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Analysis of multi-storey buildings using water tank as a liquid damper using E-tabs

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Abstract - *Current trends in construction industry demands taller and lighter structures, which are also more flexible and having quite low damping value. This increases failure possibilities and also problems from serviceability point of view. Now-a-days several techniques are available to minimize the vibration of the structure, out of the several techniques available for vibration control, concept of using TLD is a newer one. In the present work, the structure without and with tuned liquid damper buildings of G+10, G+20, and G+30 storey height structural models are considered. The vulnerability of without and with tuned liquid damper structures under various load conditions are studied and for the analysis seismic region 3 with different water depths are considered. Analysis is carried out for different heights to study the seismic behavior of structure without and with tuned liquid damper building analysis is for different heights to see what changes going to take place if the height of both structural systems varies. Therefore, the characteristics of the seismic behavior of both structural systems suggests the additional measures for guiding the conception and design of these structures in seismic regions and also to improve the performance of these structural systems under seismic loading.Present work provides a good source information on the parameters lateral displacement, storey drift, base shear. The analysis is carried out by E-Tabs software.*

***Key Words*: Tuned liquid damper, water tank, storey displacement, storey drift, base shear.**

1. INTRODUCTION

Vibration in buildings can be caused by many different external sources, including industrial, construction and transportation activities. The vibration may be continuous, impulsive or intermittent. Vibration in buildings also occur from internal sources, such as a road development forming part of the building or mechanical vibration sources in buildings. Vibration and its associated effects are usually classified as continuous, impulsive or intermittent as follows.Continuous vibration continues uninterrupted for a declined period, usually throughout day time or night time. Impulsive vibration will build up rapidly to a peak followed by damped decay that may or may not involve several cycles of a vibration depending on frequency and damping. Intermittent vibration can be defined as interrupted period of continuous (For ex- a drill) or repeated periods of impulsive vibration (For ex- a pile driver) or continuous vibration that varies significantly in magnitude. Modern tall buildings have become relatively light and flexible with the plentiful application of high strength materials in civil engineering making the structure collapse early or exceed the comport limitation at the action of dynamic loads such as seismic and wind. The structure vibration control in the buildings can be a successful method of mitigating the effects of these dynamic responses. Response control technologies are also available to improve performance under strong wind excitations. The technologies have been developed to improve the inhabitants comfort during strong wind.

2. LITERATURE REVIEW

Modi V.J and Seto.M.L (1997) [1], They proposed a numerical study considering non-linear behavior of the TLD. It includes the effects of wave dispersion as well as boundary-layers at the walls, floating particle interactions at the free surface, and wave-breaking. However, the analysis does not account for the impact dynamics of the wave striking the tank wall. Furthermore, at lower liquid heights, corresponding to wave breaking occurrence, the numerical analysis is not very accurate and a large discrepancy exists between numerical and experimental results.

Sigurdur Gardarsson et al. (2001) [2], Investigated the performance of a sloped-bottom TLD with an angle of 30° to the tank base. It is shown that despite the hardening spring behavior of a rectangular TLD, the sloped-bottom one behaves as a softening spring. Also, it is observed that more liquid mass participates in sloshing force in the slopped-bottom case leading to more energy dissipation.

Siddique M.R and Hamed M.S (2005) [3], He presented a new numerical model to solve Navier-Stokes and continuity equations. Theymapped irregular, time-dependent, unknown physical domain onto a rectangular computational domain where the mapping function is unknown and is determined during the solution. It is indicated that the algorithm can accurately predict the sloshing motion of the liquid undergoing large interfacial deformations. However, it is unable to predict the deformations in the case of surface discontinuity such as existing of screens or when wave breaking occurs.

Warnitchai .P and Pinkaew (1998) [4], He proposed a mathematical model of TLDs that includes the non-linear effects of flow dampening devices. Experimental investigations with a wire mesh screen device were carried out. With the introduction of the flow dampening device an increase in sloshing damping and the nonlinear characteristic of the damping was observed; and the slight reduction in sloshing frequency agreed well with the model predictions.

Yamamoto.K and Kawahara.M (1999) [5], They used arbitrary Lagrangian-Eulerian (ALE) form of Navier-Stokes equations to predict the liquid motion. Improved-balancing-tensor-diffusivity and fractional steps methods were employed to discretize and solve the Naiver-stokes equations in space and New marks method was used in time domain to predict the TLD- structural interaction response. However the model did not verified with experiments.

