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Torsional Effect on Multi-Storeyerd Buildings with Water Tanks Due to the Seismic Forces by using Sap 2000 Software

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Abstract— **Many multi-storeyed buildings tend to have irregular features in configuration, which are not suitable for the buildings to resist the forces generated during an earth quake. The presence of heavy roof top masses like water tanks, air handling units, swimming pools etc., increases the seismic forces in the members of a building .The present study compares the forces in the columns of a few building models which have the water tanks supported on columns considerably above the roof level.**

Elevated tanks are important structures in storing vital products, such as petroleum products for cities and industrial facilities, as well as water storage. These structures have various types and are constructed in a way that a greater portion of their weight is concentrated at an elevation much about the base. Damage to these structures during strong ground motions may lead to fire or other hazardous events. The liquid mass of the tank will modelled as lumped mass known as sloshing mass, or impulsive mass. The corresponding stiffness constants associated with the lumped mass will be determined depending upon the properties of the tank wall and liquid mass. Tank responses including base shear, overturning moment, tank displacement, and sloshing displacement will also be calculated.

Two models for the same building will be developed by changing the position of the tank one placed eccentrically and another placed by splitting equally and located symmetrically. The forces in the columns will be obtained for both the cases.

Index Terms – normal building, building with empty weight, building with full water weight

INTRODUCTION:

Elevated tanks are important structures in storing vital products, such as petroleum products for cities and industrial facilities, as well as water storage. These structures have various types and are constructed in a way that a greater portion of their weight is concentrated at an elevation much about the base. Damage to these structures during strong ground motions may lead to fire or other hazardous events. In the research , a reinforced concrete elevated tank, with 900 cubic meters capacity, exposed to three pairs of earth quake records was analyzed in time history using mechanical and finite element modeling techniques. The liquid mass of the tank was modeled as lumped mass known as sloshing mass, or impulsive mass. The corresponding stiffness constants associated with the lumped mass were determined depending upon the properties of the tank wall and liquid mass. Tank responses including base shear, overturning moment, tank displacement, and sloshing displacement were also calculated. Obtaining results revealed that the system responses are highly influenced by the structural parameters and the earthquake characteristics such as frequency content

SAP 2000 represents the most sophisticated and user- friendly release of the SAP series of computer programs. When initially released in 1996, SAP2000 was the first version of SAP to be completely integrated within Microsoft Windows. It features a powerful graphical user interface that is unmatched in terms of ease- of-use and productivity. Creation and modification of the model, execution of the analysis, and checking and optimization of the design, and production of the output are all accomplished using this single interface. A single structural model can be used for a wide variety of different types of analysis and design

RESEARCH SIGNIFICANCE:

Proper configuration and design of the structural members are essential for the safety of a building against seismic forces. Though the placement of heavy water tanks above the roof level is a functional requirement and may not be critical for a building in terms of resisting gravity loads, it increases vulnerability of some columns in the building for seismic forces, especially if they were not adequately designed for seismic forces.

The results from the present study quantify the vulnerability in terms of the torsion in the multi-storeyed building. The study helps in creating awareness in the design of such buildings located in earthquake prone areas. Such type of investigation is necessary where the water distribution to the individual apartments /offices in a multi-storied building is based on gravity flow from the roof tanks

Design of building with gravity loads:

Two ten storied building was considered. In that building one which is having 5 panels in x direction and 5 panels in y direction which are of 5m length. In this here it has fixed moments at the bottom floor that is ground floor. In that building two which is having 6 panels in X direction and 4 panels in Y direction which are of 5m length.

Second building was taken into consideration for middle placing of the water tank for getting the accurate results. Then the earthquake loads and gravity loads are applied for empty tanks. Then gravity loads and earthquake loads are applied for the full water tank.

Dimensions:

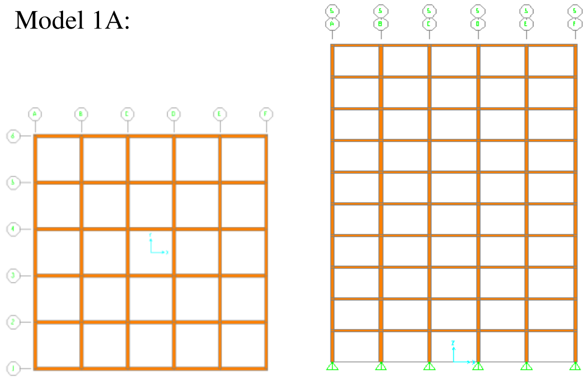
Building no 1:

These are the dimensions of the building which is having 5 bays in x direction and 5 bays in y direction which are of length 5m in both x and y direction.

