Analysis of RC Building Using Base Isolation and TM Damper System

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Abstract: - Used to protect the structures from the damaging effects of earthquake the installation of base isolators at the base increases the flexibility of the building structures and TM dampers reduce structural integrity with possibilities of failure. In this study reinforce concrete structures are taken for seismic performance evaluation. This RC building is modelled with different structural control system such as High Density Rubber Bearings, Friction Pendulum System and Tuned Mass Damper with use of commercial computer software ETAB. After that various ground motion data is applied to the building model to evaluate structural response. Nonlinear time history analysis is carried out for building model with each control system and the result of seismic response of each compared with other control system. The results obtained from analysis were base shear and Storey drift it is greatly reducing by use of FPS over HDRB and TMD. Also concluded that FPS gives maximum base displacement compared to HDRB and TMD.

Key Words: — ***Base isolation, Tuned Mass Dampers, Storey Drift, Base shear, Displacements, ETABS.***

I. INTRODUCTION

Earthquakes cause damage to structural element as well as non-structural element of building. Earthquake mainly affects structural components of lateral load resisting system. Earthquake produces huge amount of stresses and deformations on structural element of building. From last few decades' structural engineers have been doing research on the characterization and evaluation of structural damage. The different approaches to characterize damage such as ductility, drift ratio, maximum deformation, strain softening and energy dissipation characteristics at component, element or structural level.

Today large number of low rise or medium rise and high rise buildings existing in the world. Mostly these structures are having low natural damping. So, increasing damping capacity of a structural system, or considering the need for other mechanical means to increase the damping capacity of a building, has become increasingly common in the new generation of tall and super tall buildings. But, it should be made a routine design practice to design the damping capacity into a structural system while designing the structural system.

A. Base Isolation

To protect structures from earthquake damages, the use of base isolation systems has been suggested in contrast to the conventional technique of strengthening the structural members. The main concept in base isolation is to reduce the fundamental frequency of structural vibration to a value lower than the predominant energy containing frequencies of earthquake ground motions. The other purpose of an isolation system is to provide means of energy dissipation and thereby, reducing the transmitted acceleration into the superstructure. Accordingly, by using base isolation devices in the foundations, the structure is essentially uncoupled from the ground motion during earthquakes.

B. High density rubber bearings

The use of high density natural rubber bearings eliminates the need for supplementary damping devices. Their composition is similar to that of the natural rubber bearings except for the type of elastomeric material used. The increase in damping is achieved through the addition of fillers such as carbon, oils and resins. The addition of fillers increased the damping to 20-30% of critical damping. Basic functions of HDRB are as follows:

- Vertical load bearing function: Multilayer construction rather than single layer rubber pads provide better vertical rigidity for supporting a building.
- Horizontal elasticity function: With the help of HDRB earthquake vibration is converted to low speed motion. As horizontal stiffness of the multi-layer rubber bearing is low, strong earthquake vibration is lightened and the oscillation period of the building is increased.

- Restoration function: Horizontal elasticity of HDRB returns the building to its original position. In a HDRB, elasticity mainly comes from restoring force of the rubber layers. After an earthquake this restoring force returns the building to the original position.
- Damping function: Provides required amount of damping up to a higher value.

C. Friction Pendulum bearings

The building is supported by bearing pads that have a curved surface and low friction. During an earthquake the building is free to slide on the bearings. Since the bearings have a curved surface, the building slides both horizontally and vertically. The advantages of FPS are as follows:

- It is possible to set the oscillation period of a building regardless of its weight.
- This system can reduce costs not only because of low cost of its device but also due to the low cost of installation.
- The device is simple, works well and easy to install. Furthermore, it saves space and is practical for a seismic reinforcement.
- Performance of such device is stable due to the high durability of the device.
- As it requires only a simple visual check to maintain the device, maintenance is very easy.

D. Dampers

The control of structural vibrations produced by earthquake or wind can be done by various means such as modifying rigidities, masses, damping, or shape, and by providing passive or active counter forces. To date, some methods of structural control have been used successfully and newly proposed methods offer the possibility of extending applications and improving efficiency.