2.2 OBJECTIVES:

1. To study the behavior of structure without dampers.
2. To study the performance of tuned liquid dampers with various depths of water tank in earthquake zone III.
3. To study and compare structure without TLD and structure with TLD, with different structure height for different combinations of loading.
4. To study the vulnerability of with and without TLD models considering different factors such as Storey drift, lateral displacement and base shear for dynamic loading with varied building height.

3. MODELLING AND ANALYSIS

The structure consists of columns, beams and slabs. Analysis of the structure is done using ETABS. Dead load, live load and earthquake load are considered for analysis.

3.1 Material property

Grade of concrete = M30

Grade of steel = Fe415

Young's modulus of concrete = 25000Mpa

Young's modulus of steel =200000Mpa

Unit weight of steel = 78.0KN/m^3

Unit weight of concrete = 25 KN/m^3

3.1.2 Geometry of model

Size of beam for G+10, G+20, G+30 storey = 300x600mm

Size of column for G+10 = 600x600mm

Size of column for G+20 = 600x1000mm

Size of column for G+30 = 600x1200mm

Thickness of slab = 175mm

Thickness of wall = 230mm

Story height = 3m

3.1.3 Consideration of loads

The dead load is considered as per IS 875-1987 (Part I-Dead loads). The imposed load is considered as per IS 875-1987 (Part II-Imposed loads).

3.1.4 Earthquake Load (EL)

The earthquake load is considered as per the IS 1893-2002(Part 1). The factors considered are

- Zone factors = 0.16 (zone 3)
- Importance factor = 1.0
- Response reduction factor = 1.0
- Soil condition = Hard soil
- Damping = 5%

3.2 About the Models

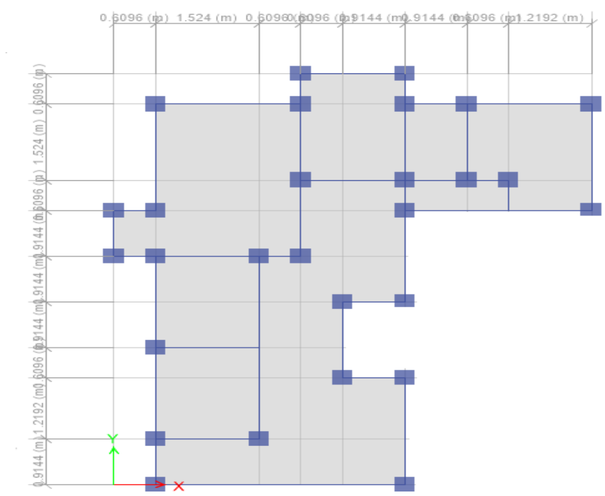
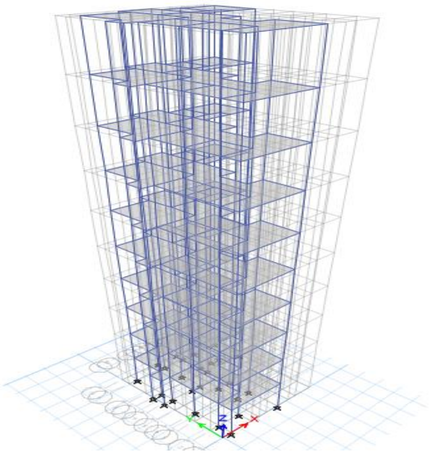


Fig.1: Plan of the model



Model 1: G+10 structure without tank

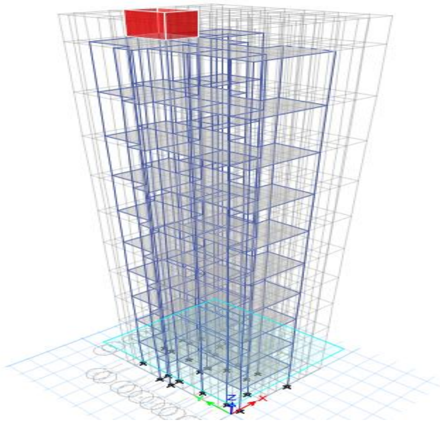
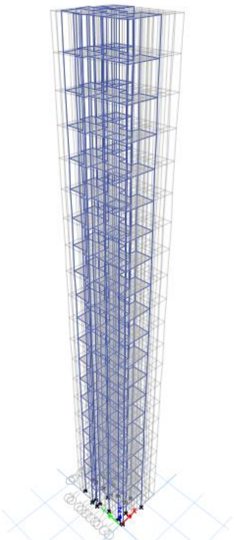


