COMPARATIVE ANALYSIS OF HIGH RISE BUILDING WITH OUTRIGGERS AND WATER TANK IN DIFFERENT ZONES

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ABSTRACT

In tall structures high lateral forces develop due to wind load and earthquake load are crucial. Thus the effects of lateral loads need consideration for strength and stability of the structures. The Outrigger in structures provides lateral stiffness that provides significant drift control for tall buildings. An outrigger is a stiff beam that connects the shear walls to exterior columns when the structure is subjected to lateral forces. Nowadays, in modern tall buildings, lateral loads induced by wind or earthquake forces are often resisted by a system of multi-outriggers. The Tuned Liquid Damper (TLD), which can reduce earthquake demands on buildings. This positive effect is accomplished taking into account the oscillation of the free surface of a fluid inside a tank (sloshing). 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. Individually we studied about working of outriggers and tuned liquid dampers, in this study we introduce combination of both in different levels to reduce base shear and over turning moments, displacements and stresses using ETABS 2016 with application of lateral loads in G+40 Rcc model examined with Parameters of earthquake and wind loading has been defined as per IS 1893 (Part-1):2002 and IS 875 (Part-3):1987 respectively and analyze the wind and seismic forces with and without providing combination of dampers. In the study includes Rigid Frame, Shear Wall/Central Core, Wall-Frame Interaction, and Outrigger effect on tall structures with tuned liquid dampers in different zones (zone2 and zone5).Comparative study has been carried out to observe the change in parameters such as lateral storey displacements, storey drifts and base shear. From the results, it was concluded that provision of outriggers and water tanks is effective in reducing the displacements and drifts significantly, while base shear of the building showed not much change with the introduction of outriggers and tuned liquid dampers.

Keywords *- Analysis in different zones, outriggers, tuned liquid dampers, vibration control.*

1. INTRODUCTION

Tall Building has always been a vision of dreams and technical advancement leading to the progress of the world. Vibration control is an important aspect when designing buildings, especially if they are tall. Tall buildings are usually designed for Residential, office or commercial use. As population is getting denser the availability of land is diminishing and cost is also increasing. Hence to overcome these problems multi-storey buildings is most prominent and efficient solution. Buildings can get subjected to substantial vibration due to wind and earthquakes. When an earthquake waves travel through the building, it is subjected 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 also can cause sea sick feeling for the residents living on top.

This paper describes wind and seismic analysis of high-rise building in very severe zones of Indian subcontinent. For the analysis purpose a G+60 story building of reinforced concrete framed structure is selected and provided with outriggers with belt truss system along with tuned liquid dampers. The wind loads are estimated by Indian code IS: 875 (Part3)-1987 and earthquake loads are estimated by IS 1893:1984.

1.1 Objective of the study

The present work aims at the following objectives:

- To evaluate the top story displacement and base shear in building with outriggers and combination of outriggers with tuned liquid dampers.

- To study the moments, stresses and base shear in building having outriggers and water tank at different location under seismic loading using equivalent static method.
- To study the moments and stresses in the building subjected to seismic and wind loading for building with outriggers and outriggers with tuned liquid dampers(water tanks) in zones 2 and zone5.
- To compare various analysis results of building under different categories by using Etabs software.

1.2 Design consideration of outrigger system

All multi-story buildings require at least one core to accommodate elevators, stairs, mechanical shafts, and other common services. Because views are a significant part of the intrinsic value in tall buildings, it is most common for their core or cores to be centrally located within the floor plan to place occupants along exterior walls. A central core also locates the center of lateral stiffness close to the center of lateral wind load and center of mass for lateral seismic loads, minimizing torsional forces. In high-seismic regions many tall buildings have a dual system, sometimes called “core and frame” or “tube in tube,” with a perimeter moment frame providing significant torsional stiffness but a smaller contribution to overturning stiffness.