TMDs have been successfully installed in high-rise buildings and towers all over the world. TMD is attached to a structure in order to reduce the dynamic response of the structure. The frequency of the damper is tuned to a particular structural frequency so that when that frequency is excited, the damper will resonate out of phase with the structural motion. Then the excess energy that is built up in the structure can be transferred to a secondary mass and is dissipated by the dashpot due to relative motion between them at a later time. Mass of the secondary system varies from 1-10% of the structural mass.

II. Structural Modeling

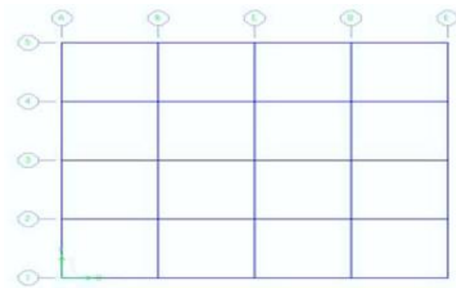

Fig.1.Plan of RCC Building

The study is carried out for RCC building in ETAB software using High Density Rubber Bearing (HDRB) & Frictional Pendulum System (FPS) isolators and Tuned Mass Damper (TMD). The numerical data for (G+20) storey RCC buildings are shown in Table.

Table 1: Design Data for RCC Building

Live load	3 KN/m^2
Earthquake Data	Bhuj Earthquake ground motion 1.078g
Depth of foundation below GL	1.5 m (consider as fixed)
Storey height	3.0 m for all storey
Plinth height	1.5 m
Size of Beam	0.35m x 0.5m
Size of Column Ground to 4 th storey	1.0m x 1.0m
Size of Column 5 th to 9 th storey	0.75m x 0.75m
Size of Column 10 th to 20 th and	0.6m x 0.6m
Size of Column 10 th to 20 th and	130 mm thick as rigid diaphragm
Material Properties	Concrete- M25 HYSD reinforcement of grade Fe 415

A. Properties of HDRB & FPS

As design example we consider a G+20 storey structures. Which designing the High Damping Rubber Bearing & Friction Pendulum System, we consider the site to be situated in zone 5 with S_D soil type and assumed that site is not less than 15 km from known active fault. Using UBC-97 Appendix Chapter 16 requirements, the parameter associated

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with location are Z-0.4, Soil type - S_D, N-1. The structural system can be taken as special moment resisting frame. The properties required for the modeling of structures with base isolation in ETAB software for both High Density Rubber Bearing and Friction Pendulum System for (G+20) storey RCC structure are shown in Table 2.

Table.2. Properties of Isolators for (G+20) storey structure.

Types	HDRB	FPS
Vertical Stiffness (U1)	3908894.085 KN/m	39088941 KN/m
Linear Stiffness (U2 & U3)	2168.09 KN/m	1954 KN/m
Non-linear Stiffness (U2 & U3)	1719.90 KN/m	39088 KN/m
Yield Strength (Q)	150.44 KN	-
Damping (β)	0.13	0.10
Radius of dish (R)	-	1.51 m
Friction Coefficient, Fast	-	0.05
Friction Coefficient, Slow	-	0.03

B. Properties of Tuned Mass Damper

The properties of tuned mass damper are calculated based on optimum parameter given by Den Hortog. The stiffness and damping of TMD are calculated for different mass ratio as shown in Table 3.

Table.3. Properties of Tuned mass damper

			G+20 storey	
Mass ratio (μ)	Frequency ratio (α)	Damping ratio (ξ)	Stiffness of TMD (Kd)	Damping of TMD (Cd)
0.01	0.988	0.061	7934	117.7
0.02	0.975	0.086	15480	328
0.03	0.964	0.105	22656	593.8
0.04	0.952	0.121	29479	901
0.05	0.94	0.135	35966	1241

III. Results And Discussion

Total 4 analyses were done for four (G+20) storey buildings by using HDRB & FPS isolators and TM damper by using earthquake ground motion data.