Fig Model 4, 5, 6: G+10 structure with tank of water depth 1.5m, 1.8m, and 2.1m



Model 2: G+ 20 structure without tank

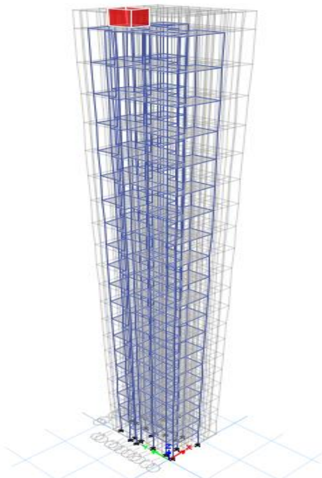
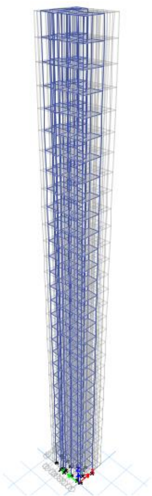


Fig Model 7, 8, 9: G+20 structure with tank of water depth 1.5m, 1.8m, and 2.1m



Model 3: G+ 30 structure without tank

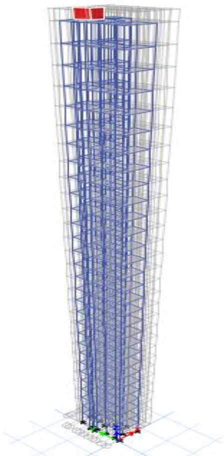


Fig Model 10, 11, 12: G+30 structure with tank of water depth 1.5m, 1.8m, and 2.1m

