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# Comparative Analysis of Responses of a Plane Building, with Outriggers and Water Tank as Tuned Liquid Damper

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***Abstract*— The Tuned Liquid Damper (TLD) is a passive supplemental damping device which can be used for effective mitigation of wind and earthquake induced responses. The use of TLDs in low to medium rise reinforced concrete (RC) buildings is a less explored area and needs to be investigated. The outrigger and belt truss system are commonly used as one of the structural system to effectively control the excessive drift due to lateral load, so that, during small or medium lateral load due to either wind or earthquake load, the risk of structural and non-structural damage can be minimized. For high-rise buildings, particularly in seismic active zone or wind load dominant, this system can be chosen as an appropriate structure. An outrigger is a stiff beam that connects the shear walls to exterior columns. When the structure is subjected to lateral forces.**

**During the last three decades, numerous studies have been carried out on the analysis and behavior of outrigger structures. Studies have shown that a tuned liquid damper (TLD) is effective in controlling the response of a structure to small amplitude and narrow-banded motions. But when these two are combined it may give further reduction in response of building. This work presents the working of water as tune mass damper with outriggers at different levels. TLDs have been mounted with outrigger on the roof of the building model and two intermediate stories, the response of the building without TLD and with TLD using outriggers and without outriggers have been carried out. The response of building was analyzed in terms of displacement, base shear and over turning moments at all stories and stresses in outriggers using Csi ETABS with application of wind and seismic loads separately.**

**It has been noticed that providing the combination of TLD and Outriggers has very great impact of 65%, 3%,&67% decrease on Storey displacements, Overturning moments, Base shear. It has been found that Outriggers and TLD can control the displacement of high rise building model satisfactorily. Also, TLDs at different heights gives better performance in reducing the structural response**

***Index Terms*— Vibration control, Tuned liquid Damper, TMD effects on Outriggers.**

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I. INTRODUCTION

Many different analysis and optimization methods are used in skyscraper design. These methods help in minimizing deflection, maximizing height, and providing cost efficient designs for the next age of high-rise buildings. Vibration control is an important aspect when designing buildings, especially if they are tall. Buildings can get subjected to substantial vibration due to wind and earthquakes. When an earthquake waves travel through the building, it is subjected to massive forces, acceleration and displacement that makes the building highly unstable and eventually it collapses. This repeated load cycles can induce fatigue into the beams and columns. Mass damper, Liquid dampers, base isolators and other supplemental damping systems (SDSs) are among the various alternatives used to reduce the vibrations on the structures. This work will focus on one of these methods, Tuned liquid Damper (TLD). A TLD 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. TLD has also been found to be very effective in cancelling vibrations caused due to wind. Tuned Mass Dampers (TMDs) are the origins of TLDs.

A Tuned Liquid Damper (TLD) is a type of TMD where the mass is replaced by a liquid (usually water).Tuned Liquid Column Dampers (TLCDs) are a special type of TLDs relying on the motion of a column of liquid in a U-tube like container to counteract the forces acting on the structure. Damping is introduced in the oscillating liquid column through an orifice in the liquid passage. The damping, however unlike TMDs, is amplitude dependent, and thus the TLCD dynamics are non-linear. The advantages of TLCD systems include low cost and maintenance and most importantly, such containers can be utilized for building water supply, unlike a TMD where the dead weight of the mass has no other functional use. Some of the innovative applications for liquid dampers studied in the past were in ship stabilization, satellite stabilization and recently in building applications. Passive dampers have inability to respond quickly to sudden loads and their inability to maintain the optimal level of damping at all levels of excitation. This paper highlights some of the key features of these dampers. The semi-active TLCD can boost the performance of the passive TLCD with fixed orifice by 15-25%. TLCDs require low or no maintenance as compared to traditional TMDs. A conventional TMD requires frictionless rubber bearings, special floor for installation, activation mechanism, springs, dashpots and other mechanical elements which drive up the cost of the vibration absorber. TLCDs, by the nature of their design, are low cost inertial devices with performances comparable to TMDs.

Outrigger systems are widely used to provide efficient lateral load resistance in tall slender contemporary buildings. Outriggers are rigid horizontal structures connecting a building core or spine to distant columns. They improve stiffness against overturning by developing a tension-compression couple in perimeter columns when a central core tries to tilt, generating restoring moment acting on the core at the outrigger level. Optimal outrigger locations will differ for different buildings and for different optimization criteria (top floor drift, story drift).

II. ANALYTICAL MODELS AND METHODOLOGY

In the present study 60 story RCC building model is being considered. The building is shear walled structure. The building does not represent a particular real structure that has been built or proposed in this study.

