INVESTIGATION ON SEISMIC BEHAVIOUR OF RCC FRAMED STRUCTURE WITH TUNED LIQUID DAMPERS.

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Abstract— This paper presents the numerical analysis of a G+6 storey RCC [Reinforced Cement Concrete] framed structure equipped with TLDs of two different shapes: square and cylindrical. The main objective is to understand how the shape of the damper influences the building's response during an earthquake. ETABS software is used to model and analyze the structure under seismic loads. Dynamic analysis methods such as Response Spectrum Analysis are recommended by IS 1893 (Part 1):2016, are used to study parameters like lateral displacement, inter-storey drift, and base shear.

Index Terms— Framed structure, Response Spectrum Analysis Seismic Analysis, ETABS, Dynamic Response, Base shear, Storey Drift, TLDs, Earthquake Resistance, Numerical Modelling.

I. INTRODUCTION

In the evolving landscape of structural engineering, the resilience and dynamic performance of high-rise buildings have become critical considerations in design, particularly in regions prone to seismic and wind-induced excitations. Among various vibration mitigation strategies, Tuned Liquid Dampers (TLDs) have emerged as a cost-effective and efficient solution due to their ability to dissipate dynamic energy through fluid motion and wave generation within a container (Sun et al., 1992; Banerji & Fujino, 1994) with the help of ETABS software.

This project focuses on a G+6 RCC framed structure, analyzing its dynamic response when integrated with TLDs of varying geometric configurations. ETABS software is widely used for the structural analysis and design of the structure and also used to model and simulate the behavior of the RCC structure under different loads. Comparison of two different structure for the difference structure.

High-rise buildings are susceptible to seismic forces, which can lead to significant structural damage. Traditional methods of enhancing seismic resistance often involve increasing the building's mass or stiffness. However, these approaches can lead to increased costs and material usage.

Tuned Liquid Dampers (TLDs) offer an efficient alternative by utilizing the dynamic properties of liquid sloshing to TLDs operate on the principle of resonating liquid motion counteracting building vibrations, making them a promising choice for structural retrofitting. However, the shape of the liquid container influences its damping efficiency. While previous studies have focused mainly on rectangular tanks, comparative analysis of square and circular shapes remains limited, especially in the context of Indian seismic zones.

II. LITERATURE REVIEW

1) Lalit Arya et.al (2020): This study focused on the vibrational load controlling is an important aspect while designing the structure get subjected to substantial vibrations due to wind and earthquakes. At the point when a quake waves travel through the structure, it is oppressed huge powers, speeding up and uprooting that makes the structure profoundly insecure and inevitably it breakdown. Seismic examination is a subset of basic investigation and is the estimation of the reaction of a structure exposed to seismic risks. A liquid damper is water confined in a container that uses the sloshing energy of the water to reduce the dynamic response of the system when the system is subjected to excitation.

2) Roshni and Ritzy (2015): An investigation on the performance of a new type of cost-efficient damper for mitigating wind and earthquake induced vibrations in tall buildings. Tuned Liquid Damper (TLD) is a kind of Tuned Mass Damper (TMD) where the mass is supplanted by a fluid (typically water). A TLD depends upon the movement of shallow fluid in an unbending tank for changing the dynamic attributes of a structure and dispersing its vibration vitality under symphonious excitation. The viability of TLD is assessed dependent on the reaction decrease of the structure which is a two-celebrated steel building outline. Different parameters that impact the exhibition of TLD are additionally contemplated.

3) G.V. Rama Rao (2016): This research investigated the factors affecting the ductility of shear walls using nonlinear finite element modeling in ABAQUS with the Concrete Damaged Plasticity model. The study emphasized that ductility is influenced by aspect ratio, axial load level, and reinforcement percentages. To ensure a ductile seismic response, it was recommended that the axial load on a shear wall should not exceed 30% of its ultimate axial capacity. The findings led to valuable recommendations for modifying codal provisions to enhance ductile design practices in seismic zones.

