Seismic Analysis of High Rise Structure with Upper Slab Isolated System

Sandeep Bharne[1] Dr. Pankaj Singh[2]
[1]M. Tech. Scholar [2]Head of Department
[1,2]Department of Civil Engineering
[1,2]S.R.K. University, Bhopal, India

Abstract— Vibration absorbers consisting of a comparatively small mass-spring-dashpot system in resonance with the structure on which they are installed have been proven effective to reduce wind-induced vibrations in high-rise buildings, floor vibrations induced by occupant activity, and the seismic response of buildings. From the practical point of view, these vibration absorbers, first suggested by Frahm in 1909 and often called tuned mass dampers, represent an attractive alternative to protect structures against the detrimental effect of earthquakes. First of all, they require a relatively large mass and, hence, a large space for their installation. Melkumyan (2014), introduced the isolation techniques using laminated rubber bearing. Providing flexibility to the damper using laminated rubber bearings (LRBs) converts the system of an ordinary TMD into the system of an additional isolated upper floor – (AIUF), which actually is a roof isolation system.

Key words: Tuned Mass Damper, ISO (Isolated), Roof Isolation, Lead Bearing Rubber

I. Introduction

Study of seismic behaviour and performance of a multi-storied building with additional upper slab isolated is performed with three configurations, i.e. 6 storied, 9 storied and 14 storied structures. Each configuration is divided into 7 cases on basis of variation in mass of slab being isolated i.e. the mass of isolated slab kept equal to 3%, 4%... up to 9% of that of bare frame model. The typical height of the column is 3 meters. Plan of the structure is 16m X 16m with columns equally spaced at 4 meters. The structures are analysed for seismic loads using SAP2000 (Structure analysis program) software. To study the behaviour, parameters selected are lateral displacement, storey drift ratio, and base shear. All cases are assumed to be located in seismic zone 4.

Earthquake is a natural phenomenon which induces vibration in the structure. The seismic load acting on the structure due to the earthquake is the function of the dead weight of the structure. So there is a need to make high-rise structure lighter and flexible. System or structure subjected to earthquake or wind force must resist a part of later with its inertia. The inertia of structure is a function of the dimension of the structure. A certain amount of force is resisted by damping, which is an inherent property of materials used; vary with factors such as internal stressing, rubbing and plastic deformation of structural material. With these innovations, modern structures are provided with additional damping devices to maintain an equilibrium of structure. The degree of control on vibration due to unbalanced forces depends on the efficiency of a damping device which is attached to structure.

Taipei 101, a steel braced building is the 3rd tallest building in the world. Here the TMD was used for architectural purpose along with structural purpose. To reduce the vibration of the building sphere shaped TMD of weight 728 ton, diameter 5.5 m, between 88-92 floors is used. The enormous sphere was suspended by four set of cables, and the dynamic energy is dissipated by eight hydraulic pistons each having a length of 2 m. The damper can reduce 40% of the tower movement. Another two tuned mass dampers, each weighing 6 metric tons sit at the tip of the spire. These prevent damage to the structure due to strong wind loads. As shown in figure:

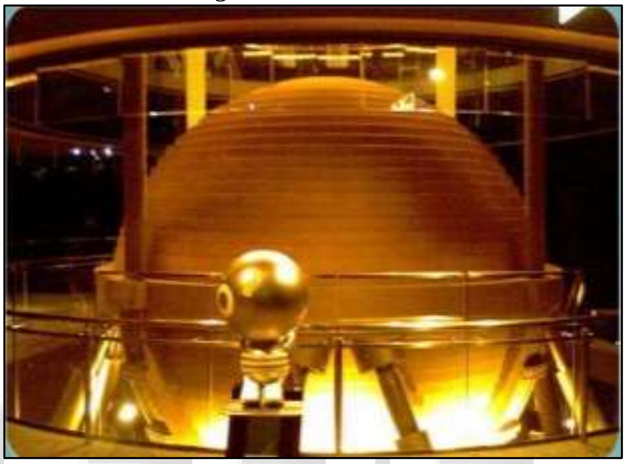

Fig. 1: Largest Tuned Mass Damper (Taipai 101)– 730 Tons, 5.5 m Diameter

II. Objective

1) To design RC (reinforced concrete) building as per IS 456-2000 and IS 1893-2002.
2) To analyse a model of proposed RC structures for time history of different PGA (peak ground acceleration) with and without roof slab isolation system.
3) To compare seismic performance of proposed roof isolated RC structures by story displacement, base shear and analyse results for variations.
4) To optimise the mass ratio (mass of slab to the mass of structure) that is more effective in terms of displacements, drift ratio and shear reduction.

III. Methodology

A. General

To study the seismic behaviour and performance of a multi-storied building with additional upper slab isolated, three configurations are used, i.e. 6 storied, 9 storied and 14 storied building. The basis of variation in mass of slab being isolated, the configuration of slab further divided into different cases.

To study the behaviour, parameters selected are lateral displacement, storey drift, and base shear. All cases are assumed to be located in seismic zone IV.

B. Description of Structure

Three-dimensional frame slab structure used in three configurations i.e. 6 stories, 9storey and 14 stories for the

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analysis purpose. The typical height of the column is 3 meters. Plan of the structure is 16m X 16m with columns equally spaced at 4 meters. The structures are analysed for seismic loads using SAP2000 (Structure analysis program) software.