A. Base Shear

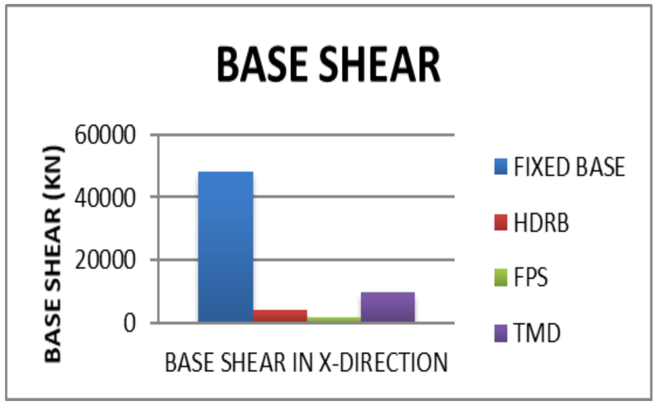

Fig.2.Base Shear in X-Direction

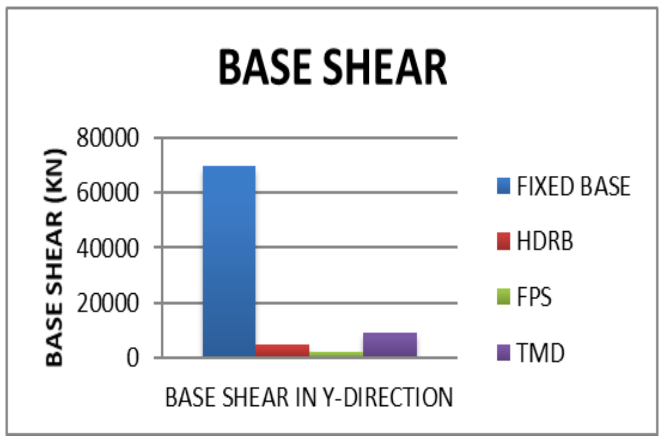

Fig.3.Base Shear in Y-Direction

It is seen that base shear in X-direction is reduced by 96% and in Y direction it is reduced by 97% for the case of Friction Pendulum System when compared with fixed base. The base shear in X-direction is reduced by 91% and in Y-direction it is reduced by 93% for the case of High Density Rubber Bearing When compared with fixed base. The base shear in X and Y direction is reduced by 80% and 87% respectively for the case of Tuned Mass Damper when compared with fixed base.

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B. Storey Displacement

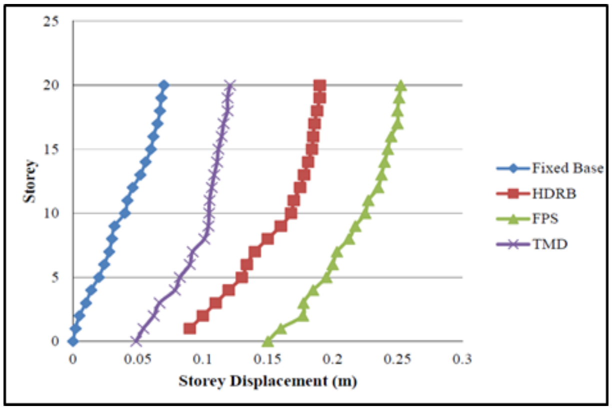

Fig.4. Storey Displacement

It is seen that base displacement given by friction pendulum system isolator compared to the high density rubber type isolator and tuned mass damper. But maximum top displacement is given by high density rubber bearing type isolators.

C. Storey Drift

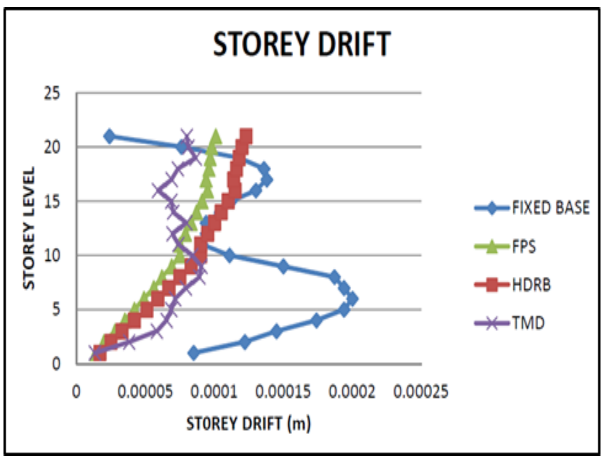

Fig.5.Storey Drift

It is seen that storey drift was greatly reduces by friction pendulum type isolator compared with high density rubber bearing and tuned mass damper. Both type of isolator and tuned mass damper reduce drift at greater extent compared with fixed base structure.