4) Mukul Srivastava et al (2020): This study is focused on installing the TLD on the terrace, the seismic efficiency of the structure has been significantly improved. ESA method shows that installation of TLD narrows down the base shear, maximum storey displacement, and storey drift in a significant amount with all the depth ratios were performed and reported that the TLCD was more effective over to TLD for controlling the oscillation.

5) Bhattacharya et. al. (2016): The authors paper dealt with evolution of the various numerical codes so as to signify the effectiveness of tuned sloshing dampers considering fluid structure interaction effects. The case study included a five-storey structure under harmonic ground excitation maximum percentage reduction of 47.7% in response of the structure as top floor displacement was observed for mass proportioning of 90% at fifth floor and 10% at the i

6) Mondal,et.al. (2014): The primary objective of the author was to present the effectiveness of a tuned liquid damper (TLD) which is used in building structures to damp structural vibrations. The experiment apparatus included building model with beams and truss where the base was made movable using an electronic motor so as to stimulate similar to an earthquake. The apparatus used several sensors in form of an accelerometer which was used to measure the acceleration generated at the top most part of the structure when subjected to earthquake vibrations and readings were recorded in absence and presence of Tuned Liquid Damper. The recurrence extends around the full recurrence (first normal recurrence) was considered for excitation in both the cases. The outcomes displayed that the TLD viably hosed the vibrations (up to 80% decrease in vibration) when energized and the hosing impact was observed to be greatest around the reverberation recurrence. The hypothetical model was fruitful in displaying the conduct of the structure yet missed the mark in demonstrating the conduct of water. This was because of utilizing a low precision model for displaying water and improvement in such a manner.

III. DAMPER

Dampers is devices used to dissipate kinetic energy in buildings and reduce vibrations caused by external dynamic loads such as wind, earthquakes, or machinery. These systems improve the safety, comfort, and performance of structures by controlling displacements and minimizing the risk of structural and non-structural damage. Dampers can be broadly categorized into passive, active, and semi-active types, depending on how they operate and respond to vibrations. Among passive systems, which require no external power source, Tuned Mass Dampers (TMDs) and Tuned Liquid Dampers (TLDs) are commonly used in buildings.

Tuned Liquid Dampers (TLDs) are a type of passive damping system that utilize the sloshing motion of liquid within a container to counteract structural vibrations. The effectiveness of a TLD depends on its tuning the natural frequency of the liquid sloshing must match or closely approximate the fundamental frequency of the building.

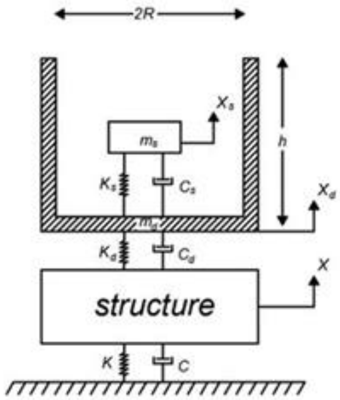

Fig.no:1-Mechanical model of TLD

TLDs are especially beneficial for mid-rise to high-rise structures, and are favored for their low cost, simplicity, and low maintenance compared to mechanical systems. In this study, TLDs are modeled in ETABS by simulating their dynamic behavior through equivalent mass, damping, and stiffness parameters. The primary goal is to analyze the effect of TLDs on reducing lateral displacements, base shear, and internal-storey drifts of a G+5 RCC framed structure.

