International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 04 | Apr 2021 www.irjet.net p-ISSN: 2395-0072

Water Tank as a Tuned Mass Damper

Vibhavari Shankar Bangi[1], Vidya Malgonda Patil[2], Dr. Someshwar Jagannath Arwikar[3]

[1-3]Department of Civil, Annasaheb Dange College of Engineering and Technology, Ashta, Sangli, India.

Abstract - *Water tanks are integral part of all buildings and they impart large dead load on the structure. This additional mass can be utilized as TMD to absorb extra energy imparted on the structure during earthquake. The present work is limited to linear analysis of 10 & 15 storey buildings subjected to real earthquake data. Water tank position is changed by keeping it at center and at extreme corners of the building. Also effect of water tank as TMD with variation of sizes is checked.*

Key Words: Tuned Mass Damper (TMD), Water tank, Energy Dissipation mechanism, Oscillation.

1. INTRODUCTION

Now a days due to rapid urbanization and industrialization there is an increasing demand of high-rise buildings. These buildings inspired the use of high-strength, light-weight materials which reduces the stiffness of structures. When the natural phenomenon like earthquake occurs these high-rise buildings and other civil engineering structures undergo oscillations. Earthquake create vibrations on the ground that are translated into dynamic loads which cause the ground and anything attached to it vibrate in a complex manner. The dynamic response of structures caused by earthquake may induce the problems of structural safety and serviceability.

Tuned mass damper is one type of successful seismic response control devices. There are two major types of dampers: active and passive. In active control system an external source of powers control actuators that supply forces to the structure in order to both add and dissipate vibration energy in the structure. Power failure is one of the biggest problems in actively controlling structures during earthquake. Another problem of active control is the amount of power needed for controlling large structures during intense earthquake, also it is uneconomical to common man.

2. MATERIALS AND METHODS

Study of behavior of water tank as Tuned Mass Damper (TMD) is carried out as follows:

- Software ETAB is used to model multistory buildings with different height to base ratios.
- Water tanks of different weights with different locations is considered to study seismic behavior of the modeled structure in ETAB.
- The data obtained is evaluated to find the role of water tanks in multistoried buildings in effective control of seismic deformations i.e. their role as Tuned Mass Damper without considering sloshing effect.

Two buildings of 15 storey & 10 Storey are modelled. For these two buildings both rectangle and square shape of tank is used. 15 Storey & 10 storey buildings are also Square & rectangle in shape. All above cases are modelled with full and empty water tank. Water tank at top of building and Middle of building is also studied. Following table shows some cases which are covered in present study.

Table 1. Shape of building and water tank

Case No.	Shape of Building	No. of Storey	Shape of Water Tank	Location of tank	Situation of tank
Case 1	Square	10	Square	Centre	Empty
Case 2	Square	10	Square	Centre	Full
Case 3	Square	15	Square	Centre	Empty
Case 4	Square	15	Square	Centre	Full
Case 5	Square	10	Rectangular	Centre	Empty
Case 6	Square	10	Rectangular	Centre	Full
Case 7	Square	15	Rectangular	Centre	Empty
Case 8	Square	15	Rectangular	Centre	Full
Case 9	Rectangular	10	Rectangular	Centre	Empty
Case 10	Rectangular	10	Rectangular	Centre	Full

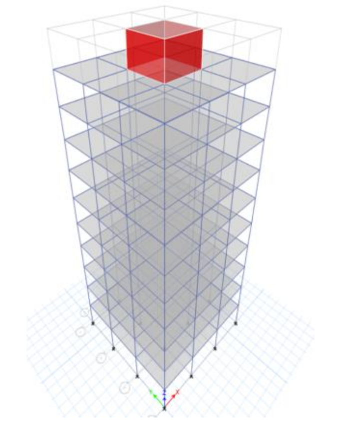
Table 2. Size of model with H/B ratio is enlisted below.

Case No.	Size of Building in Plan			H/B Ratio
	L	B	H	
Case 1	15	15	33	2.20
Case 2	15	15	33	2.20
Case 3	15	15	48	3.20
Case 4	15	15	48	3.20
Case 5	15	15	35	2.33
Case 6	15	15	35	2.33
Case 7	15	15	50	3.33
Case 8	15	15	50	3.33

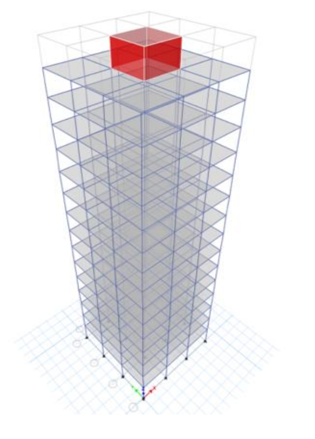
Case 9	20	15	31.5	2.1
Case 10	20	15	31.5	2.1

Images of Size of water tank for different cases is enlisted below.