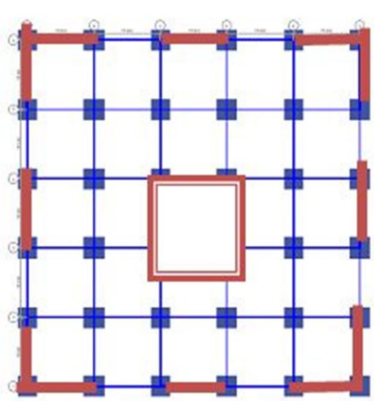


Fig 3.1 plan of the building showing core and shear walls

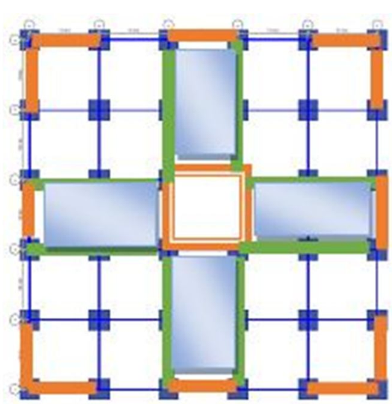


Fig 3.2 plan of the building showing core, shear walls and water tanks

Four different building models and detailed application of wind and seismic loads on these models separately based on Indian code IS 1893:2002 are studied in work.

## III. DESIGN DATA

### *A. Material Properties*

| | |
|---|---|
| Grade of concrete | =M40 |
| Young's modulus of (M25) concrete, E | =25 X 106 kN/$m^2$ |
| Density of Reinforced Concrete | =25 kN/$m^3$ |
| Assumed Dead load and Live load intensities: | |
| Live load | =4 kN/$m^2$ |
| Partition wall load | =1 kN/$m^3$ |
| Thickness of Slab | =0.15m |
| Thickness of shear walls | =230mm |

For the analysis of building model for the present work, wind pressure is assumed to be acting on the building. This wind pressure acts on both face in different load patterns.

### *B. ETABS analysis for lateral loads*

The building was then analysed by performing static wind analysis and seismic analysis to get displacements with outriggers without outriggers, outriggers with water tanks only water tank using the software ETABS 2016 for which the following considerations were made the walls and slab were considered to be shell type to provide in plane stiffness. The slab sections were modelled as rigid diaphragms. The contribution of slabs and floor systems from the out of plane bending stiffness of slabs are neglected because of cracking due to creep and shrinkage effects at supports. A wind pressure of 1kN/$m^2$ was applied once at a time on each face of the building respectively. The wind load was applied as point loads at each floor level on the rigid diaphragm.

Seismic loads were applied by considering the 4 building models for following IS codal provisions:

| | |
|---|---|
| Zone factor | = 0.36(zone 5) |
| Soil type | =II |
| Importance factor | =1.5 |
| Response reduction factor | =5 |
| Time period | =1.2 sec |

## IV. RESULTS & DISCUSSIONS

### *A. Storey displacement due to wind loads*

The top roof displacement of the building with outrigger, water tank and combination are reduced by 57.32%, 88.57, 98.5% respectively when wind load was applied in x & y direction. It is noticed that placing the water tank with outriggers have decreased the top Storey displacement due to sloshing impact forces on walls when wind loads are acting and next best method to damp the wind effect is placing outriggers

### *B. Storey displacement due to seismic loads*

Under the seismic loads in x & y direction, placing the outriggers, water tanks, combination of both decreases the top roof displacement by 57.5%,42.38%,65.08% as compared to building without any of the above.It is observed from the above comparison that water tank with outriggers have the best combination in order to resist the seismic forces, and also it was observed that placing only water tank also have great impact on decreasing displacements.

### *C. Overturning moments due to wind loads*

Under the seismic loads, placing the outriggers, water tanks, combination of both decreases the overturning moments by 4.27%, 5.54%, and 5.26% as compared to building without any of the above.The overturning moment effect is similar to overturning moment in wind load because pressure intensity is higher.

*D. Overturning moments due to seismic loads*

In Moments results under the wind loads, placing the outriggers, water tanks, combination of both decreases the overturning moments by 2.6%, 2.89%, and 2.60% as compared to building without any of the above.From the fig.3 it seen that overturning moment doesn't have higher effect by placing the combination of outriggers and water tank because pressure intensity will be higher due to area parameter. As per moment formula M = wl2 /2, length is squared here giving higher value and pressure intensity due to water tanks is M = wl, which gives lesser value

*E. Base shear due to wind loads*

Under the wind loads, placing the outriggers, water tanks, combination of both decreases the base shear by 36.69%, 28.05%, and 53.07% as compared to building without any of the above.The effect of base shear while applying the wind loads is also similar to seismic effect.

*F. Base shear due to seismic loads*

In base shear results under the seismic loads, placing the outriggers, water tanks, combination of both decreases the base shear by 48.175%, 60.43%, and 67.53% as compared to building without any of the above.Water tanks with outriggers gives a drastic impact on base shear which almost makes it zero at 140m height. And negative base shear represents the effect of sloshing forces due to water effect on walls.