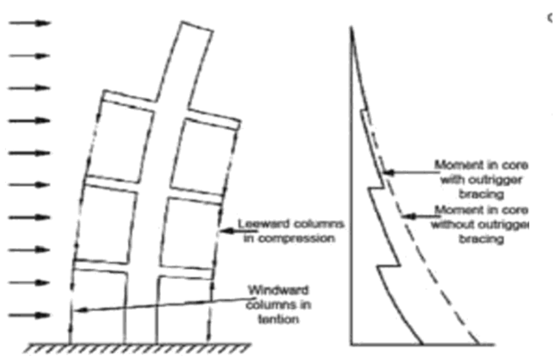

Fig:1 Behavior of outrigger system

1.3 Advantages of outriggers

- The outrigger systems may be formed in any combination of steel, concrete, or composite construction.
- Core overturning moments and their associated induced deformation can be reduced significant reduction and possibly the complete elimination of uplift and net tension forces throughout the column and the foundation systems.
- The exterior column spacing is not driven by structural considerations and can easily mesh with aesthetic and functional considerations.

2. LITERATURE REVIEW

Numerous studies have been carried out to study the behaviour of building with outriggers and tuned mass dampers. This chapter comprises of four sections, the first section deals with the behaviour of buildings with outriggers, the second section deals with the moments and stresses in the outriggers, the third sections deals with the behaviour of the outriggers with TLD with seismic and wind forces and the last section deals with behaviour of outriggers with TLD with seismic forces in zone2 and zone5.

M. R. Suresh [1] has been carried out to evaluate the most common structural systems that are used for reinforced concrete tall buildings under the action of wind and gravity loads. These systems include Rigid Frame, Shear Wall/Central Core, Wall- Frame Interaction and Outrigger. There is a great increase in flexural stiffness with respect to rigid frame and Outrigger system. It reduces the overturning moment in the core structures. The outrigger structural systems are not only efficient in controlling the top displacements but plays a substantial role in reducing the inter storey drifts also.

R. Jaiswal, Durgesh C. Rai and Sudhir K. Jain124I (2007) Study the effect of Seismic Codes on Liquid - Containing Tanks. Liquid storage tanks generally possess lower energy-dissipating capacity than conventional buildings. During lateral seismic excitation, tanks are subjected to hydrodynamic forces. These two aspects are recognized by most seismic codes on liquid storage tanks and, accordingly, provisions specify higher seismic forces than buildings and require modeling of hydrodynamic forces in analysis. In this paper, provisions of ten seismic codes on tanks are reviewed and compared. This review has revealed that there are significant differences among these codes on design seismic forces for various types of tanks. Reasons for these differences are critically examined and the need for a' unified approach for seismic design of tanks is highlighted.

A Samanta and P Banerji121 (2008) investigated the Structural control using modified tuned liquid dampers. This paper presents a numerical study 'for structural control using a modified configuration of the tuned liquid damper (TLD), which is a passive damper consisting, of a solid tank filled with water used for controlling vibration of structures. The TLD damper relies on the sloshing of water inside it to dissipate energy. One characteristic of TLDs is that energy dissipation is greater when water sloshing is more.

Hi Sun Choi, et.al, (2012) have given guidelines on design of outrigger system in building. The design has been not being available in any codes nor proper guidelines for design of this system. In this paper the Council of Tall Buildings and Urban Habitat (CTBUH) have done lot of construction work on outrigger system and its design has published design guidelines. Various benefits associated with outrigger system has been discussed. After the design process the challenge's faced during construction has been brought to notice. The concept of floor diaphragm in virtual and conventional outrigger system and its behavior has been explained. Using an outrigger also reduces the functionality of the building and this has to be taken into considerations. Shortening effect on the outriggers, the load path transfer on outriggers has been discussed elaborately. Different core materials used and its impact on the building in reducing the deformation and the construction sequence of the outriggers plays a very important in the stability of the building. A lot of research and practical consideration has to been known by the engineer to adopt these techniques in the building.

3. ANALYTICAL MODELS AND METHODOLOGY

3.1 Defining Automatic Dead Load (DL)

The unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24kN/m3 and 25kN/m3 respectively. Other considerations are taken from code book IS 875 part1.

3.2 Defining Automatic Live Load (LL)

Imposed loads do not include loads due to wind, seismic activity, snow, and loads imposed due to temperature changes to which the structure will be subjected to, creep and shrinkage of the structure, the differential settlements to which the structure may undergo. Other considerations are taken from code book IS 875 part2.