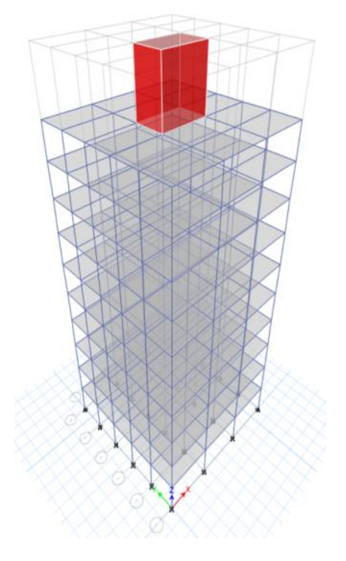
Case 1 & Case 2



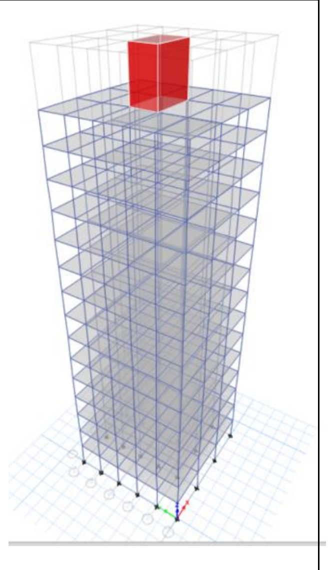
Case 3 & Case 4



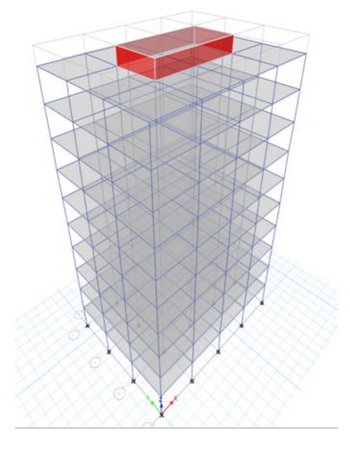
Case 5 & Case 6



Case 7 & Case 8



Case 9 & Case 10



3. RESULTS AND DISCUSSION

This includes linear static analysis of frame building with full & empty water tank. All results obtained after the analysis to meet the objective are discussed below.

3.1. Base shear:-

Following table shows the base shear at different cases.

-EQ X is the base shear in X direction.

-EQ Y is the base shear in Y direction.

-Water X is the base shear due to water load in X direction.

-Water Y is the base shear in Y direction due to water load in Y direction.

-TMD X is the base shear in X direction due to combine effect of water and earthquake force.

-TMD Y is the base shear in Y direction due to combine effect of water and earthquake force.

Table 3. Base Share at different cases.

Case No.	Base Shear in KN						Resultant X	Resultant Y
	EQ X	EQ Y	Water X	Water Y	TMD X	TMD Y		
Case 1	-1423	-1423	0	0	-1423	-1423	-1423	-1423
Case 2	-1455	-1455	5175	5175	3720	3720	-1455	-1455
Case 3	-1065	-1065	0	0	-1065	-1065	-1065	-1065
Case 4	-1065	-1065	7425	7425	6360	6360	-1065	-1065

Case 5	-1577	-1577	0	0	-1577	-1577	-1577	-1577
Case 6	-1577	-1607	5625	9375	4018	7768	-1607	-1607
Case 7	-1203	-1203	0	0	-1203	-1203	-1203	-1203
Case 8	-1203	-1203	7875	13125	6672	11922	-1203	-1203
Case 9	-2242	-1939	0	0	-2242	-1939	-2242	-1939
Case 10	-2281	-1972	2419	4838	138	2865	-2281	-1972

3.2 Time period & frequency: -

Time period and frequency for all cases is computed. First 3 modes are considered in the study. Following table shows the time period and frequency for all cases.

Table 4. Time period and frequency at different cases.

Case No.	Frequency	Time Period		
		Mode 1	Mode2	Mode 3
Case 1	0.33	3.029	2.424	2.323
Case 2	0.324	3.029	2.424	2.323
Case 3	0.23	4.341	3.548	3.34
Case 4	0.227	4.401	3.6	3.345
Case 5	0.499	2.002	1.848	1.683
Case 6	0.49	2.041	1.885	1.685
Case 7	0.328	3.046	2.852	2.543
Case 8	0.324	3.087	2.891	2.545
Case 9	0.384	2.604	2.061	2.052
Case 10	0.378	2.649	2.088	2.067

3.3 Lateral displacement: -

Whenever lateral forces are acting on building, it results in the lateral displacement of structure. Following response of graph shows lateral displacement for all cases along observation on each.

-EQ X is the lateral displacement in X direction.

-EQ Y is the lateral displacement in Y direction.

-Water X is the lateral displacement due to water load in X direction.

- Water Y is the lateral displacement in Y direction due to water load in Y direction.