D. Storey Shear

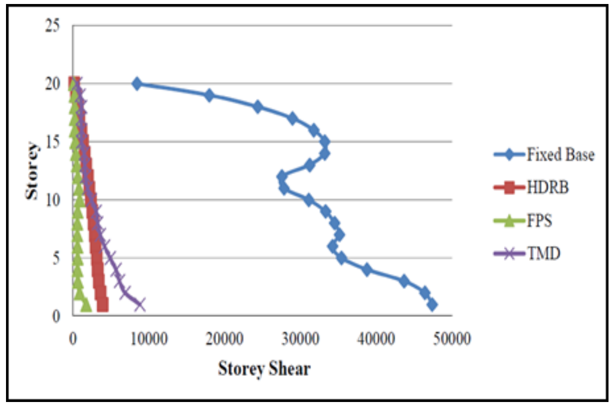

Fig.6. Story Shear in Y-Direction

Storey shear was greatly reduces by the use of friction pendulum type isolator compared with high density rubber bearing isolator. It was 50% reduce storey shear in friction pendulum type isolator than density rubber bearing isolator and 60% more reduce storey shear in friction pendulum type isolator compared with tuned mass damper. Both types of isolators and tuned mass damper reduce storey shear at greater extent compared with fixed base structure.

E. Storey Acceleration

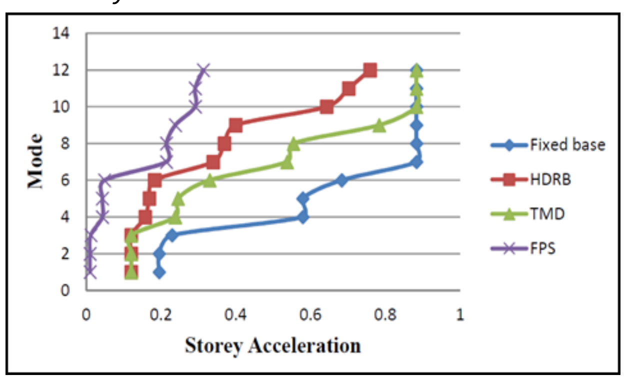

Fig.7.Story Acceleration

Storey Acceleration was greatly reducing by the use of friction pendulum type isolator compared with high density rubber bearing isolator. Both types of isolators and tuned mass damper reduce storey shear at greater extent compared with fixed base structure.

IV. CONCLUSION

- Tuned mass damper installed at the top of building gives better performance during earthquake excitation.

- Tuned mass damper and isolation system with optimum parameters reduces displacement and acceleration significantly.
- It is concluded that time period of the structure in case of FPS, HDRB and TMD it is increased over conventional fixed base structure.
- It is concluded that base shear of structure reduces by the use of base isolator and tuned mass damper. But it is greatly reducing by use of FPS over HDRB and TMD.
- It is also concluded that FPS gives maximum base displacement compared to HDRB and TMD.
- Storey drift is reduce by both TMD, HDRB and FPS. But it is greatly reducing by the use of FPS.
- It is seen that base isolation technique lengthens the time period of structure at greater extent for midrise structure. But, as the number of stories goes on increasing the proportion of increment in time period of base isolated structure goes on decreasing.
- It is concluded that as the number of storey increase, the friction pendulum system gives minimum value for top displacement. Hence, it is concluded that this type of system helps to minimize top displacement for multi storey structure.
- Maximum reduction in lateral displacement for mass ratio 0.05 was observed for building employed with TMD.
- Maximum reduction is observed in maximum base shear and maximum bending moment for mass ratio of 0.05 for building with TMD.
- Maximum reduction in drift is observed for mass ratio 0.05 for building with TMD.
- It is concluded that Friction Pendulum system helps in reducing storey drift &storey acceleration at greater extent than High Density Rubber Bearing and tuned mass damper for both mid-Storey and multi-storey structure.
- Friction pendulum system is beneficial than tuned mass damper & slightly higher than high density rubber isolator in terms of cost.

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