3.3 Defining Automatic Wind Load (WL)

3.3.1 Wind Load Calculations

The basic wind speed (V_b) for any site shall be obtained from and shall be modified to include the following effects to get design wind velocity at any height (Vz) for the chosen structure:

1. Risk level.(K_1)
2. Terrain roughness, height and size of structure.(K_2)
3. Local topography.(K_3)

$\mathbf{P_d = 0.6Vz^2}$ (IS:875 Section 5.4)

Where, P_d = Design wind pressure

Vz = Design wind speed in m/sec

Vz = Vb.k1.k2.k3

The wind load estimation when using the exposure from area objects method is based on IS:875 part 3.

3.4 Defining Automatic Seismic Loads (SL)

Seismic load can be calculated taking the view of acceleration response of the ground to the super structure. According to the severity of earthquake intensity they are divided into 4 zones.

1. Zone I and II are combined as zone II.
2. Zone III.
3. Zone IV.
4. Zone V.

3.4.1 Design Seismic Base Shear

The total design lateral force or design seismic base shear (Vb) along any principal direction shall be determined by the following expression:

$\mathbf{V_B = A_h\, W}$

Where:

Ah = horizontal acceleration spectrum.

W = seismic weight of all the floors.

The design horizontal seismic coefficient "Ah" for a structure shall be determined by the following expression:

$A_h = \dfrac{ZISa}{2Rg}$ (IS:1893 Section.6.4.2)

Where,

Ah = the design horizontal spectrum value

Sa/g = Spectral acceleration coefficient computed using expressions given in section 6.4.5 of IS:1893 for 5% damping

R = Response reduction factor.

I = Importance factor.

W = Seismic weight of the building (based on specified mass)

The base shear, Vb, is distributed over the height of the building in accordance with equation given in Section 7.7 of IS:1893.

3.4.2 Design seismic lateral force

$$Q_i = V_B \frac{W_i h_i^k}{\sum_{i=1}^{n} W_i h_i^k}$$

Where,

Qi = Design lateral force at floor i,

Wi = Seismic weight of floor i,

hi = Height of floor i measured from base, and

n = Number of storeys in the building is the number of levels at which the masses are located.

Vb = Base shear.

k = 2

3.4.3 Fundamental Natural Period

The approximate fundamental natural period of vibration (Ta), in seconds, of a moment-resisting frame building without brick in the panels may be estimated by the empirical expression:

$Ta=0.075\ h^{0.75}$ for RC frame building

$Ta=0.085\ h^{0.75}$ for steel frame building

Where:

h = Height of building, in m. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected.

The approximate fundamental natural period of vibration (Ta), in seconds, of all other buildings, including moment-resisting frame buildings with brick lintel panels, may be estimated by the empirical Expression:

$$Ta = \frac{0.09H}{\sqrt{D}}$$

Where,

h= Height of building in m

d= base dimension of the building at the plinth level in m, along the considered direction of the lateral force.

4. RESULTS AND DISCUSSIONS

4.1 Description of building model

The building under consideration has the flowing parameters

i. The present building has 60 stories with shear walls and with floor plan 40mx40m

ii. Number of bays in x direction is 5

iii. Number of bays in y direction is 5

iv. Total number of stories is 60

v. Height of each story is 3m the plan of the building is shown in fig, while fig shows the 3-d view of the building

vi. shear wall of thickness 230mm used in the building

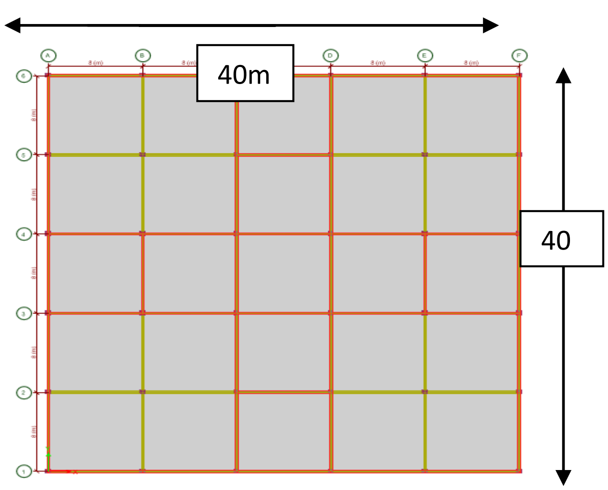

Fig: 2 plan of the building

Fig: 3 3-d model of the building

Number of stories 60

Height of each storey = 3m

4.2 Design Data

Material Properties:

Grade of concrete = M40

Young's modulus of (M25) concrete,

$E = 25 \times 10^{6}$ KN/m2

Density of Reinforced Concrete = 25 KN/m3

Assumed Dead load intensities

Live load	=3.75 KN/m2
Partition wall load	= 1 KN/m3
Thickness of Slab	= 0.15m
Thickness of shear walls	= 230mm

4.3 Wind speed details

4.3.1 For load pattern in x & y direction

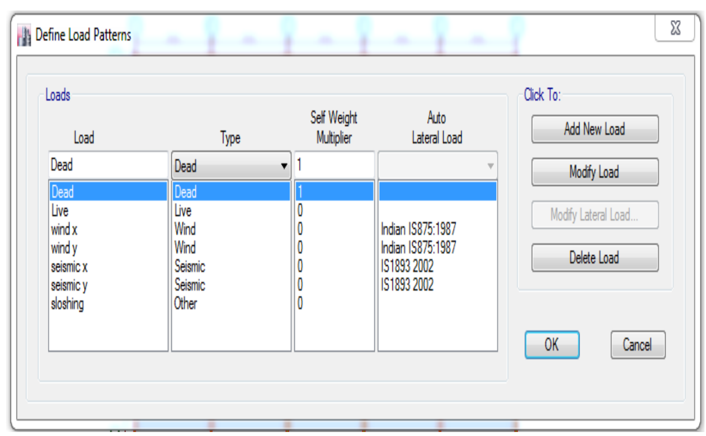

Fig: 4 defining load patterns

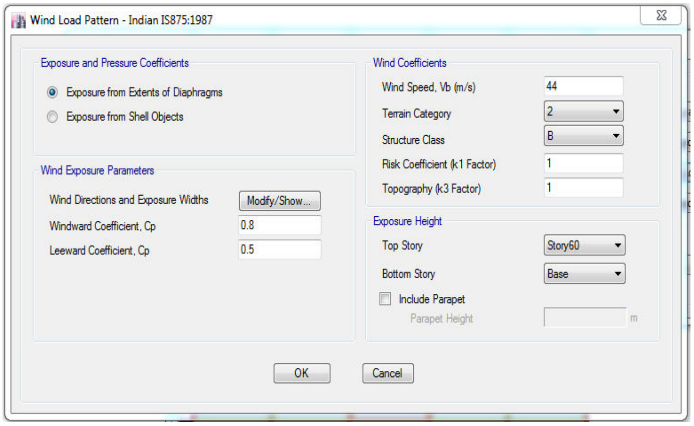

Fig: 5 wind load pattern

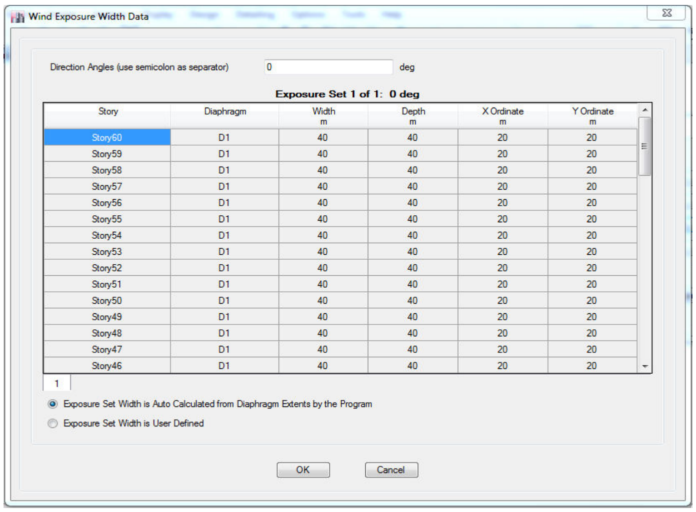

Fig: 6 Angle of wind in x direction

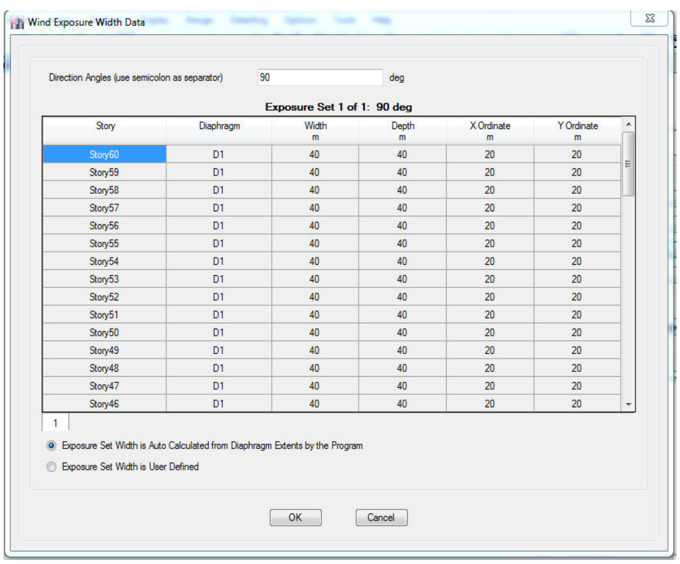

Fig: 7 Angle of wind in y direction

4.4 Seismic load details

4.4.1 For load pattern in x & y direction

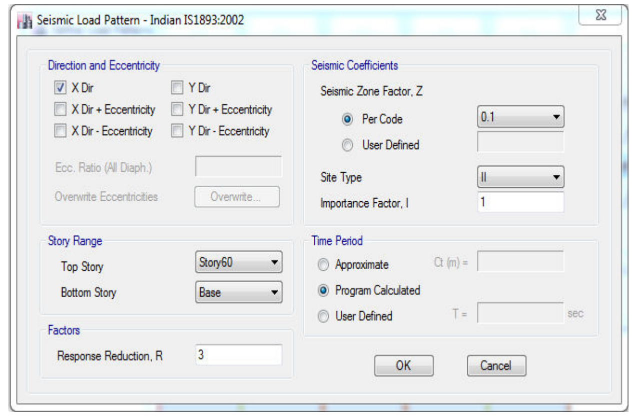