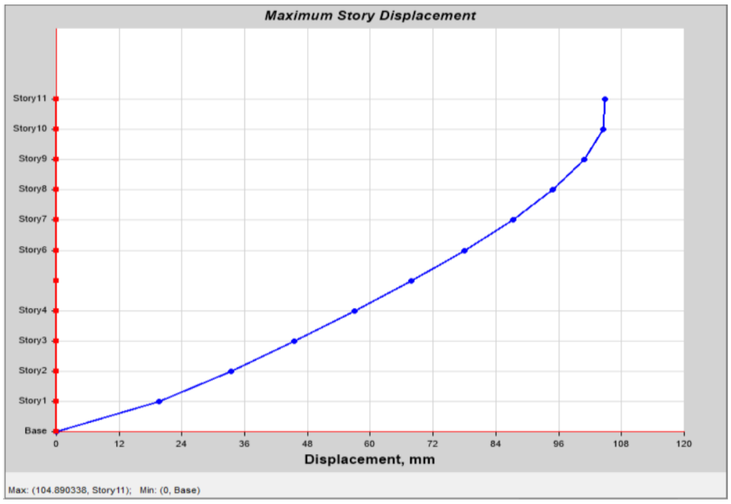
-TMD X is the lateral displacement in X direction due to combine effect of water and earthquake force.

-TMD Y is the lateral displacement in Y direction due to combine effect of water and earthquake force in.

Lateral displacement results clearly show that water tank can be utilized as Tune mass damper. In each case a result shows that seismic forces are resisted effectively by water tank's water force.

Lateral Displacement for case (1) -

Displacement due to EQ X -

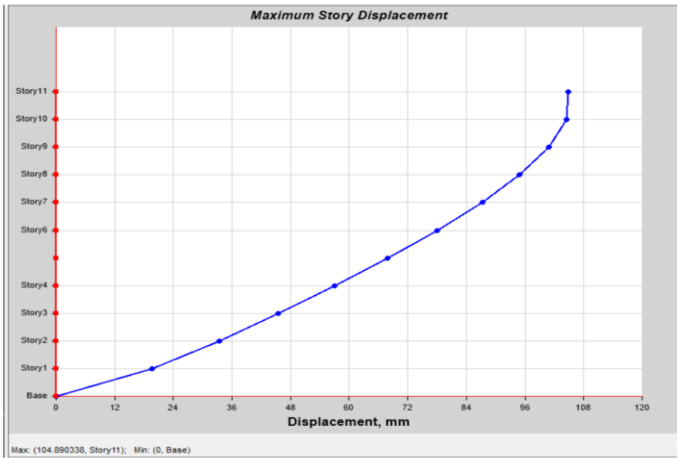


Displacement = + 104.89 mm

Displacement due to Water X -

Displacement = - 0 mm

Displacement due to TMD X -

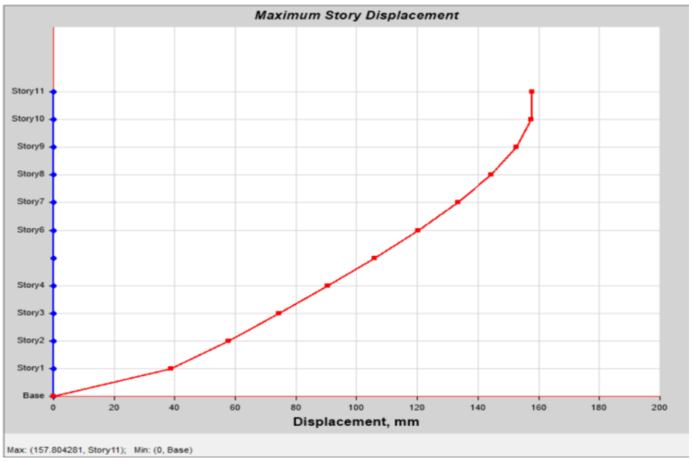


Displacement = + 104.89 mm

Observation - As there is no water load in X direction hence Resultant displacement TMD X is due to only EQ X.

