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Seismic analysis of high-rise building with tuned mass damper and core column

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Abstract. Earthquakes are one of the most vulnerable disasters that effected many countries including India. Due to continuous ground motions caused by an earthquake the structure gets damaged or even collapses causing human loss, property loss and psychological fear among humans. Many techniques are available to resist the structure from seismic loads like base isolation devices, seismic dampers, shear walls, outrigger structure, braces. All of these devices aid in lowering the structure's responsiveness, but they also have their limitations. Once a major earthquake strikes the structure, these devices must be replaced. The newest technology structures that use Tunes Mass Damper (TMD) and ancient technology Core Column (central pillar or shinbashira) function better during earthquakes. In order to reduce the vibration of the building, the TMD is tuned to the same damping ratio of the main structure, whereas Core Column is placed at the centre of the building throughout the height. In this project, a 40-storey three dimensional RCC building without any devices, with TMD and with Core Column in seismic zones V, with soil type-medium will be modelled and analysed using SAP2000 v.20 software. As to IS 1893: 2016 Part-1, dynamic analysis, such as Time History analysis of Bhuj 2001 earthquake and El – Centro 1940 earthquake will be performed. Maximum displacement, storey drift, and maximum accelerations are recorded as responses to the analysis. The data from the results are plotted using MATLAB software.

1 Introduction

Continuous seismic waves that go through the earth and create ground trembling might be extremely strong or very weak. For machinery, seagoing vessels, aircraft, the space shuttle, and the infrastructure industry, vibration control is essential.

One of the most significant natural disasters is an earthquake. The abrupt shaking of the ground brought on by the passage of ground waves is known as an earthquake. When large rocks in the earth's crust rub up against one another, seismic waves are created. They have caused untold numbers of fatalities and unfathomable amounts of property damage. Other types of earthquakes include volcanism, which involves volcanic eruptions, tsunamis, which are earthquakes brought on by big underwater nuclear explosions, and deep mine excavation. The effects of earthquakes are extensive and include altered geological features, structural damage, effects on people physiologically and psychologically, as well as effects on animals.

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This can cause serious damage to structures like buildings, bridges, monuments, railroads, and roads. In India, reinforced buildings are increasingly common, especially in cities and towns. Buildings collapse as a result of the horizontal pressure caused by earthquake waves. Most of the time, collapsed structures result in the loss of millions of rupees and multiple fatalities. We must build the structures to be earthquake-proof in order to protect them from this tragedy. The structure can be protected by having a flexible foundation so that when an earthquake strikes, only the base moves and the structure remains stable. Another method is to use damping, where a large weight device or hydraulics moves in the opposite direction of the earthquake's movement to dampen or dissipate the energy. Braces, tuned mass dampers (TMD), core columns, and many more earthquake-resistant devices are available and in use. Dampers protect the building from vibrations and strengthen it using earthquake-resistant materials.

1.1 Tuned Mass Damper

A tuned mass damper, times referred to as a seismic damper, is a mechanical device created to add damping to a structure for a specific range of excitation frequencies. The additional dampening will bring down the structure's movement to a manageable level. By absorbing the energy from the system, TMD lowers the vibration's amplitude. It is a covert mechanism that is employed in skyscrapers to shield both the buildings and the occupants from the powerful wind and seismic action. TMD is constructed of 300-800 tonnes of steel and concrete. It lessens damage to the building and structural component failure, as well as the discomfort of those who live there.

Components of tuned mass damper

1. Spring
2. Mass
3. Damper

Types of tuned mass damper

1. Horizontal TMD – It is generally used in slender buildings, communication towers, etc.
2. Vertical TMD – It is generally used in long horizontal span structures like bridges, floors and walk ways.

A. Tuned Mass Damper Optimization

The fundamental concepts of Tuned Mass Dampers for lowering structural response are well known, but determining the best Tuned Mass Damper configuration is a completely separate issue.

It would be ideal to give appropriate damper parameters when designing any control device to suppress unwanted vibrations in order to maximise its efficiency. The components of a typical tuned mass damper are a mass "m" that moves in relation to the structure and is fastened to it by a spring with stiffness "k" and a viscous damper with coefficient "c."