Fig: 8 Seismic loads in x direction

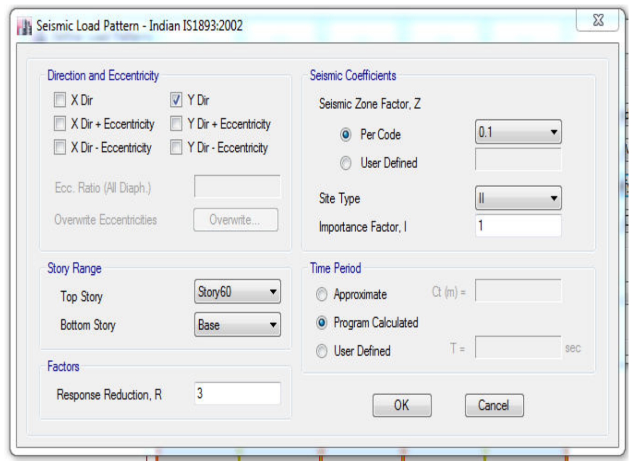

Fig: 9 Seismic loads in y direction

4.5 Etabs analysis for lateral loads

- The slab sections were modeled as rigid diaphragms
- The contribution of slabs and floor systems from the out of plane bending stiffness of slabs is neglected because of cracking due to creep and shrinkage effects at supports.
- A wind pressure of 1kN/m2 was applied once at a time on each face of the building respectively.
- The wind load will be 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:

i.Zone factor = 0.36(zone 5) Darbhanga
=0.1 (zone 2) Hyderabad
ii.Soil type = II
iii.Importance factor = 1
iv.Response reduction factor = 3
v.Time period = Based on program