No of stories	10
Story height	350mm
Characteristic strength of Concrete	M30
Characteristic strength of steel	Fe 415
Beams in X direction	300x400 mm
Beams in Y direction	300x300 mm
External columns	600x 600 mm
Internal columns up to 4th floor	900x 900 mm
Internal columns above 4th floor	550x 550 mm
Dead load	1.5KN/ sq.m
Live load on slab	1 KN/sq.m
Live load on remaining floors	3 KN/sq.m

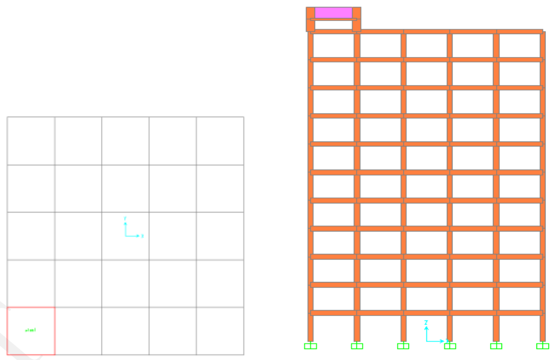
Model 1A: Normal building with 5 x 5 bays and each bay length is 5m
Model 1B: Building with water tank dimensions 5m x 5m x 3.5m at the eccentric position
Model 1C: Building with tank dimensions 10m x 10m x 3.5m at the eccentric position
Model 1D: Building with tank 10m x 10m x 3.5m at the eccentric position close to the centre of building

Model 1A:



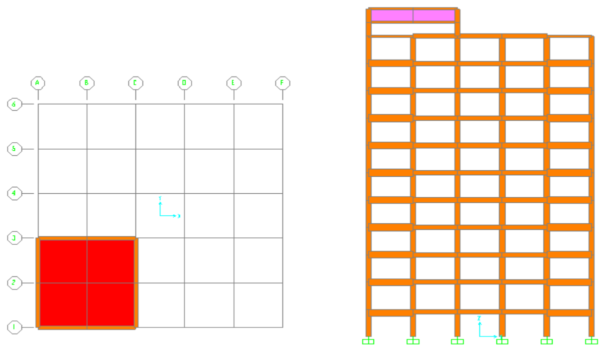
plan elevation

Model 1B:



plan elevation

Model 1C:



plan elevation

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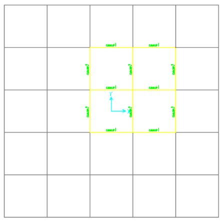
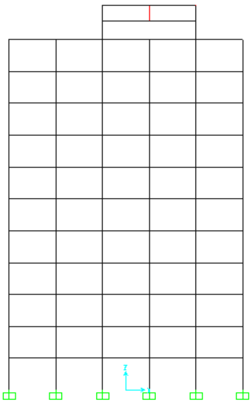
Model 1D:



plan



elevation

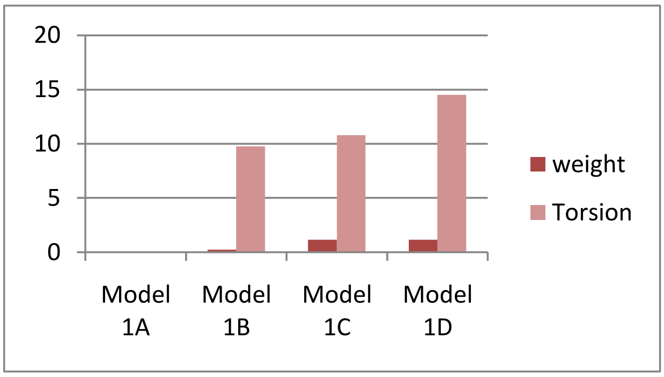
By using SAP2000 we constructed these symmetrical building with 5x5 bays with 5 m length each and we checked the stability of the structure by designing. We calculated the area of steel (AST) of the building for the economical calculations we got. For each model we calculate the AST of beams and columns of models separately and we will add those both and this is the model 1A are shown and all the models are done like that only

Ast of beams as 2.654 m^2
Ast of columns as 11.58 m^2
Total ast of building is 14.234 m^2