The tuning, mass, and damping ratios of a tuned mass damper define it. The fundamental frequency difference between the Tuned Mass Damper's ωt and the building's ωo fundamental frequencies is known as the tuning ratio 'f'.

$$f = \frac{\omega t}{\omega o}$$

$$\mu = \frac{m}{M}$$

μ = Mass ratio
m = TMD mass

M = Generalized mass of MDOF structure

Damping ratio is given by $\xi = \frac{c}{2m\omega t}$

1.2 Core Column

The central pillar that supports a building's whole height is referred to as the core column. It is a more than a thousand-year-old example of a traditional Japanese pattern known as shinbashira. This is the Japanese pagoda's movable centre pillar. It is displayed in the middle of the building. The oil dampers, a mechanism that dampens unwelcome vibrations, are used to connect the column to the main structure rather than directly. The structure and core column sway in the opposite directions. Due to this, the entire structure vibrates 50% less during earthquakes and 30% less during severe winds. It was recently employed in the Tokyo Sky tree, a structure whose purpose is to eliminate the swing of the building. This technique was more recently used in San Francisco to renovate the fourteen-story, steel-built 680 Folsom Street building from the 1960s. The pillar framework is made from straight Japanese pine trunks. (hinoki). The pillar runs the whole length of the construction, starting at the top "layer" of the pagoda, where it supports the finial. The shinbashira is a typical element of pagodas in Japan that frequently experience earthquakes; however, it is not present in China or Korea because those nations rarely, if ever, experience earthquakes, and other techniques have been developed there in its place.

1.3 Software used

A general-purpose civil engineering programme called SAP2000 V.20 is ideal for jobs including engineering related to transportation, commercial public works, residential constructions, etc. To model, analyze, design, and optimise simple and complex systems, spanning from 2D to 3D, of simple geometry to complex, one can use an efficient and user-friendly object-based modelling environment that streamlines and speeds the engineering process. The models created using the members represent the physical reality because they are object-based. Instead of presenting analysis and design results for each individual component element, the full structure is shown, making the information easier to understand and more in accordance with the actual structure. It displays deformed geometry on any load or combination of loads as an output. All input data, analytical results, and design outputs can all be displayed in tables. Additionally, it creates video files to graphically represent a collection of study results that change over time, such as in a time history analysis.

2 Review of Literature

Anmol Gupta and J N Vyas (2022) had previously conducted research and reached the following conclusion: determine the TMD's ideal positioning in the structure by determining the maximum and minimum displacement and storey drift under response spectrum analysis. He was aware of how time history analysis and response spectrum analysis result in the production of spectral acceleration. He investigated the application of TMD in an atypical building and at various floor levels.

Vuyyuri Raghu and Ch. Bhavannarayana (2022) had claimed that the G+15 building's use of TMD has resulted in less story drift than other seismic devices. Storey drift, accelerations, natural time period, and displacement amplitude have all been decreased.

Daniel Caicedo et al. (2021) had found that using TMDs with the best possible designs makes them appear as a better alternative for controlling seismically excited structures. TMD typically contributes to decreases in the horizontal peak displacements, RMS response of displacement, and horizontal peak floor acceleration of up to 14%, 24%, and 17%, respectively.

Md Matiur Rahman, Tahmina Tasnim Nahar et al. (2021) has used TMD to low-rise, medium-rise, and high-rise structures. The regulations of the Korean Building Code are followed when designing frames. The reduction of peak lateral displacement by TMD is believed to be possible at any height, but not always in the same way; it relies on the ground motion frequencies. Peak deflection was noticeably reduced for low- and medium-rise buildings, but not significantly for high-rise structures. The structural capacity of high-rise buildings rose by 26%. At a particular ground motion, TMD performance is better in the low-frequency content zone than in the higher-frequency content zone.

Prateek Papriwal and Nivedita et al. (2021) has said that TMD performs better on the upper deck than the other, and that the first mode's inherent frequency produces the best outcomes. TMD successfully lowers acceleration and displacement.