Different cases of building with outrigger systems

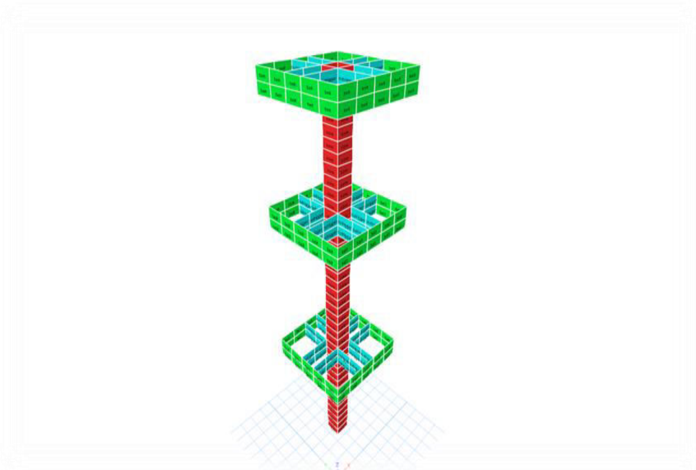

Fig: 10 3d model showing outriggers, belts & core

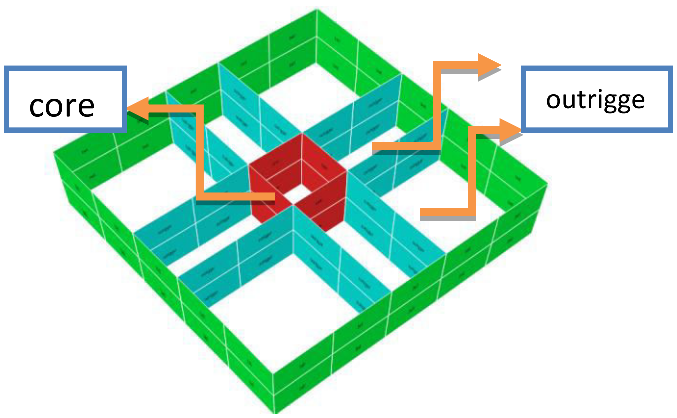

Fig: 11 Isometric view showing only belt, outrigger and core

4.6 Comparison of roof displacement in zone2

4.6.1 Displacement in x direction because of wind forces

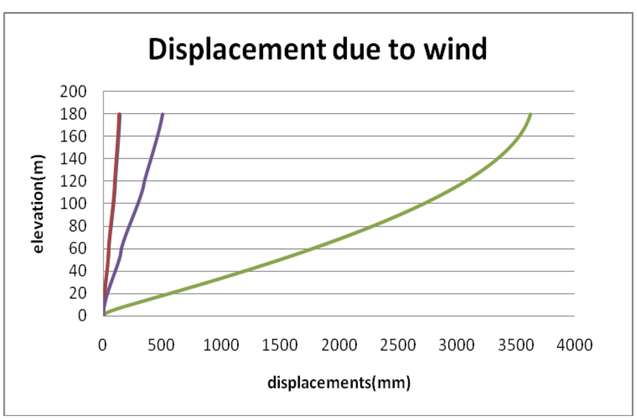

Fig: 12 Displacement in x-direction due to wind forces

4.6.2 Displacement in x-direction due to seismic forces

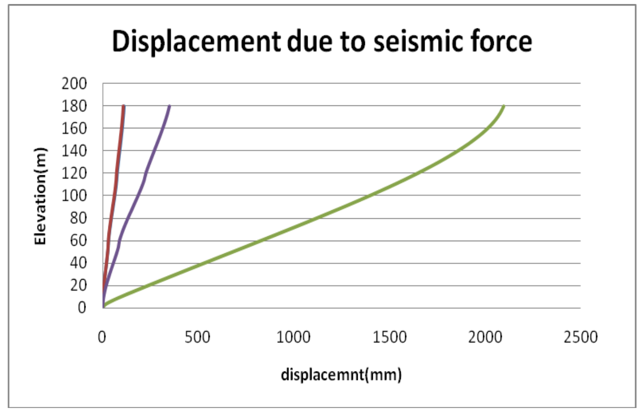

Fig: 13 Displacement in x-direction due to Seismic forces

4.7 Comparison of Base shear in zone2

4.7.1 Base shear in x-direction due to wind forces

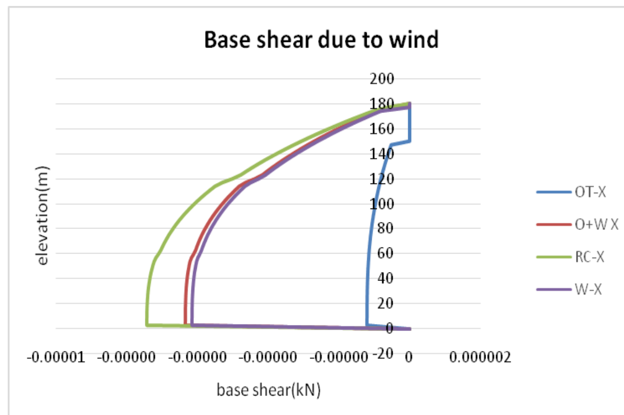

Fig: 14 Base shear in x direction due to wind forces

4.7.2 Base shear in x-direction due to seismic forces

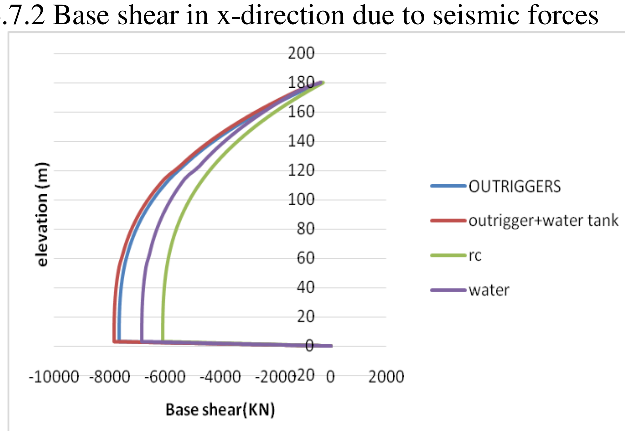

Fig : 15 Base shear in x-direction due to seismic forces

4.8 Comparison of displacement in zone5

4.8.1 Displacements in x-direction due to wind forces

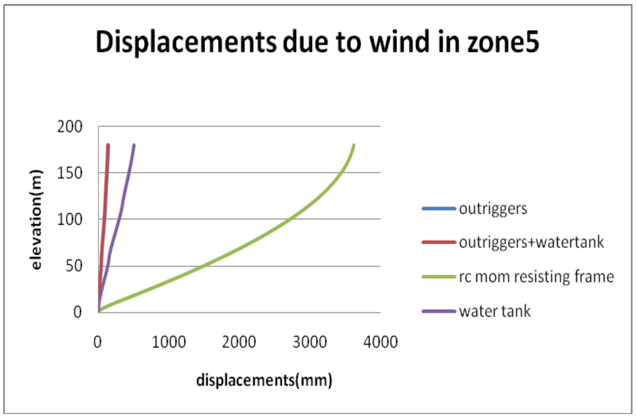

Fig: 16 Displacements in x-direction due to wind forces

4.8.2 Displacement values in x-direction due to seismic forces

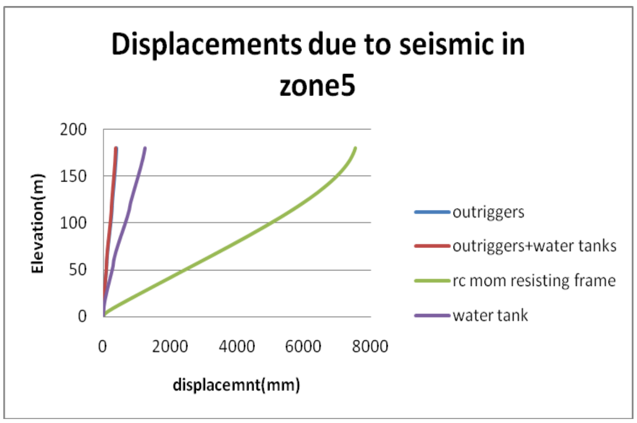

Fig: 17 Displacement values in x-direction due to seismic forces

4.9 Comparison of base shear values in zone5

4.9.1 Base shear in x-direction due to wind forces

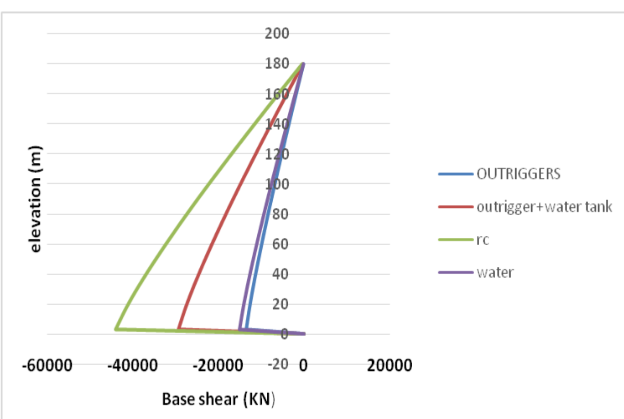

Fig: 18 Base shear values in x-direction due to wind forces

4.9.2 Base shear in x-direction due to seismic forces

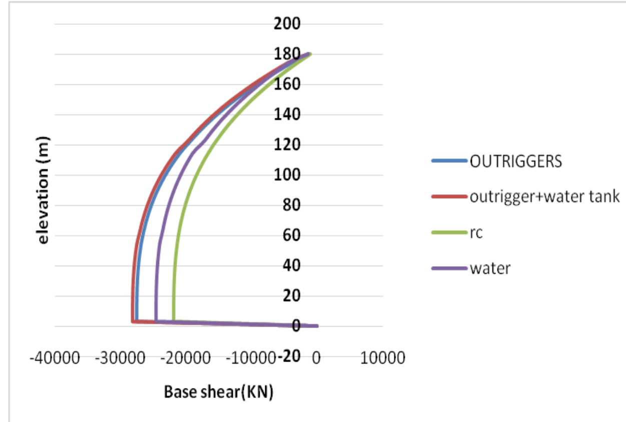

Fig: 19 Base shear values in x-direction due to seismic forces

4.10 Results

1.The top roof displacement of the building with outrigger, water tank and combination are reduced by 86%, 92%, 96.2% respectively when wind load was applied in x & y direction in zone2.