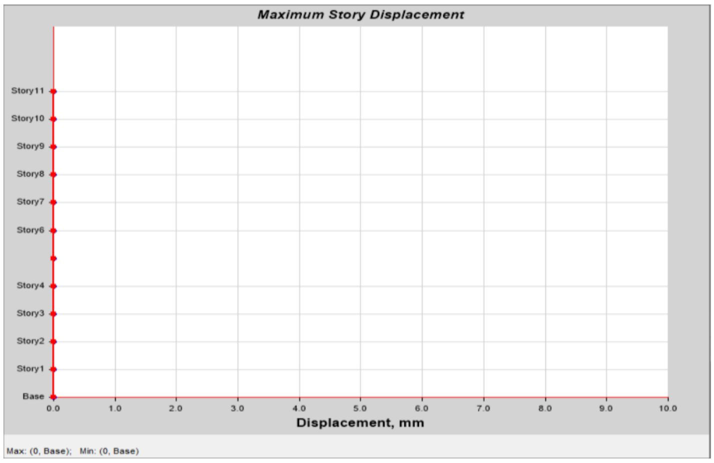
Lateral Displacement for case (1) -

Displacement due to EQ Y-



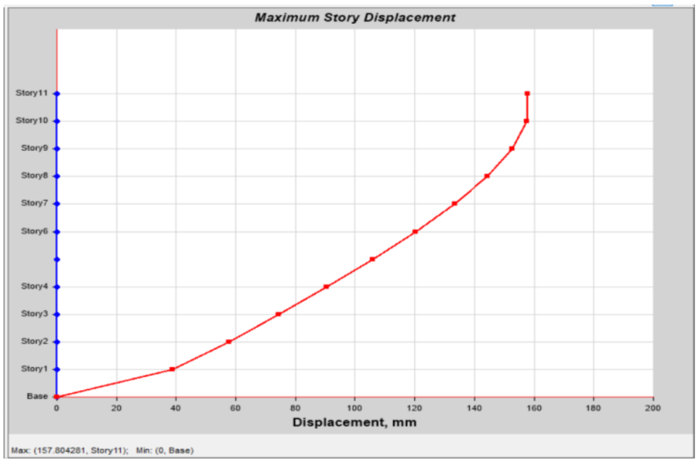
Displacement = + 157.80 mm

Displacement due to Water Y -



Displacement = - 0 mm

Displacement due to TMD Y -



Displacement = + 157.80 mm

Observation - As there is no water load in Y direction hence Resultant displacement TMD Y is due to only EQ Y.

Lateral Displacement for case (2) -

Displacement due to EQ X -

Displacement = + 108.49 mm

Displacement due to Water X -

Displacement = - 470.09 mm

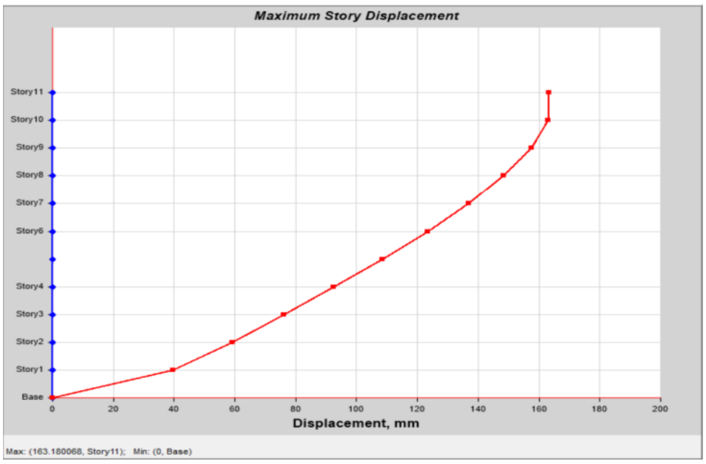
Displacement due to TMD X -

Displacement = - 361.60 mm

Observation - As there is water load in X direction hence Resultant displacement TMD X is due to Combine effect of water load in X direction as well as EQ X in X direction.