4. RESULTS AND DISCUSSION

4.1 Analysis by Response spectrum analysis

4.1.1 Maximum displacement

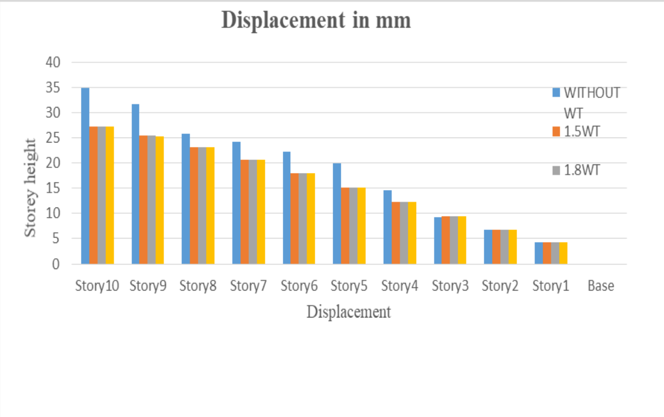


Fig 4.1 maximum displacement for G+10 along x direction

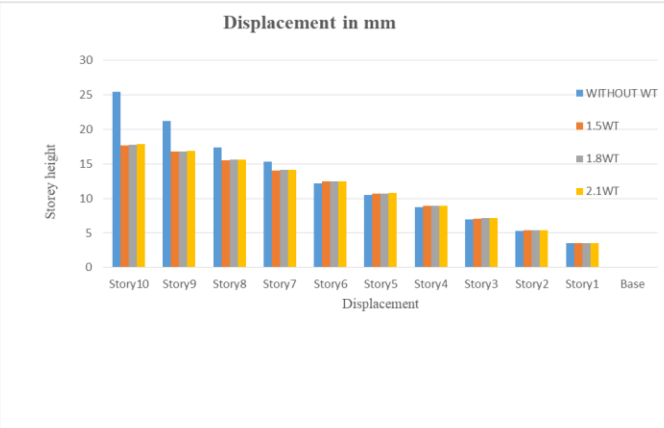


Fig 4.2 maximum displacement for G+10 along y direction

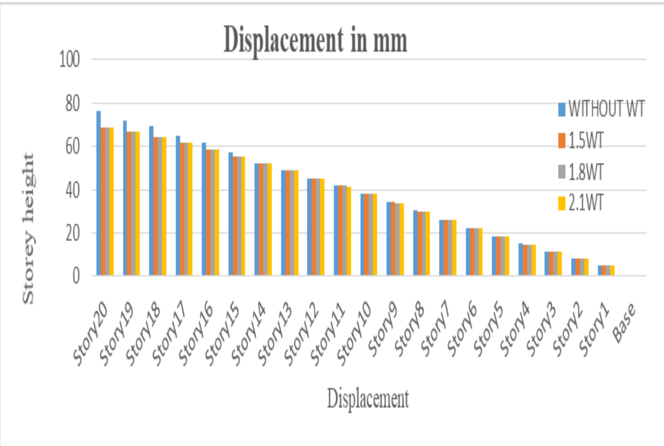


Fig 4.3 maximum displacement for G+20 along x direction

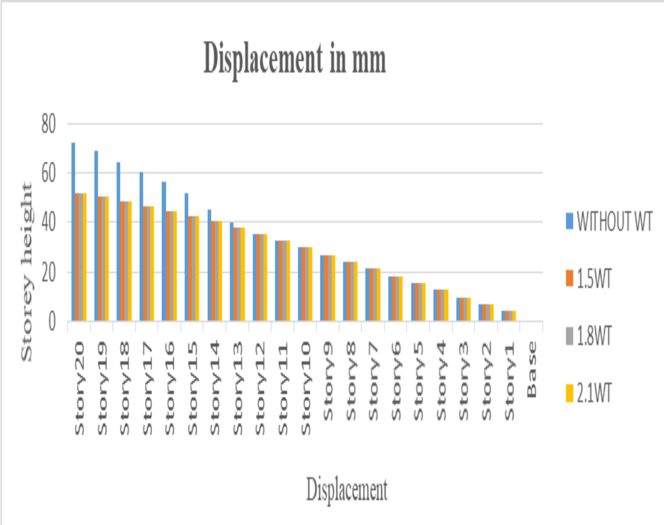


Fig 4.4 maximum displacement for G+20 along y direction

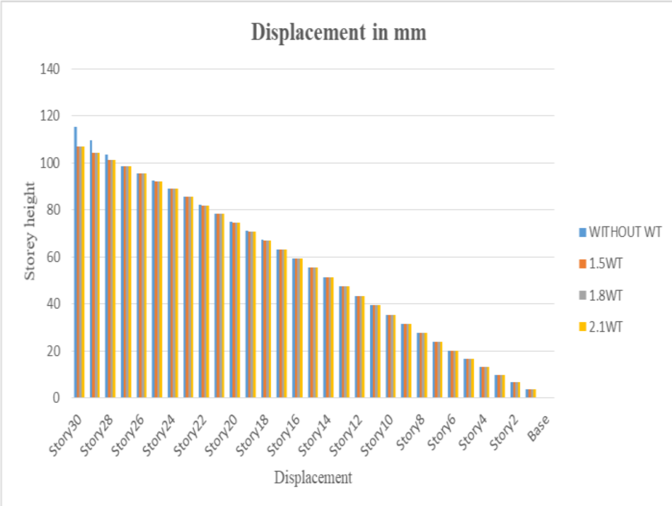


Fig 4.5 maximum displacement for G+30 along x direction

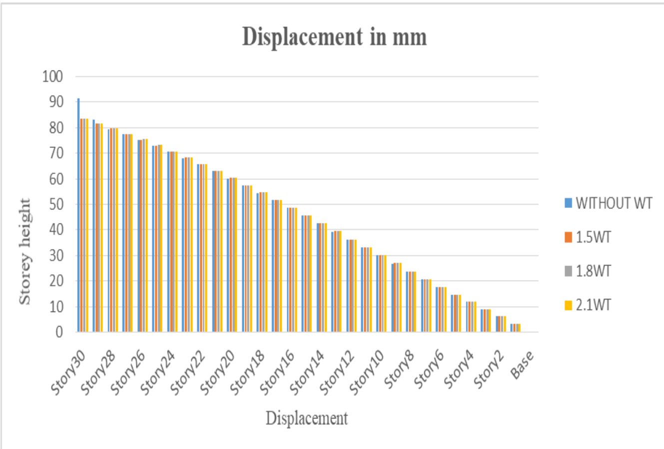


Fig 4.6 maximum displacement for G+30 along y direction

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4.1.2. Maximum Storey Drift

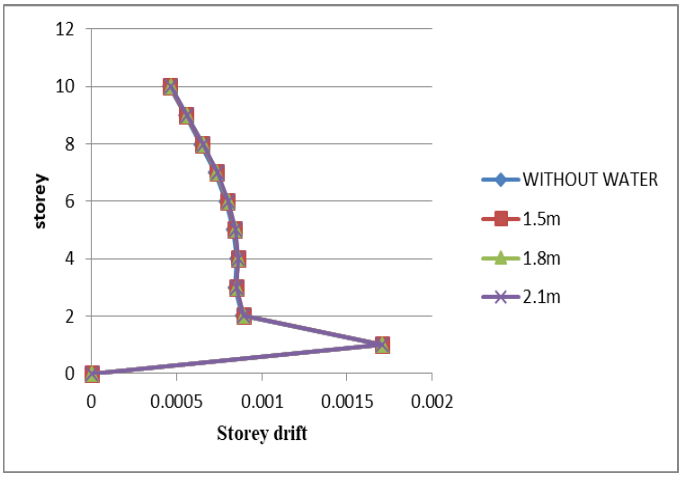

Fig 4.7 maximum storey drift for G+10 along x direction

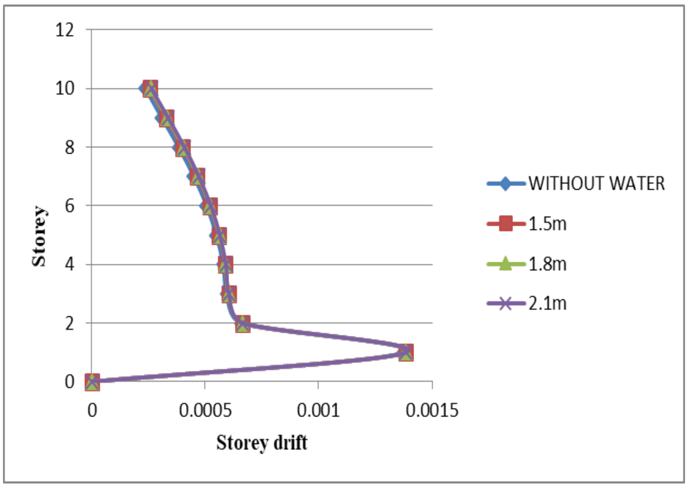

Fig 4.8 maximum storey drift for G+10 along y direction

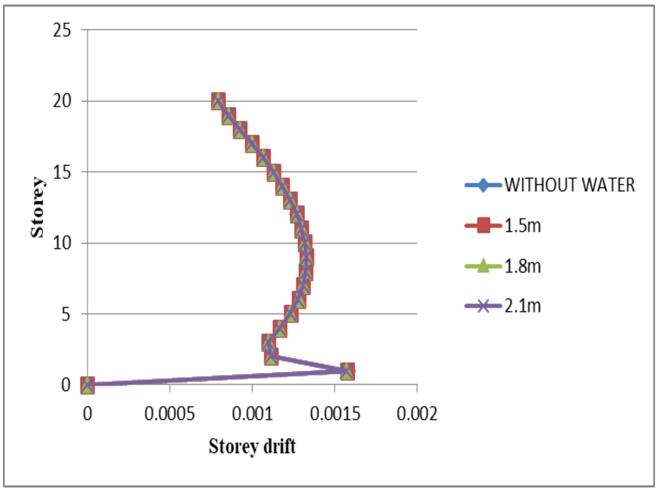

Fig 4.9 maximum storey drift for G+20 along x direction

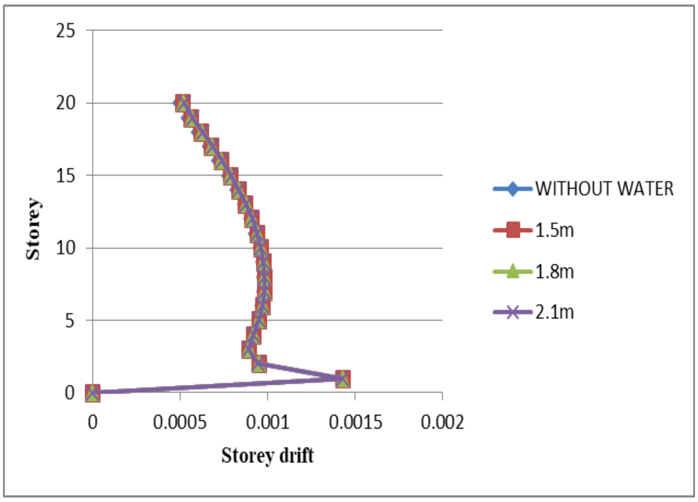

Fig 4.10 maximum storey drift for G+20 along y direction

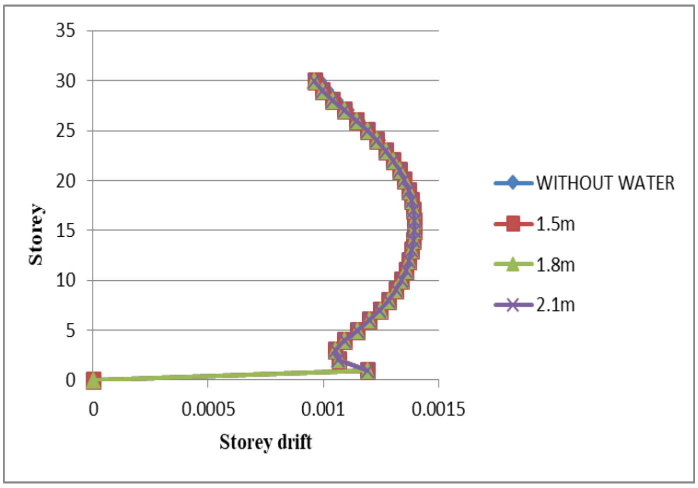