Calculation of Torsion:

Building	Weight (KN)	%change in weight	Torsion (KN-m)	%change in torsion
Model 1A	100921	---------	3860	----------
Model1B	101174	0.25%	4277	9.75%
Model 1C	102090	1.15%	4330	10.8%
Model 1D	102090	1.15%	4518	14.5%

Here we have the bar graph between the % change in weight and % change in torsion shows us the clear variation between them



Here we have come to know from the above table that for model 1C and model 1D % change in weight will be same but the change in torsion is more. This means by changing the position of the tank we can get the change in percentage of torsion

Here we can observe that the torsion is more in the tank placed near to the central position then the tank placed at the eccentric position.

Building no 2:

We constructed another building with horizontal 6 and vertical 4bays and with length and breadth area of 6m X 4m and we designed it by using sap2000 because the central position of the building can be fixed at the central if the building has non symmetrical bays. The data of the building is

Dimensions :

No of stories	10
Height of the storey	350 mm
Beam dimension	600 x 400 mm^2
Dimension of column 1	700 x 700 mm^2
Dimension of column 2	600 x 600 mm^2
Dead load	1 KN/m^2
Live load on terrace	1 KN/m^2
Live load on remaining floors	2.5 KN/m^2
Characteristic strength of concrete	M30
Characteristic strength of steel	Fe 415

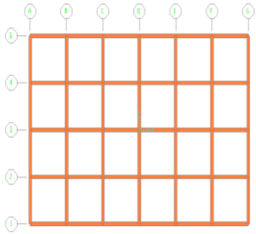
Model 2A: normal building with 6 x 4 bays and each bay length is 5m
Model 2B: Building with water tank dimensions 10m x 10m x 5m at the eccentric position
Model 2C: building with water tank dimensions 10m x 10m x 5m at the centre of building

These are the figures which can be shown the different models which are stated above

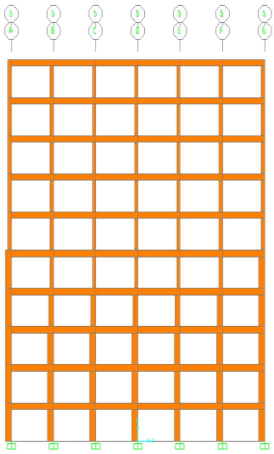
By using SAP2000 we constructed these symmetrical building with 6 x 4 bays with 5m length each and we checked the stability of the structure by designing.

We calculated the torsion of a building by placing water tanks at different positions on the roof of a building and we compared with the torsion in normal building without any tank.

Model 2A:

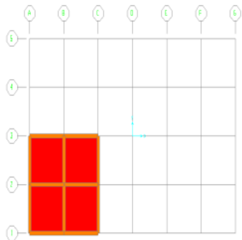


plan

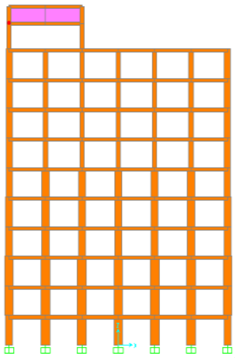


elevation

Model 2B:

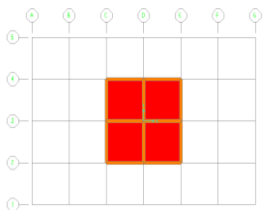


plan

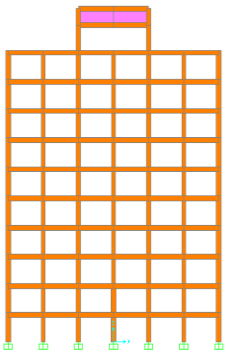


elevation

Model 2C:



plan

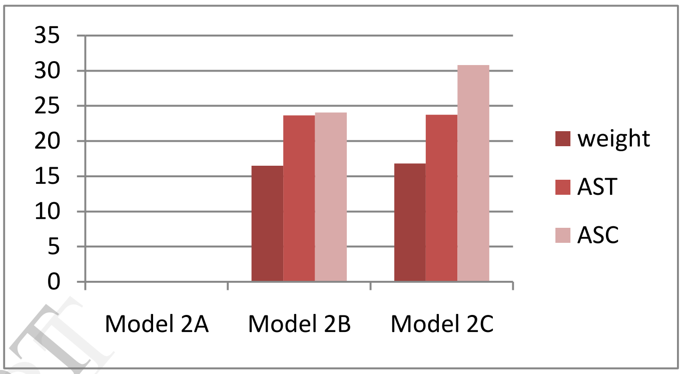


elevation

Calculation of Area of Steel and Concrete:

Building	Weight (KN)	%change in weight	Area of steel AST(m^2)	% change in AST	Area of concrete ASC	% change in ASC
Model 2A	108775	----------	2.82	--------	875.797	-----------
Model 2B	126729	16.5%	3.487	23.65 %	1085.945	24.05%
Model 2C	127154	16.8%	3.490	23.75 %	1145.465	30.8 %

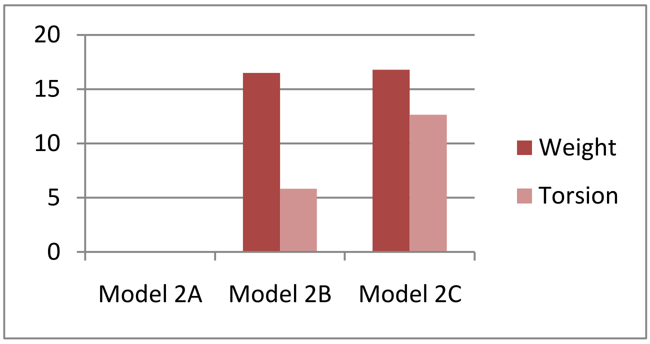
By using this tabular form we will a draw a graph which gives a clear comparison between different models and their values. And that bar graph is shown below



Calculation of Torsion:

Building	Weight (KN)	% change in weight	Torsion (KN-m)	% change in torsion
Model 2A	108775	---------	1115	-----------
Model 2B	126729	16.5%	1180	5.83%
Model 2C	127154	16.8%	1256	12.64%

By using this tabular form we will a draw a graph which gives a clear comparison between different models and their values. And that bar graph is shown below



Here whether the percentage change in weight in buildings is same but due to the position of the water tank the %change in torsion is different.

Design of building with gravity loads and earthquake loads (IS1893-2002):

Earthquake can cause damage not only on account of the shaking which results from them but also due to other chain effects like landslides, floods, fires and disruption to communication. It is, therefore, important to take necessary precautions in the sitting, planning and design of structures so that they are safe against such secondary effects also.

Here we consider the zone III for medium soils we have done

Assumptions:

The following assumptions shall be made in the earthquake resistant design of structures:

a) Earthquake causes impulsive ground motions, which are complex and irregular in character, changing in amplitude and period each lasting for a small duration. Therefore, resonance of the type as visualized under the type as visualized under steady- state sinusoidal excitations, which will not occur as they would need time to build up such amplitudes.

b) Earthquake is not likely to occur simultaneously with maximum flood or wind or maximum sea waves.

c) The value of elastic modulus of materials, wherever required, may be taken as for static analysis unless a more definite value is available for use in such condition

In the limit state design of reinforced and pre stressed concrete structures, the following load combinations shall be accounted for:

1) 1.5 (DL + IL)
2) 1.2 (DL + IL+ EL)
3) 1.2 (DL + IL – EL)
4) 1.5 (DL – EL)
5) 1.5 (DL + EL)
6) 0.9 DL + 1.5EL
7) 0.9 DL – 1.5EL

Model Designing:

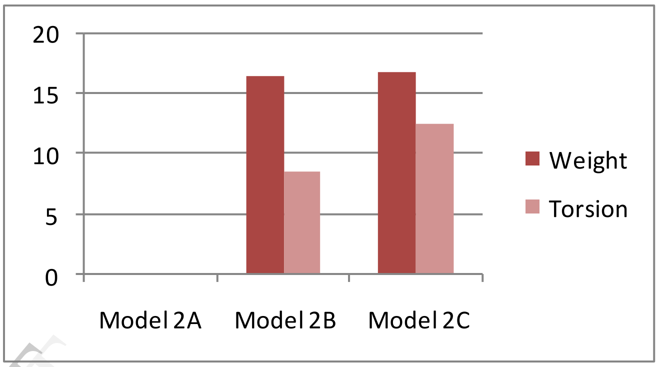
We constructed model 2 building with horizontal 6 and vertical 4bays and with length and breadth area of 5m X 5m and we designed in such a way that we applied all the load combinations and the earth quake forces according to IS 1893: 2002 specifications by using sap2000. The data of the building is