C. Time-History Analysis Method

In this method mathematical model of the building subjected to accelerations from earthquake records that represent the earthquake records that represent the expected earthquake at the base of the structure. The method consists of a step by step direct integration over a time interval the equation of motion solved with the displacement, velocity, and accelerations of the previous step serving as initial functions.

1) General Parameters for Structure

S.No.	Specifications	Details
1.	Type of structure	Special RC moment resisting frame
2.	Seismic zone	IV
3.	Zone Factor	0.24
4.	Importance factor	1.2
5.	Response spectra	As per IS 1893 (part 1):2002
6.	Response reduction Factor	5
7.	Type of Soil	II
8.	Number of storey	6, 9& 14
9.	Floor Height	3 m
10.	Impose load	3 kN/m^2
11.	Materials	Concrete -M25 Reinforcement - Fe415
12.	Specific weight of RCC	25 kN/m^3
13.	Link Length	0.2 m

Table 1: General Parameters for Structure

D. Displacement

Lateral deflection is the predicted movement of a structure under lateral loads, and story drift ratio is defined as the ratio of the difference in lateral deflection between two adjacent stories to the height of that storey. During an earthquake, large lateral forces can be imposed on structures; both the 1997 UBC (the basis of the 2001 California Building Code) and ASCE 7-02 (which is based on NEHRP) require that the designer assess the effects of this deformation on both structural and non-structural elements. Lateral deflection and drift have three primary effects on a structure;

1) The movement can affect the structural elements (such as beams and columns);
2) The movements can affect non-structural elements (such as the windows and cladding);
3) And the movements can affect adjacent structures.

E. Base Shear

Apart from strain and derivatives, shear stress in columns is another important factor to be analysed. Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculations of base shear depend on soil conditions at the site and proximity to potential sources of seismic activity (such as geological faults). Analysing shear resistance would call the work complete.

IV. RESULT & DISCUSSION

The seismic performance evaluation of 6, 9 and 14 story building with top slab isolated by LBR is done by non-linear time history analysis method, and compared with bare frame structure. The parameters which are selected for comparing bare building with top slab isolated building are as follows:

1) Base Shear

It represents the shear force developed at the base due to ground motion.

2) Floor Displacement

It represents the story wise maximum floor displacement due to ground motion.

3) Drift Ratio

It is ratio of difference between the displacements of two adjacent stories due to ground motion divided by the storey height.

Notations followed in Graphs and Tables are as Follows:

1) Case 1: No Iso Bare frame structure i.e. without isolation
2) Case 2: Iso 3% Mass of slab = 3% mass of bare frame structure
3) Case 3: Iso 4% Mass of slab = 4% mass of bare frame structure
4) Case 4: Iso 5% Mass of slab = 5% mass of bare frame structure
5) Case 5: Iso 6% Mass of slab = 6% mass of bare frame structure
6) Case 6: Iso 7% Mass of slab = 7% mass of bare frame structure
7) Case 7: Iso 8% Mass of slab = 8% mass of bare frame structure
8) Case 8: Iso 9% Mass of slab = 9% mass of bare frame structure

A. Discussion

For more detailed understanding summarised behaviour of 6, 9 and 14 storied structures obtained by analysing it against time histories (YERMO1, YERMO Y, YERMO Z) was studied by percentage reduction base shear of structure for cases i.e. without and with top slab isolation where the weight of the top slab varies from 3% to 9% of total weight of bare frame structure. The plots obtained are in the X direction as follows:

Average X	% reduction
38.54%	Iso-3%
40.44%	Iso-4%
42.33%	Iso-5%
44.28%	Iso-6%
54.26%	Iso-7%
56.38%	Iso-8%
58.85%	Iso-9%

Table 2: 6-Storey Percentage reduction in base shear – 6 Storey – X Direction

Average X	% reduction
18.12	Iso 3%
23.98	Iso 4%
27.92	Iso 5%
31.66	Iso 6%

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32.14	Iso 7%
34.32	Iso 8%
35.73	Iso 9%

Table 3: 9-Storey Percentage reduction in base shear – 9 Storey – X Direction

Average X	% reduction
7.24	Iso 3%
8.59	Iso 4%
9.63	Iso 5%
11.29	Iso 6%
13.54	Iso 7%
15.42	Iso 8%
17.28	Iso 9%

Table 4: 14-Storey Percentage reduction in base shear – 14 Storey – X Direction

V. CONCLUSION

Base shear is found to follow the same pattern as noticed in deflection and drift. The reduction in base shear is significant in 6 and 9 storied structures but is not found effective for 14 storied structures. The reduction in base shear in 6 and 9 storied 6%-Iso models is found to be 44.28% and 31.66% respectively.

1) Additional upper slab isolation approach is effective for mid-rise buildings i.e. 6 storied and 9 storied configurations but not for high-rise 14 storied configuration.
2) On providing isolation, decrease in displacement below isolation for 9 and 14 storied structures is significant i.e. average of 44.28% and 31.66% respectively.
3) For 6 and 9 storied configurations, on increasing mass of slab above isolation, significant reduction in displacement is noticed and it is a most linear up to roof level.
4) The reduction in base shear in 6 and 9 storied 6%-Iso models is found to be 44.28% and 31.66% respectively.
5) The average percentage reduction of base shear for 14 storied structures is found low.
6) Providing additional upper isolation slab in mid- rise structures with slab mass ratio (mass of slab to mass of bare structure) 6 percentage is optimum for 6storied and 9 storied structures.

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