IV. METHODOLOGY

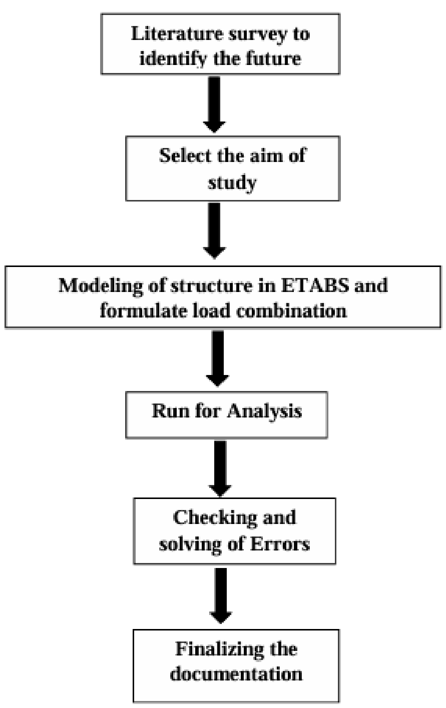

Fig.no:2-Methodology

IV.MODELLING

The structural modelling for the G+5 RCC framed building is developed using ETABS, a high-performance software designed for multi-storey building analysis. The model represents a six-storey reinforced concrete structure subjected to seismic loading, with Tuned Liquid Dampers (TLDs) installed at the roof level in two geometric configurations square and cylindrical There are many types of damper are here to perform oscillation reduction. From those Tuned Liquid Dampers [TLD's] are different one.

Because the TLD's are basically worked on the liquid sloshing mechanism. Basically, liquid sloshing of a liquid in a container are here to reduce the amount of displacement of the RCC from structure. Shape of the liquid container are play a vital role in the liquid sloshing mechanism. For that two different shapes are used to analyze the performance of different shaped liquid container are modelled. That different shapes of dampers are

- Square Shaped TLD
- Cylindrical Shaped TLD

Plan Dimension:

Grid creation in ETABS is a fundamental step in the structural modelling process. It involves the establishment of a reference framework composed of horizontal and vertical grid lines, typically defined along the X, Y, and Z axes. These grids serve as guides for accurately positioning structural elements such as columns, beams, slabs, and walls within the model. Grid creation in ETABS is a fundamental step in the structural modelling process. Creation of plan grid is common for the both structures.

The dimensional view of the structure are generally 6 nos.of 3m spacing grid axis on both X and Y axis.

Dimension parameters of Square Shaped TLD:

Width = 3.00 m

Height = 3.05 m

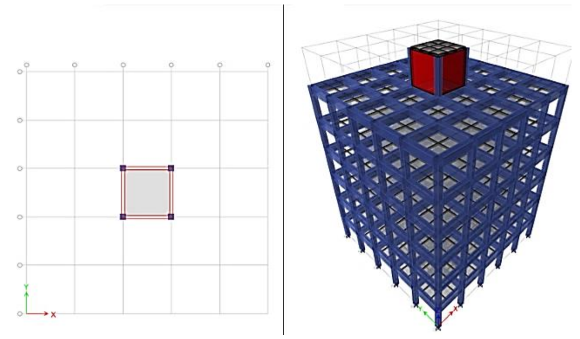

Fig.no-3 2D &3D Plan view of structure with square shape TLD

Dimension parameters of Cylindrical Shaped TLD:

Diameter = 2.121 m

Height = 3.050 m

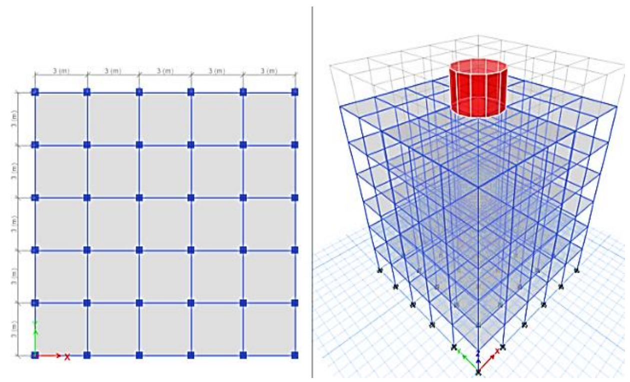

Fig.no-4 2D&3D Plan view of structure with cylindrical shape TLD

VI. PROPERTIES & DIMENSION

A) Material properties

i Grade of concrete – M30

ii Grade of steel – Fe550

iii Density of concrete – 25 KN/ m^3

B) Defining the frame Sections

i Beam size – 650 mm x 400 mm

ii Column size – 400 mm x 400 mm

C) Defining the slab Section

Floor Slab thickness – 150 mm

Bottom slab thickness – 200 mm

Top slab thickness – 200 mm

D) Load Definition

a) Live load – 3 kN/m^2

b) Floor finish – 1.5 kN/m^2

c) Dead load – width x depth x density of concrete

d) Seismic zone – v

e) Seismic zone factor - 0.36 (IS 1893:2006 – Part 1)

f) Wind Speed – 44 m/s

VII.NUMERICAL ANALYSIS

As per numerical modelling underpins the assessment of the different shape dampers with RCC structural frames anticipated seismic performance. Using ETABS, the general RCC structure frame grids are modelled as per required dimensions with the dampers and how the different shape of dampers are influence in the reduction of structural displacement which react to both the wind & seismic force. The comparison of maximum displacement values among these cases provides insight into how different TLD geometries affect the seismic response of the structure and controlling the excessive lateral movements. Analysis shows the following parameter details:

1) Maximum storey displacement

2) Maximum storey displacement due to earthquake load

3) Maximum storey displacement due to wind load

4) Maximum storey drift

5) Maximum storey shear

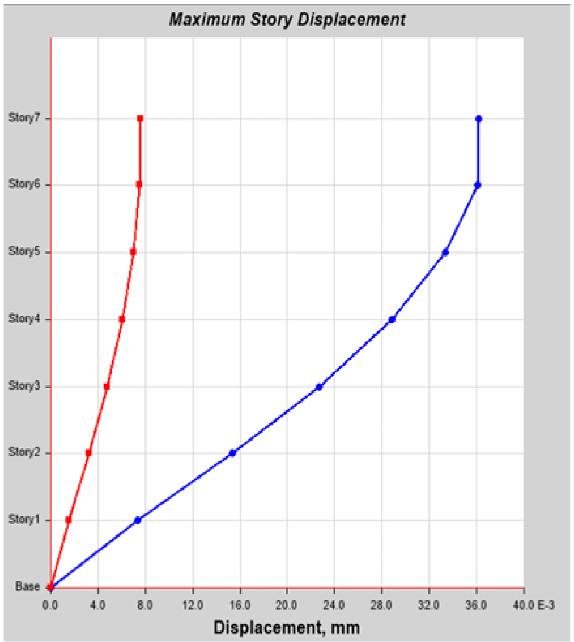

Fig.no-5 Maximum storey displacement

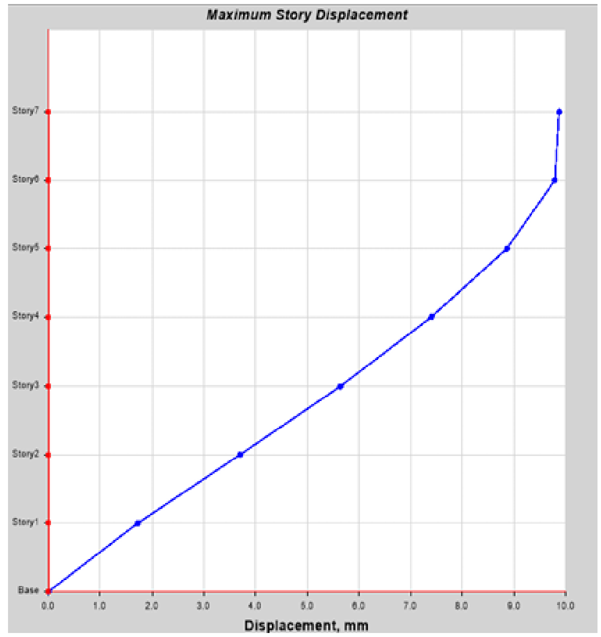

Fig.no-7 Maximum storey displacement due to earthquake load

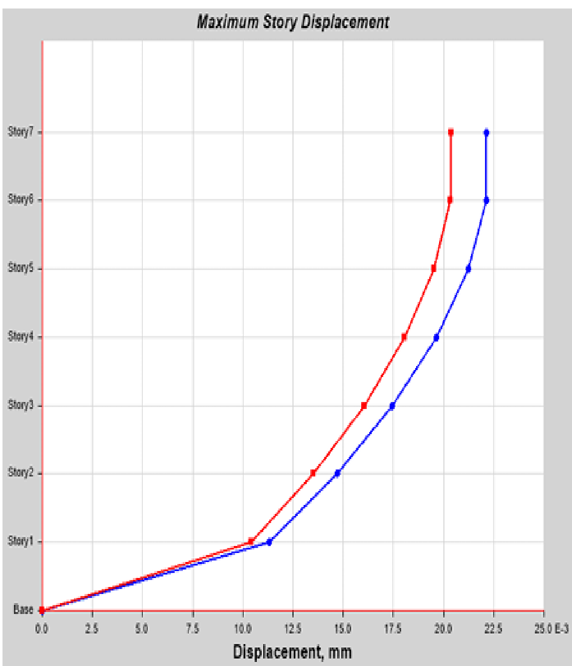

Fig.no-6 Maximum storey displacement

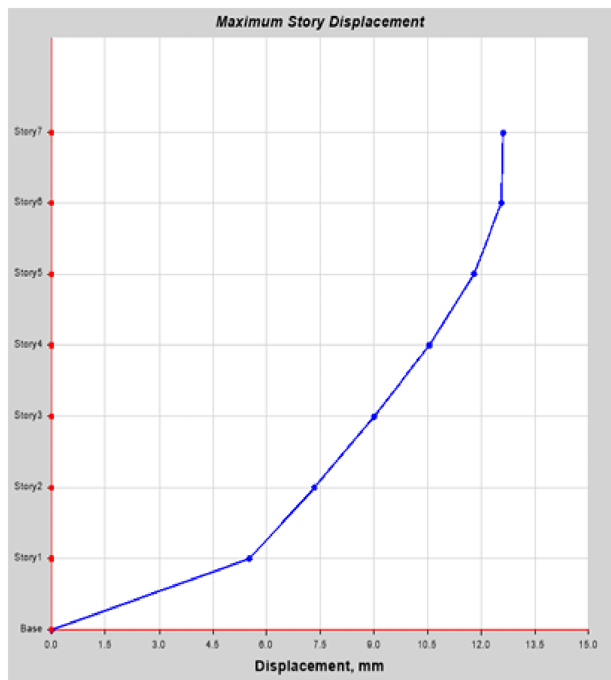

Fig.no-8 Maximum storey displacement due to earthquake load

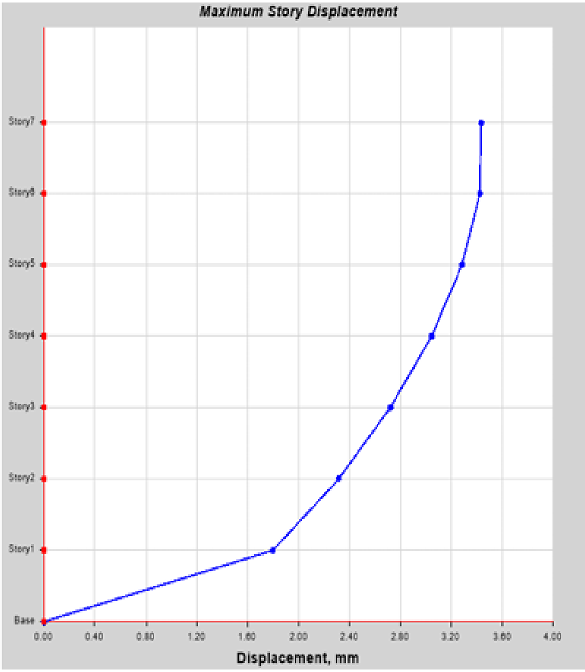

Fig.no-9 Maximum storey displacement due to wind load

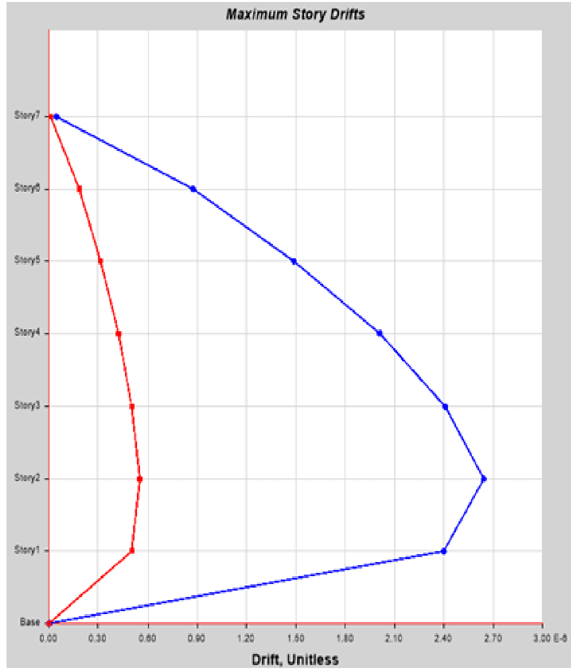

Fig.no-11 Maximum storey drift

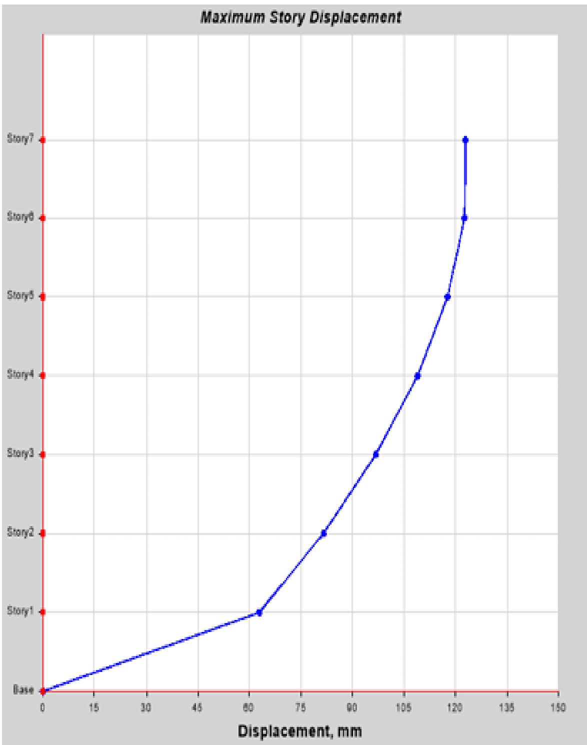

Fig.no-10 Maximum storey displacement due to wind load

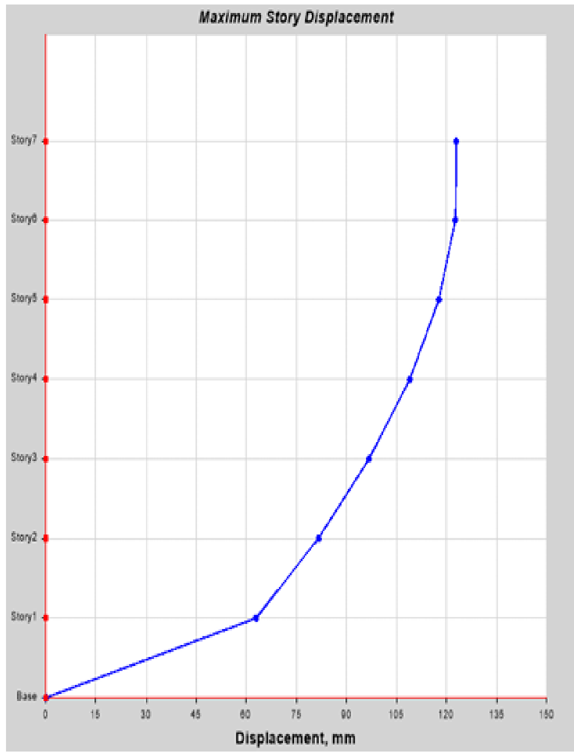

Fig.no-12 Maximum storey drift

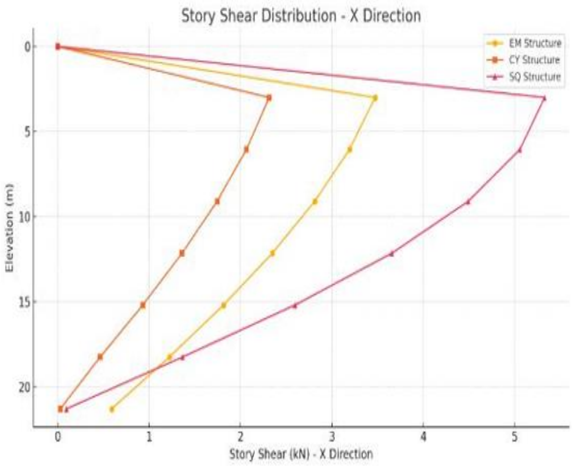

Fig.no 9 Maximum storey shear

VIII.RESULTS

The results obtained from the numerical analyses lateral displacement of the structure under seismic loading was observed to be highest in the bare frame model. With the introduction of tuned liquid dampers, there was a significant reduction in the top-story displacement.

- The square-shaped TLD configuration reduced the peak lateral displacement by approximately 20.7% compared to the bare frame.