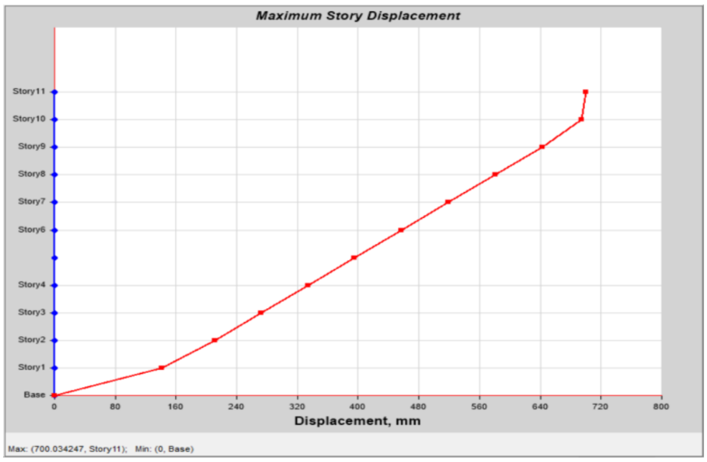
Lateral Displacement for case (2) -

Displacement due to EQ Y-



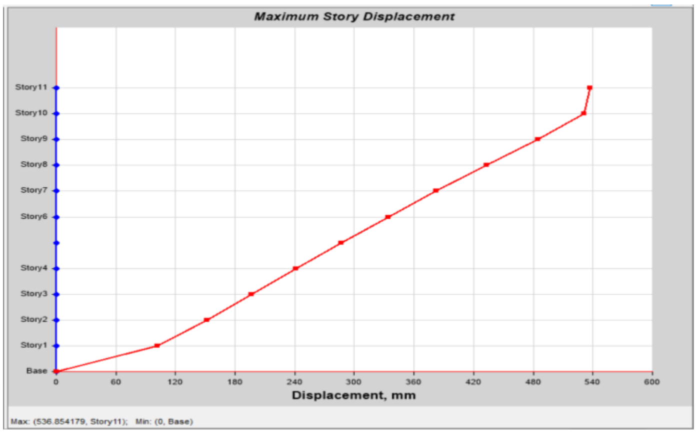
Displacement = + 163.18 mm

Displacement due to Water Y -



Displacement = - 700.03 mm

Displacement due to TMD Y -

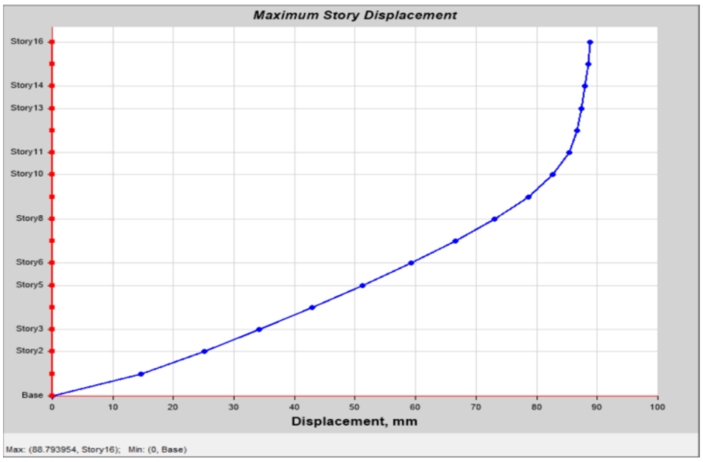


Displacement = - 536.65 mm

Observation - As there is water load in Y direction hence Resultant displacement TMD Y is due to Combine effect of water load in Y direction as well as EQ Y in Y direction.

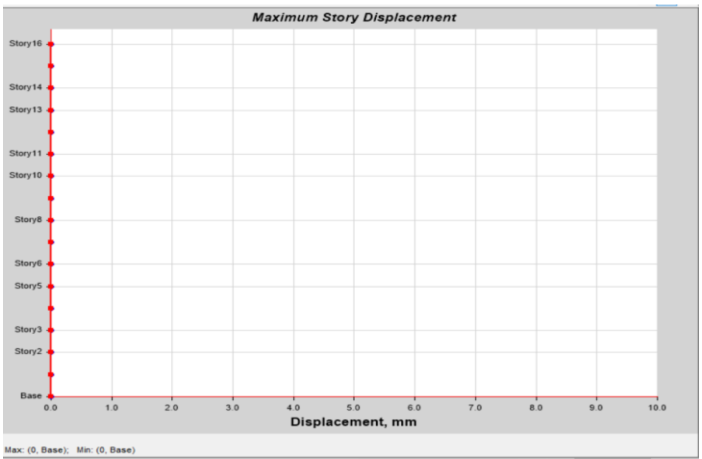
Lateral Displacement for case (3) -

Displacement due to EQ X -



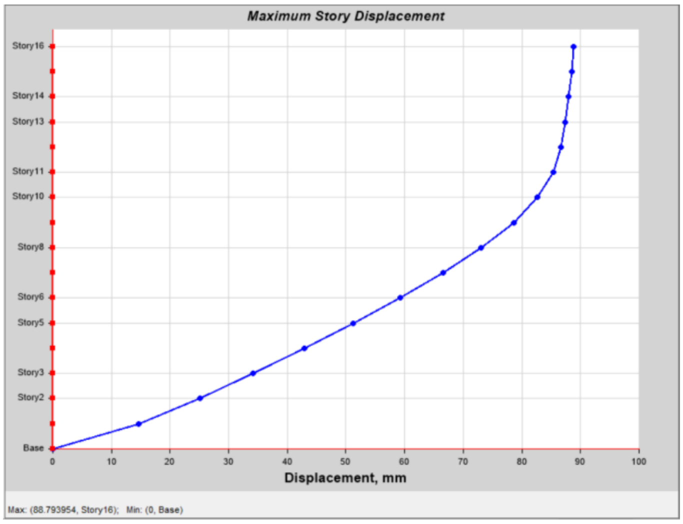
Displacement = + 86.79 mm

Displacement due to Water X -



Displacement = - 0 mm

Displacement due to TMD X -

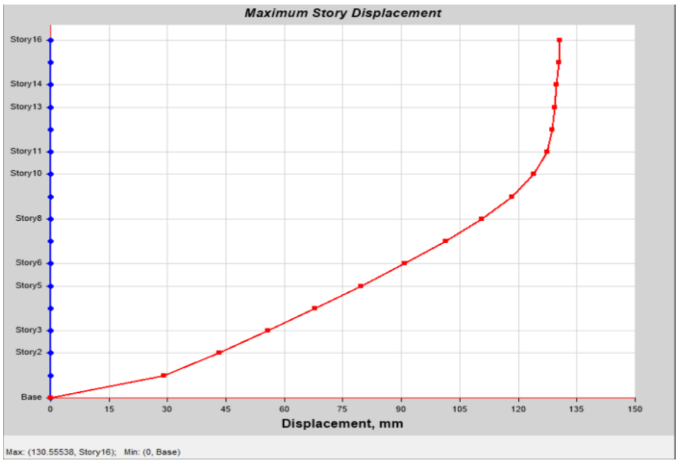


Displacement = 86.79 mm

Observation – No. of storey increases as compare to previous case hence lateral displacement in X direction is reduced for same intensity of load.