No. of stories	10
Height of the storey	350mm
Beam dimensions	600 mm x 400 mm
Dimensions of column 1	700 mm x 700 mm
Dimensions of column 2	600 mm x 600 mm
Dead load	1 KN/m^2
Live load	2.5 KN/m^2
Characteristic strength of concrete	M30
Characteristic strength of steel	Fe 415

Calculation of Area of steel:

Building	Weight (KN)	%change in weight	Area of steel AST(m^2)	% change in AST
Model 2A	108775	---------------	2.92	----------------
Model 2B	126729	16.5%	3.96	35.16%
Model 2C	127154	16.8%	4.10	40.41%

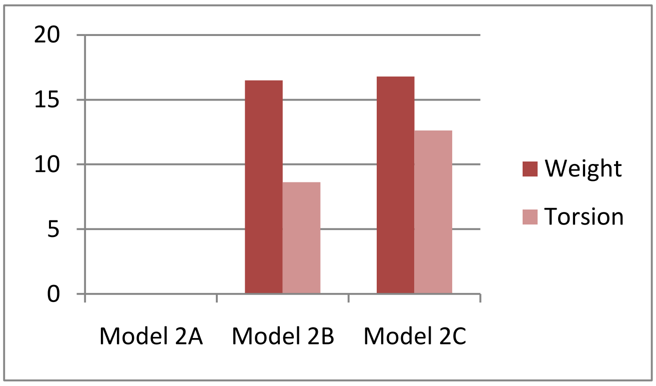
By using this tabular form we will a draw a graph which gives a clear comparison between different models and their values. And that bar graph is shown below



Calculation of Torsion:

Building	Weight (KN)	% change in weight	Torsion	% change in torsion
Model 2A	108775	---------------	4950	--------------
Model 2B	126729	16.5%	5376	8.64%
Model 2C	127154	16.8%	5575	12.62%

The bar graph is drawn showing the variation in the % change of weight and the % change of torsion from table 6



Building with gravity loads, earthquake loads (IS 1893-2002) and hydrodynamic loads (IITK-GSDMA GUIDELINES):

Water consumption rate(per capita demand in litres per day per head)with which people should be survived

Quantity = per demand x population

It is very difficult to estimate the quantity of water demand by the public, since there are many variable factors affecting the water consumption. The various types of water demands, which a city may have, may be broken into following class

S.NO	TYPES OF CONSUMPTION	NORMAL RANGE (lit/capita/day)	AVERAGE	%
1.	Domestic Consumption	65-300	160	35
2.	Industrial and commercial demand	45-450	135	30
3.	Public Including fire Demand uses	20-90	45	10
4.	Losses and Waste	45-150	62	25

Load combinations:

The load combinations according to IS 1893:2002 is taken for seismic forces and these are the combinations when hydro dynamic load is present in the tank (or) when the tank is empty.

100% + 30% rule implies following eight load combination

a) $(EL_X + 0.3EL_Y)$
b) $–(EL_X + 0.3EL_Y)$;
c) $(0.3EL_X + EL_Y)$;
d) $–(0.3EL_X + EL_Y)$
e) $(EL_X – 0.3EL_Y)$
f) $–(EL_X – 0.3 EL_Y)$
g) $(0.3EL_X – EL_Y)$

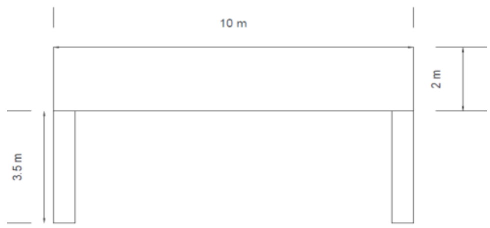
after that we will find out Spring Mass Model for Seismic Analysis for the water tank by using IITK-GSDMA guidelines which are specified for the water tank designs.