Fig 4.11 maximum storey drift for G+30 along x direction

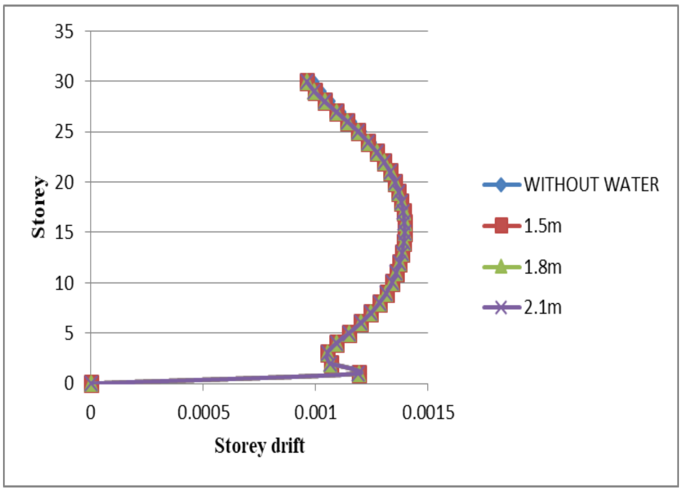

Fig 4.12 maximum storey drift for G+30 along y direction

4.1.3 Base Shear

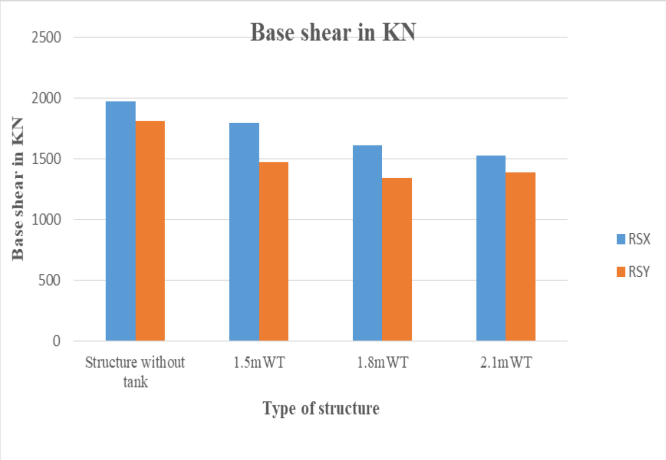

Fig 4.13: Base Shear for G+10 along RSX and RSY Direction

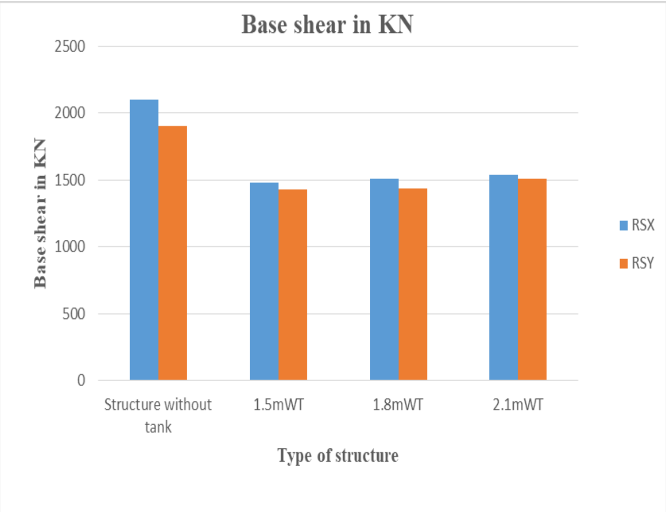

Fig 4.13: Base Shear for G+20 along RSX and RSY Direction

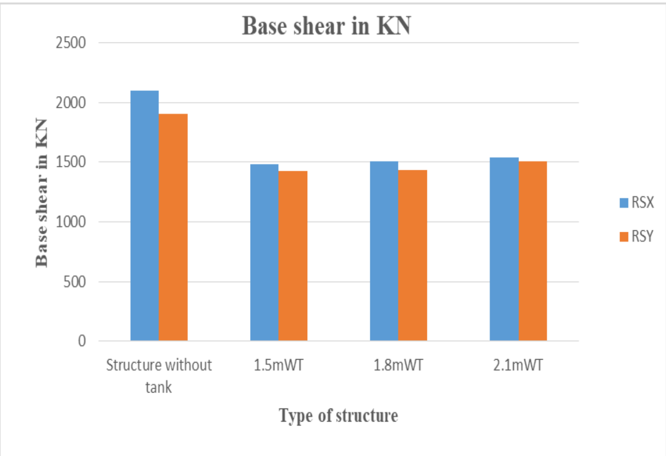

Fig 4.13: Base Shear for G+20 along RSX and RSY Direction

4.1.4 DISCUSSIONS

- From the response of the analytical models it can be noticed that displacement of the structure depends on the type of the soil, seismic zone and height of the buildings. It can be observed that maximum displacement will be higher in structure without tank and lower displacement in structure having tank.Displcement goes on increasing with the storey height.
- For G+10, storey displacement at top story reduces by 21.62% for 1.5m height water tank, 21.74% for 1.8m height water tank and 21.85% for 2.1m height water tank. It increases initially up to 3rdstorey by 1.94% for 1.5m height water tank, 1.7% for 1.8m height water tank and 1.48% for 2.1m height water tank.