Wenxi Wang and Zhilin Yang et al. (2021) said that this research looks at how well a pendulum-pounding tuned mass damper (PPTMD) controls the seismic response. The usage of the pounding damping method was looked into. In order to dampen the pounding, a layer of VE material was applied to the pounding barrier using the HEDR materials. The matching and variable analytical investigation were done on a PPTMD property. We offered the most effective parameter formulas. Experimentally and mathematically, the suggested PPTMD's control skills were evaluated. utilising various seismological recordings and tuning conditions. It is shown that the PPTMD developed utilising the optimal parameter formulas is useful in reducing the seismic response of low-damped buildings. Forecasting the seismic response of the coupled system between the structure and the PPTMD, which includes the structural reaction and impact force, is possible using the given simulation approach. Evidence is provided via shake table tests. the degree to which the PPTMD is successful in minimising seismic response. The fundamental weakness of the conventional TMD can be fixed by using a 15% frequency detuning while still achieving the large control impact of the PPTMD. The effectiveness of PPTMD's control reduces as the inherent damping of the fundamental structure grows.

Toshikazu HANAZATO et al. (2010) has performed a analysis on five-story pagoda that had seismic monitoring done on it experienced displacement of 4 millimetres in the X and 5.3 millimetres in the Y directions, with maximum storey drifts of 1 in 5300 and 1 in 4000 in the X and Y directions, respectively.

Toshikazu HANAZATO et al. (2004) has conducted research on a conventional, five-story pagoda. Both EW and NS experience displacement of 0.340 and 0.350 mm, respectively.

3 Gap of study

In India, the construction of tall buildings has increased quickly posing fresh obstacles that require solutions technical judgement. It's crucial to choose the right structural system for a tall building that will be susceptible to lateral loads. In order to minimise lateral displacement and storey drift, a structural system called a tuned mass damper system has been used. However, when a building's height increases, it lacks the necessary rigidity to keep the storey drift within acceptable bounds. A structural mechanism called TMD (tuned mass damper) was developed for such tall constructions. With the use of this method, structure movement, storey drift, and lateral displacement are all reduced.

4 Objectives

The aim of this research is to study about the effect of Tuned Mass Damper and Core Column on a high-rise building and their response to earthquake.

1. Modelling of G+39 RC building.
2. To perform seismic analysis on RC building using Time History Analysis and finding out the parameters like displacement, storey drift.
3. To perform seismic analysis on RC building with Tuned mass damper using Time History Analysis.
4. To perform seismic analysis on RC building with Core column Time History Analysis.
5. Comparing the structure with TMD and Core Column.

5 Methodology

A division of structural analysis is seismic analysis. It is used to determine how a structure, such as high-rise buildings, will respond to earthquake loads. It is a component of structural design, monitoring structural health, and retrofitting, primarily in earthquake-prone locations. In high-rise structures or during an earthquake, a building may wave (move) forward and backward. The fundamental mode, which has the lowest frequency of the structural response, is referred to as such. Although structures have stronger reaction mechanisms that become active during earthquakes. It is stated that in most situations, the first two types likely to cause the most damage.

There are two types of seismic analysis

1. Static analysis
    a. Linear analysis – also known as Equivalent static analysis
    b. Non-linear analysis – also known as Pushover analysis
2. Dynamic analysis
    a. Linear analysis – also known as Response spectrum analysis
    b. Non-linear analysis – also known as Time-History analysis

The essential values of acceleration, displacement, and duration for the structure's response, which includes inertial effects, are provided by time history analysis, a sophisticated form of response spectrum analysis. It is helpful to understand how a building would behave when subjected to seismic waves, especially for high-rise buildings. Historical earthquake data are required to complete the analysis. It is an in-depth analysis of how a structure reacts to a certain load that could change over time. The PEER ground motion database website provides access to previous earthquake data.

5.1 BUILDING MODEL

Design data of the building

1.	Building type	: Residential Building
2.	No. of storeys	: G+40
3.	Building height	: 130m
4.	Storey to storey height	: 3.15m
5.	Material used	
	a. Concrete grade	: M40
	b. Steel grade	: HYSD Fe415
6.	Soil type	: Medium stiff (II)