Preliminary Data:

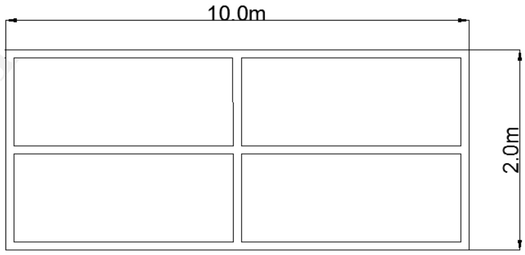
Component	Size (mm)
Roof slab	250
Wall	250
Floor slab	250
Floor beams	600 x 400
columns	600 x 600

Weight Calculations:

Component	Calculations	Weight (kN)
Roof slab	(5x5)x0.25x25x4	625
Wall	2x(5+0.6)x0.25x25x2.4	168
Floor slab	(5x5)x0.25x25x4	625
Floor beam	2x(5+0.6)x0.25x(0.4-0.25)x25	10.5
Columns	(0.6x0.6)x5.4x4x25	194.4
water	(10x10)x2x9.81	1962



Elevation of tank



Slab of the tank above the columns

According to IITK-GSDMA guidelines we will find out lateral stiffness of staging, time period, design horizontal seismic coefficient, base shear, base moment, hydro dynamic pressures, pressure due to wall inertia, pressure due to vertical excitation, sloshing wave height and the remaining which we need for us.

Calculation of Area of Steel:

Building	Weight (KN)	%change in weight	Area of steel AST(m^2)	% change in AST
Model 2A	108775	--------------	2.92	-------------
Model 2B	136293	25.29%	4.48	53.42%
Model 2C	137485	26.39%	4.53	58.13%

By using this tabular form we will a draw a graph which gives a clear comparison between different models and their values. And that bar graph is shown below

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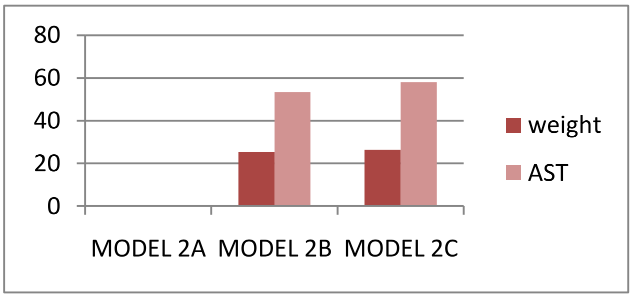
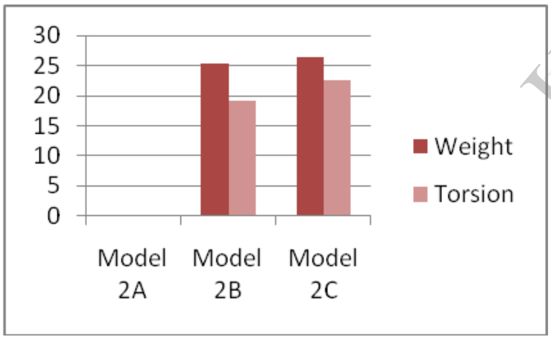


Calculation of Torsion:

Building	Weight (KN)	% change in weight	Torsion (KN-m)	% change in torsion
Model 2A	108775	-----------	4950	------------
Model 2B	136293	25.29%	5896	19.1%
Model 2C	137485	26.39%	6018	22.6%

The given graph represents the above table which compares between weight and torsion. By using this tabular form we will a draw a graph which gives a clear comparison between different models and their values. And that bar graph is shown below



BUILDING WITH WATER TANK DIVIDED INTO TWO TANKS OF EQUAL SIZE

Dimensions:

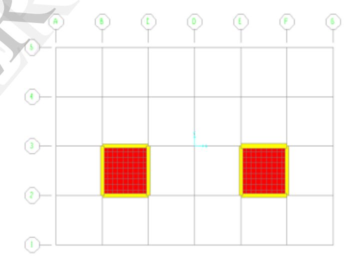
As we know that as the weight increases on the roof of the building torsion increases from previous chapters but here we are doing how the torsion will vary when the heavy tank is divided in to the tanks of small volume and
thats why we divided here the 10 m x 10 m x 3.5 m tank into two tanks of volume 5 m x 5 m x 3.5m

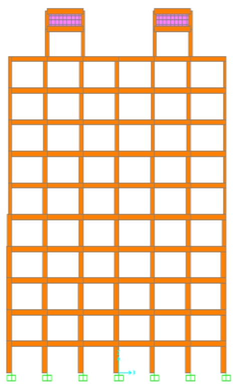
Here below the table represents the dimensions of the building which we are taking. Here we consider model 2C which is having centrally constructed over head tank and the thing which is having more torsion when compared to other buildings.