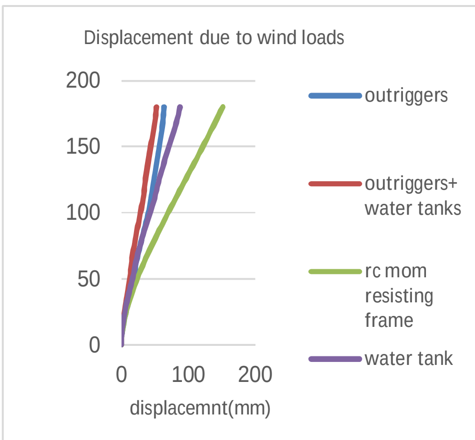



Fig :1 Displacement comparison (wind loads)

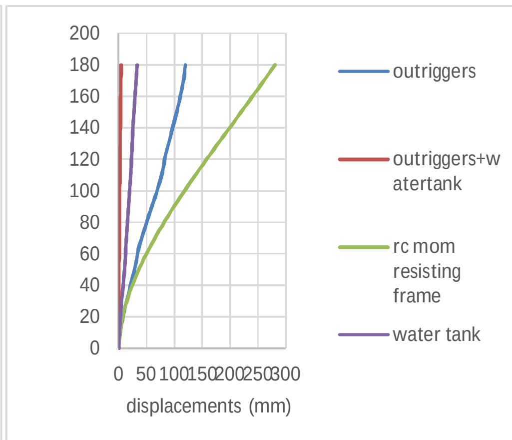



Fig :2 Displacement comparison (seismic loads)

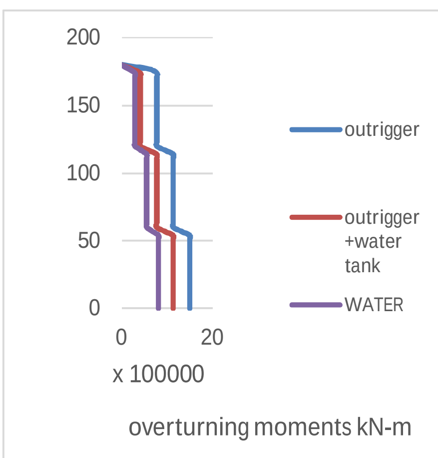



Fig: 3 Overturning moment comparison (wind loads)

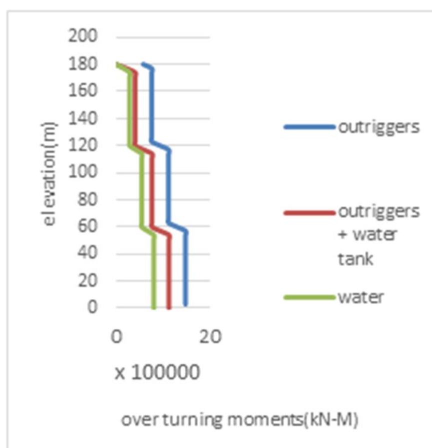
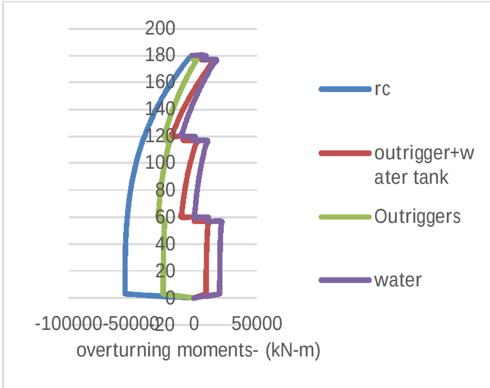



Fig: 4Overturning moment comparison (seismic loads)



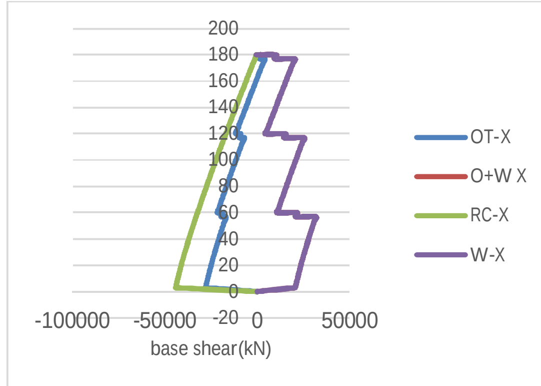




Fig :5 Base shear comparison (wind loads)

Fig :6Base shear comparison (seismic loads)

## IV. CONCLUSION

Based on the study conducted, the following conclusions are drawn:

*Under Seismic Loading*

In Moments results while applying the seismic loads, placing the outriggers, water tanks, combination of both decreases the Overturning moment. Hence it can be concluded that providing water tank have little impact on displacement. While applying the seismic loads in x & y direction it is concluded that placing the combination of outriggers and water tanks have the significant effect on top Storey displacement. In base shear results while applying the seismic loads it is concluded that placing the outriggers or combination of outriggers and water tanks have the equal impact.

*Under wind Loading*

While applying the wind loads, it can be concluded that placing the outriggers alone will control the overturning moments. The top roof displacement of the building with combination of outriggers and water tank when wind load was applied give very significant results. Hence it can be concluded that outriggers and water tank have best impact on displacement. While applying the wind loads, placing the combination of outriggers, and water tanks give the best results. Therefore, it can be concluded that outriggers and water tank is best suitable to decrease Base shear.

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