2. While applying the seismic loads in x & y direction in zone2, placing the outriggers, water tanks, combination of both decreases the top roof displacement by 83.3% , 91%, 94.8% as compared to building without placing any of the above.

3. In Stresses results while applying the wind loads, placing the water tanks, outriggers, combination of outrigger and water tanks decreases the plate stresses by 81.2%, 78%, 76% by as compared to outriggers in zone2.

4. While applying the seismic loads, placing the outriggers, water tanks, combination of outrigger and water tanks decreases the plate stresses by 84%, 75.7%, 74.8% by as compared to outriggers in zone2.

5. The top roof displacement of the building with water tank, outrigger and combination are reduced by 85.1%, 89%, 93% respectively when wind load was applied in x & y direction in zone5.

6. While applying the seismic loads in x & y direction in zone5, placing the water tanks, outriggers, combination of both decreases the top roof displacement by 81% ,88%, 95.3% as compared to building without placing any of the above.

7. In Stresses results while applying the wind loads, placing the outriggers, water tanks, combination of outrigger and water tanks decreases the plate stresses by 69.27%, 65.8%, 33.33% by as compared to outriggers in zone5.

8. While applying the seismic loads, placing the outriggers, water tanks, combination of outrigger and water tanks decreases the plate stresses by 19.04%,

32.04%, and 33.58% by as compared to outriggers in zone5.

5. CONCLUSIONS