- The cylindrical-shaped TLD further improved displacement control, yielding a reduction of about 24.3%, indicating slightly better performance in dissipating seismic energy.

The inter-story drift is a key indicator of structural performance during earthquakes. The story drift profile obtained from ETABS shows:

- Maximum story drift occurred at mid-height levels in all models, consistent with expected dynamic behaviour.

- The square TLD model exhibited a 20.5% reduction in peak drift relative to the base model.

- The cylindrical TLD model showed a 23.7% drift reduction, signifying enhanced damping efficiency and better control of relative story displacements.

These values remain within the permissible limits defined by IS 1893:2016, confirming the suitability of TLDs in improving seismic resilience of the structure.

The study demonstrates the effectiveness of tuned liquid dampers in mitigating seismic responses in mid-rise RCC structures. The numerical simulation in ETABS confirms that both square and cylindrical TLDs significantly enhance seismic performance without requiring major structural modificationsThis suggests their preferable application in real-world seismic retrofitting or new design scenarios where enhanced energy dissipation is desired.

IX.CONCLUSION

As that I concluded my project that has presented a comprehensive numerical software analysis of a G+6 reinforced cement concrete (RCC) framed structure subjected to seismic loading, with and without the inclusion of tuned liquid dampers (TLDs). Utilizing ETABS software, two structural models were analyzed. The objective was to assess the effectiveness of these passive energy dissipation devices in mitigating seismic responses, with a particular focus on lateral displacement, inter-story drift, and storey shear.

In conclusion, the implementation of tuned liquid dampers particularly cylindrical types proved effective in reducing seismic response demands in a midrise RCC framed structure.

But for actual building scenarios, especially in commercial and residential mid-rise RCC structures, square-shaped tuned liquid dampers are generally more suitable due to their ease of design, fabrication, cost-effectiveness, and architectural compatibility, despite the slightly lower performance compared to cylindrical TLDs.

However, in special structures such as tall buildings, bridges, towers, or buildings with flexible budget and dedicated damping systems cylindrical TLDs may be preferred where maximum energy dissipation and dynamic performance are critical, and where space and support systems can be customized accordingly.

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