Lateral Displacement for case (3) -

Displacement due to EQ Y-

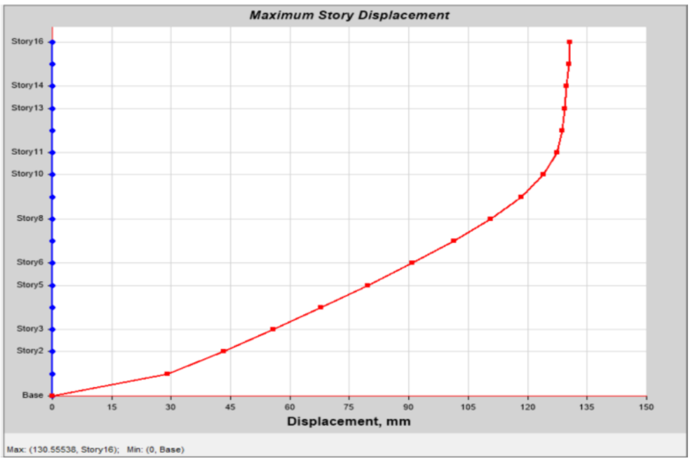


Displacement = + 130.55 mm

Displacement due to Water Y -

Displacement = - 0 mm

Displacement due to TMD Y -

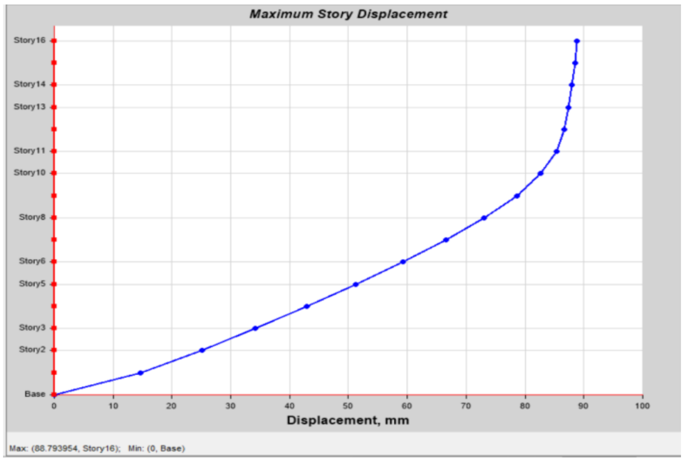


Displacement = + 130.55 mm

Observation - No. of storey increases as compare to previous case hence lateral displacement in Y direction is reduced for same intensity of load.

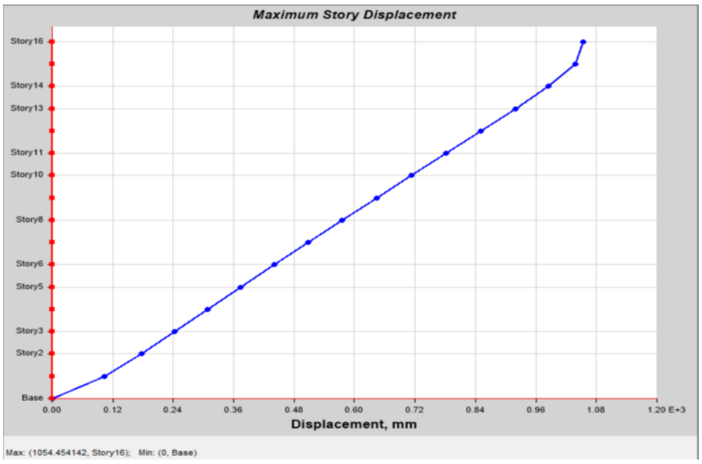
Lateral Displacement for case (4) -

Displacement due to EQ X -



Displacement = + 86.79 mm

Displacement due to Water X -



Displacement = - 1054.45 mm

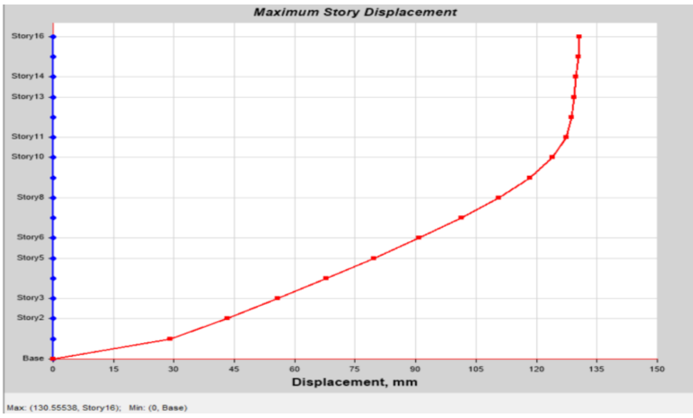
Displacement due to TMD X -

Displacement = - 965.66 mm

Observation – Displacement of X-direction is lesser as compare to Y direction because building is stiffer along X-direction due to orientation of column.