No. of stories	10
Height of the storey	350 mm
Beam dimensions	600 mm x 400 mm
Column 1	700 mm x 700 mm
Column 2	600 mm x 600 mm
Dead load	1 KN/m^2
Live load on Terrace	1 KN/m^2
Live load on remaining floors	2.5 KN/m^2
Characteristics strength of concrete	M30
Characteristic strength of steel	Fe 415

Here we have taken a 6 bays in x direction and 4 bays in y direction and we place the water tank of size 10 m x 10 m x 3.5 m is divided into two tanks of 5 m x 5 m x 3.5 m size and we placed them near to centre on the roof of building

Model 2D: The building with 6 bays of length 5m in x direction and 4 bays of length 5m in y direction and the tank is divided into two and distributed on the roof



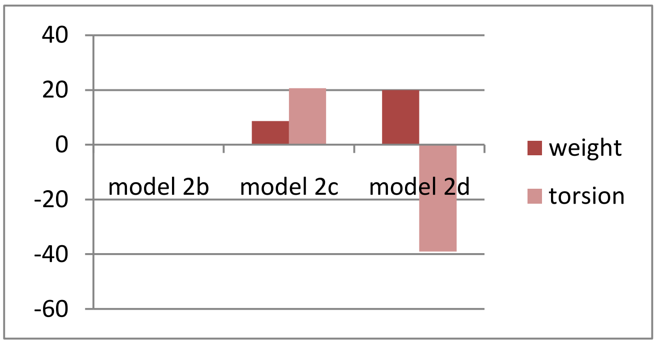


Calculation of torsion:

building	weight	% change in weight	Torsion	% change in torsion
Model 2B	136293	--------------	5896	---------------
Model 2C	137485	0.87%	6018	2.07%
Model 2D	139025	2.00%	3585.3	-39.19%

In the tanks are divided the torsion value is decreased very much compared to total mass of the tank present at one place. This represents the uniform distribution of the mass on the roof of the slab

Above is the graph which represents the comparison between weight and the torsion for the 3 models



The seismic forces on the ground floor will be more when compared to the top floors because the columns will affect more than the beams in each floor.

When we the tank is divided symmetrically on either side from the centre of the building the load will be distributed uniformly to the whole building then the affect of seismic forces on the columns will become less.

CONCLUSIONS:

1. From the design we conclude that the columns below the water tank are more affected especially from ground level to top floors.

2. Change in the weight of a building not only gives the change in torsion but also position of the extra mass also shows change in torsion

3. Change in torsion is more when we place the extra mass at the centre then at the eccentric position

4. When we keep extra mass at the centre then the central frame of the whole building will not show any torsional values that means the torsion at the central frame is zero

5. Torsion is more in YZ direction then in XZ direction of building.

6. When the tank is splitted equally into on either side of the building as shown in fig the torsion is decreased very much compared to the eccentric and central position of the building

7. In the presence of a heavy roof top water tank, the columns in the ground storey supporting the water tank experience the maximum increase of seismic forces. The situation can be critical for the columns in an open ground storey, when walls are absent for facilitation of parking or other usage.

8. The sloshing effect of water was found to be small for the size of the tank relative to the building. Hence, it can be neglected in the analysis for the member forces in a building

9. The elevation of heavy roof-top water tanks is significant with respect to the concentration of internal forces in the supporting columns. Hence, the elevation should be accounted for in the analysis of a building for seismic forces

10. The seismic forces in the columns increase when the tank is eccentrically located or centrally located in the plan of building. The forces are reduced when the tank is split equally and positioned symmetrically in plan

REFERENCES:

1. IITK-GSDMA guidelines for seismic design of liquid storage tanks (2007), Indian Institute of technology Kanpur and Gujarat state Disaster Management Authority.
2. IS 1893, " Indian Standard criteria for Earthquake Resistant Design of structures", Part 1 (2002): General provisions and buildings, part 2 (Draft):
Liquid Retaining Tanks, Bureau of Indian standards, New Delhi.
3. IS 13920: 1993, "Ductile detailing of Reinforced concrete Structures Subjected to seismic forces ", Bureau of Indian standards New Delhi.
4. Manual on Water Supply Treatment (1999), Central public health and environmental engineering Organisation, Government of India
5. Housner, G.W. (1963), " The Dynamic behaviour of Water tanks ", Bulletin of the seismological society of America vol.53, No.2,pp.381-387
6. Jojy, 1, (2011), "Effect of Heavy Roof- Top water tanks on the seismic Forces in a typical multi storied Building", B. Tech, Project report submitted to Indian Institute of Technology Madras.