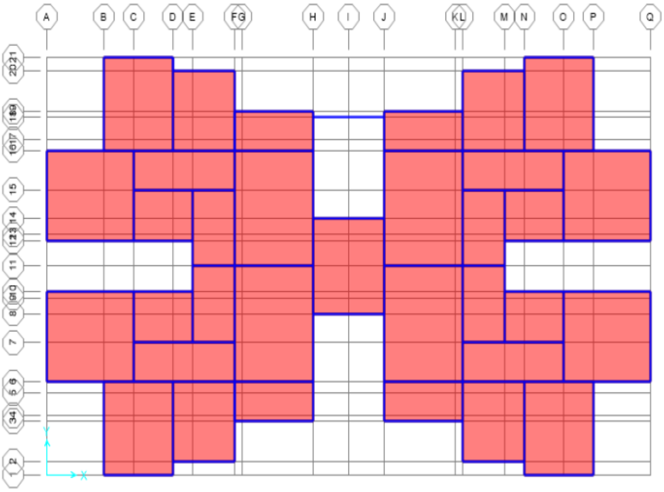

Fig 1 Plan of the Building

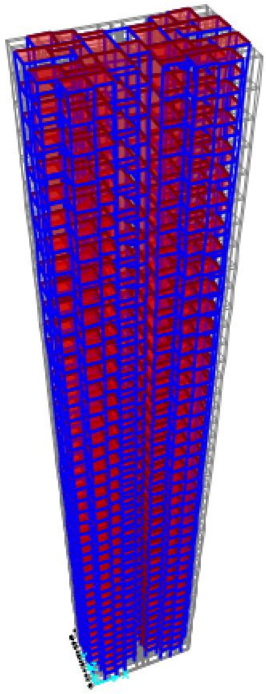

Fig 2 Elevation of the Building

6 Results

After performing the analysis in the software, the results are derived.