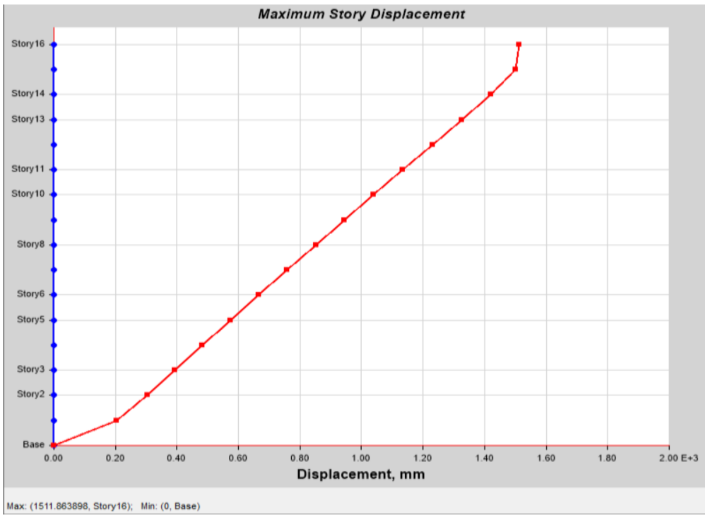
Lateral Displacement for case (4) -

Displacement due to EQ Y-



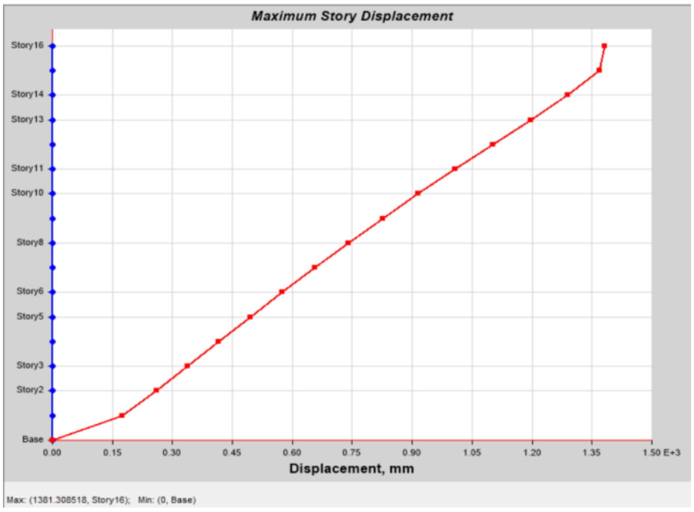
Displacement = + 130.53 mm

Displacement due to Water Y -



Displacement = - 1511.86 mm

Displacement due to TMD Y -

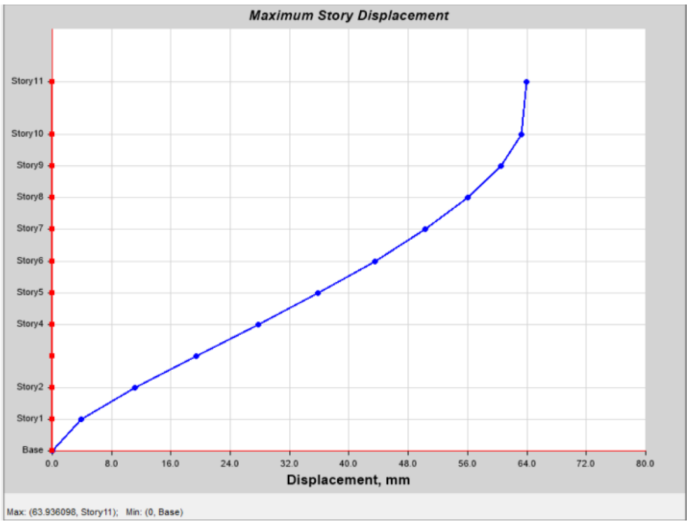


Displacement = - 1381.30 mm

Observation – Displacement of Y-direction is more as compare to X direction because building is less stiff along Y-direction due to orientation of column.