- For G+20, storey displacement at top story reduces by 9.56% for 1.5m height water tank, 9.56% for 1.8m height water tank and 9.57% for 2.1m height water tank along x direction. It can also reduce by 5.99% for 1.5m height water tank, 28.72% for 1.8m height water tank and 28.64% for 2.1m height water tank along y direction.
- For G+30, storey displacement at top story reduces by 7.25% for 1.5m height water tank, 7.27% for 1.8m height water tank and 7.29% for 2.1m height water tank along x direction. It can also reduce by 8.97% for 1.5m height water tank, 8.91% for 1.8m height water tank and 8.86% for 2.1m height water tank along y direction.
- In the comparison of the structure without tank models (model 1, 2, 3) and structure with models (model 4 to 12), the maximum drift is more for structure with tank models than structure without tanks.
- It can be noted that base shear will be higher in structure without tank and lower displacement in structure without tank. The value increases corresponds to its soil types with different types of models.

5. CONCLUSIONS

- Behavior of TLD with different water tank depths is more efficient to reduce structural vibration.
- Displacement is more for structure without tank than the structure having tank, as the depth of water decreases displacement gets increases vice-versa. Displacement is reduced by 21-22% for water tank 1.5m shows better performance.

- In comparison, the structure without tank model and with tank model, the storey drift is more in structure with tank than structure without tank. It can be observed from the analysis.
- In the comparison of the structure without tank models and structure with tank models, the design base shear is more for structure without tank than structure with tank models. The percentage variation is found to be from 18-25%. Base shear more for structure without tank, as the depth of water increases base shear gets decreases.
- On comparing 1.5m height water tank with 1.8m and 2.1m water tank, the percentage reduction in displacement, drift and base shear is marginal i.e. it reduced by 0.3%.

Scope for future work

- Analysis shall be carried out irregular buildings with different soil conditions.
- Analysis shall be carried out different width and depth dimensions of water tank.
- Study may further be extended for different seismic zones.
- Analysis shall be carried out for different in fills.
- Analysis shall be carried out using time history method.

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