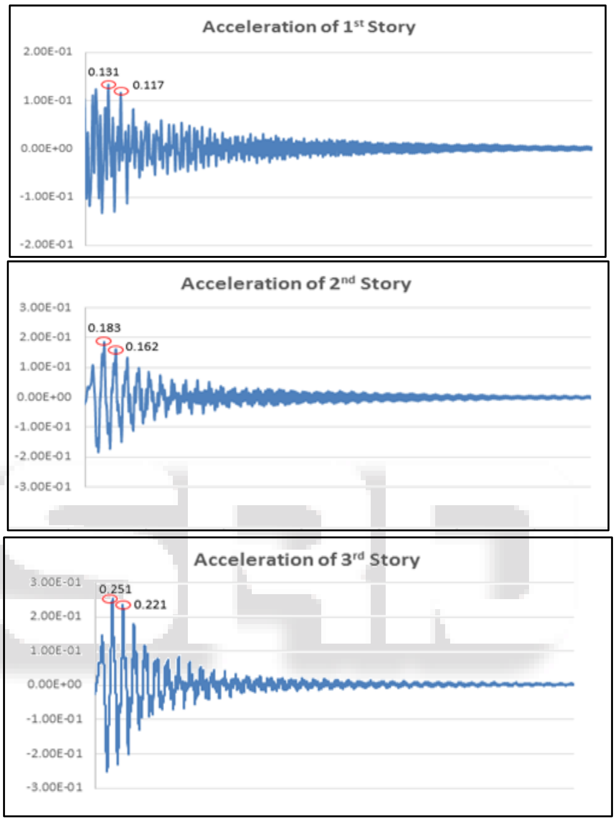

Fig. 7: Graphs

Critical Damping can be determined from the following equation [6]:

	1st Story	2nd Story	3rd Story
u_i =	0.131	0.183	0.251
u_{i+j} =	0.117	0.162	0.221
j =	1	1	1
ξ =	0.018	0.019	0.020
ξ (%) =	1.799	1.940	2.026
Avg. ξ (%) =	1.922		

Table 3: Equation for Critical Damping

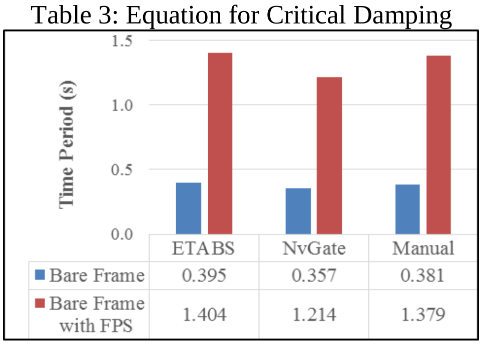

Fig. 8: Time Period Comparison

C. Shake Table Test:

Two different models were tested for given frequency of servo motor.

Frequency of servo motor	5 Hz
Displacement of shake table	+/- 15 mm
No. of Cycle Repeat	20
Actual frequency of shake table	1.875 Hz

Table 4: Shake table test

Fig. 9: Experimental Setup

1.875 Hz	Max Acceleration (m/s2)	Max. Velocity (m/s)	Max. Displacement (cm)
	0.6254	0.0646	3.623
1st Story	0.6296	0.0682	3.753
2nd Story	0.6348	0.0716	3.869
3rd Story	0.6512	0.0755	3.96

Table 5: Bare Frame Model Shake Table Test Results

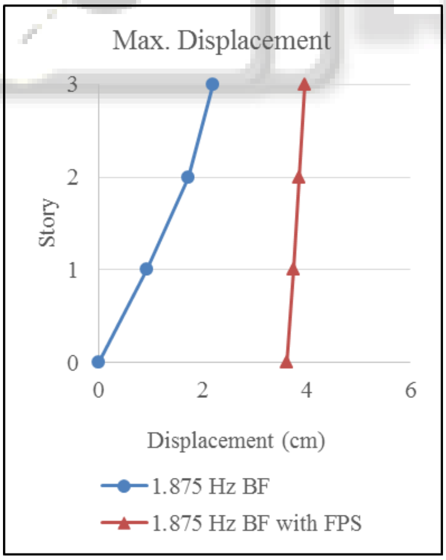

Fig. 10: Max. Story Displacement

1.875 Hz	Max Acceleration (m/s^2)	Max. Velocity (m/s)	Max. Displacement (cm)
1st Story	1.032	0.243	0.940
2nd Story	1.242	0.321	1.732
3rd Story	1.306	0.338	2.195

Table 6: Bare Frame with Fps Shake Table Test Results

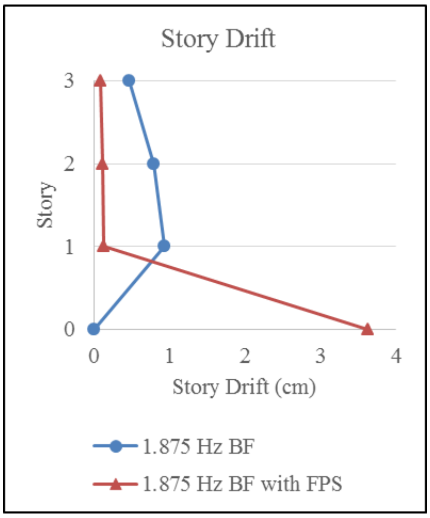

Fig. 11: Max. Story Drift

V. Conclusion

- In bare frame with FPS, acceleration is lower than bare frame and displacement is higher.
- No significant changes are shown in Acceleration, velocity & displacement in bare frame with FPS between different stories.
- Get critical damping 1.92 % in bare frame, which is compatible.
- Time periods calculated manually & given by NvGate & ETABS Software are close to each other.
- Experimental & Analytical Stiffness are also close to each other.

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