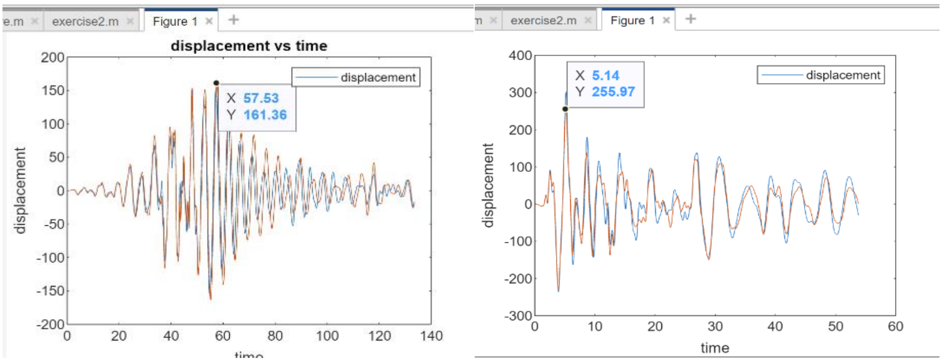

Fig 3 Displacement vs time graph for Bhuj and El-centro

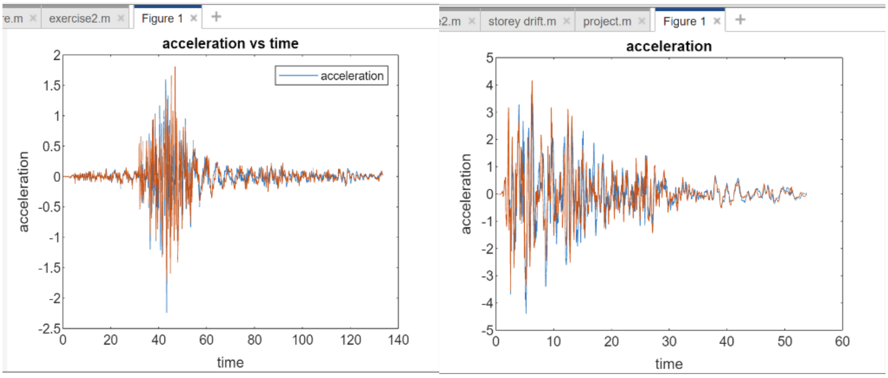

Fig 4 Acceleration vs time graph for Bhuj and El-centro

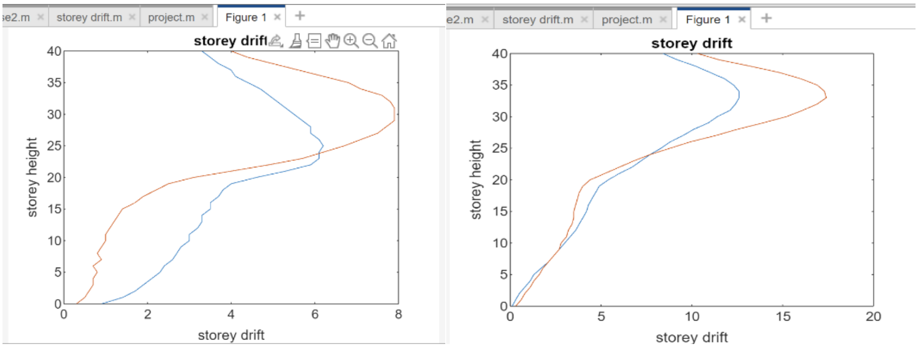

Fig 5 Storey Drift for Bhuj and El-centro

7 Conclusion

1. The results show that, Time History analysis shows better and accurate results.
2. From fig 3, we can say that maximum displacement for El-centro is 301.64mm in X-direction and 257.37mm in Y-direction, whereas for Bhuj earthquake maximum displacement is 153.28mm in X-direction and 161.36mm in Y-direction.
3. From fig 4, we can say that maximum acceleration for El-centro is 3.5864 m/s^2 in X-direction and 4.15436 m/s^2 Y-direction, whereas for Bhuj earthquake maximum displacement is 1.58944 m/s^2 in X-direction and 1.80496 m/s^2 in Y-direction.
4. From fig 5, we can say that maximum storey drift is 17.4mm in X-direction and 12.6mm in Y-direction at storey level 32 for El-centro earthquake and 7.9mm in X-direction at storey level 28, 6.2mm in Y-direction at storey level 24 for Bhuj earthquake.
5. Maximum response (Displacement, Storey drift, Acceleration) of the structure are seen in El-centro earthquake compared to Bhuj earthquake.

References

1. Anmol Gupta and J N Vyas. *IJSRD,* 210-214, (2022).
2. Raghu, V. *Journal of Engineering Sciences*, *13*(07)., 751-757, (2022).
3. Caicedo, D., Lara-Valencia, L., Blandon, J. and Graciano, C. *Journal of Building Engineering*, *34*, 101927, (2021).
4. Rahman, M.M., Nahar, T.T. and Kim, D. *Buildings*, *11*(2), p.74, (2021).
5. Srinivasa Reddy, V., Seshagiri Rao, M.V., Shrihari, S., International Journal of Engineering and Advanced Technology, 8(6), pp. 1661–1665 (2019)
6. Srinivasa Reddy, V., Seshagiri Rao, M.V., Shrihari, S., International Journal of Recent Technology and Engineering, 8(2), pp. 2125–2130 (2019)
7. Kumar, K.S.J., Seshagiri Rao, M.V., Reddy, V.S., Shrihari, S.. E3S Web of Conferences, 184, 01076 (2020)
8. Srinivasa Reddy, V., Krishna, K.V., Rao, M.V.S., Shrihari,. E3S Web of Conferences, 309, 01058 (2021)
9. Reddy, V.M., Hamsalekha, S., Reddy, V.S. AIP Conference Proceedings, 2358, 080018 (2021)
10. Reddy, V.S., Satya Sai Trimurty Naidu, K., Seshagiri Rao, M.V., Shrihari, S.. E3S Web of Conferences, 184, 01082 (2020)Papriwal, P. and Nivedita, P.V. Influence of Vibration in High-Rise Building with Tuned Mass Damper Account into Diverse Loads. *International Research Journal on Advanced Science Hub,*156-163, (2021).
11. Wang, W., Yang, Z., Hua, X., Chen, Z., Wang, X. and Song, G. *Engineering Structures*, *228*, 111554, (2021).
12. Hanazato, T., Minowa, C., Niitsu, Y., Nitto, K., Kawai, N., Maekawa, H. and Morii, M. In *Advanced Materials Research*, 79-95, (2010).
13. Hanazato, T., Fujita, K., Sakamoto, I., Inayama, M. and Ohkura, Y. *Analysis of earthquake resistance of five-storied timber pagoda*. In Actas 13th World Conference on Earthquake Engineering, August, 2004, pp. 1-6. (2004)
14. Dr. G V V Satyanarayana and A Maheswar Reddy. *IJIRSET,* 59-67, (2018).