Building core-and-outrigger systems have been used for half a century, but have kept evolving to reflect changes in preferred materials, building proportions, analysis methods and design approaches. Practical implementation of lateral force resisting systems still requires considerable thought, care and project-specific studies. Outriggers, TMD,TLD design is not amenable to a standardized procedure due to the variety of challenges posed, solutions used and new concepts being developed. This may frustrate designers looking for a single authoritative standard. However, the real value of this guideline document is to stimulate thoughtful discussions of outrigger systems within the engineering profession, encourage researchers to investigate behaviors related to such systems and address and resolve many of the issues through subsequent editions.

5.1 Limitation of study

The limitations of the study are as follows:

• The building studied is square in plan and were assumed to be located on level ground.

• The analysis carried in this study is the equivalent static which takes a single value in consideration.

• The buildings were assumed to be constructed on firm ground and soil-structure interaction was neglected.

5.2 Scope for Future Work

1. Further study can be done by maintaining different levels of water tank.
2. Further study can be done by placing water tank at different locations.
3. In this study wind and seismic analysis has been carried out using equivalent static load method, further the same model may be analyzed using response spectrum method and time history method and push over analysis etc.
4. In this work water is used as liquid for damping of induced forces but other liquid of considerable densities can be used based on region and availability.
5. Further work can be carried by applying loads on the walls as uniformly varying shell loads or dynamic water effects based on modern day study.

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