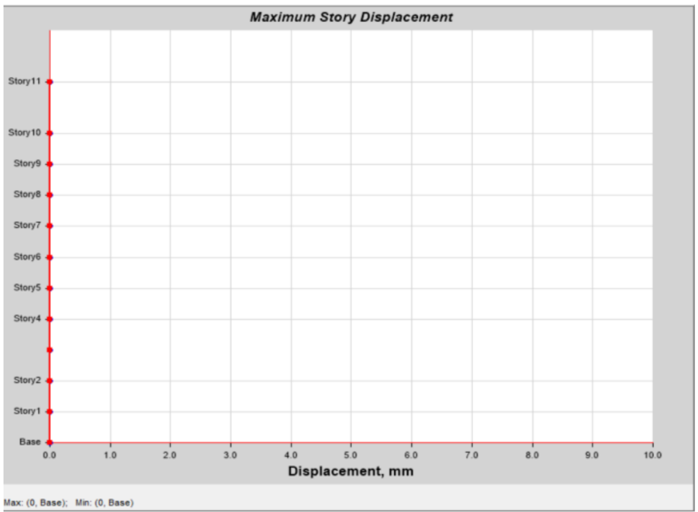
Lateral Displacement for case (5) -

Displacement due to EQ X -



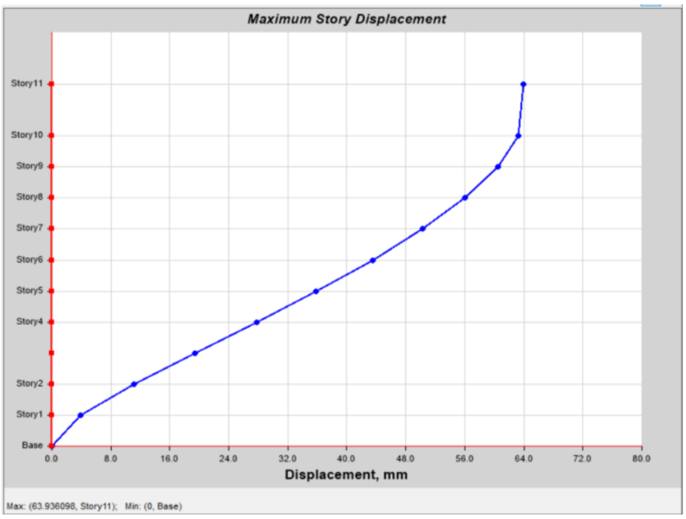
Displacement = + 63.93 mm

Displacement due to Water X -



Displacement = - 0 mm

Displacement due to TMD X -

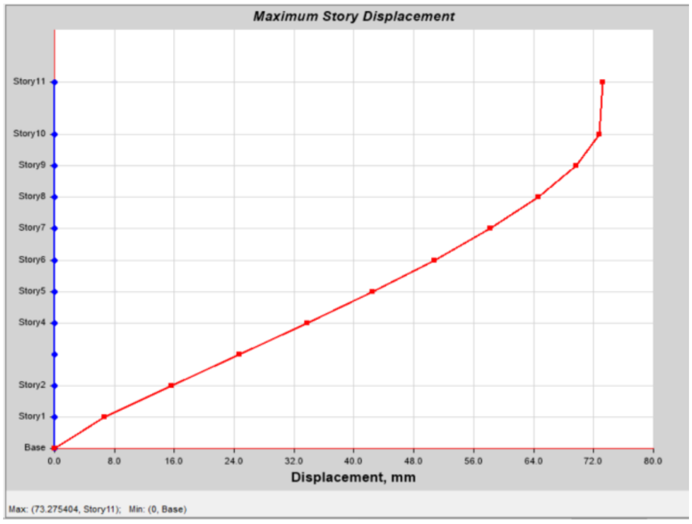


Displacement = 63.93 mm

Observation – When Rectangular water tank is preferred then it is more reliable to dissipate the energy as compare to Square tank in X direction.

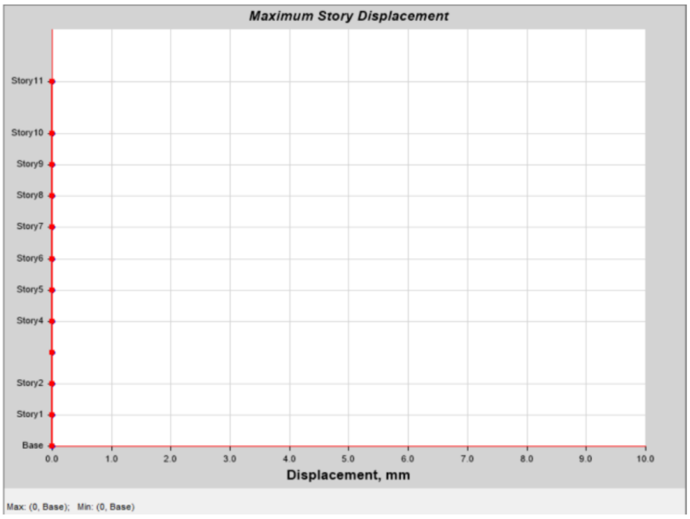
Lateral Displacement for case (5) -

Displacement due to EQ Y-



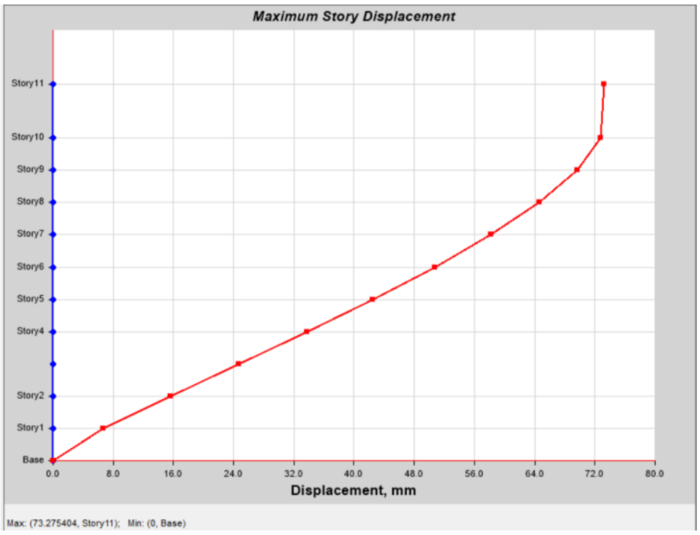
Displacement = + 73.27 mm

Displacement due to Water Y -



Displacement = - 0 mm

Displacement due to TMD Y -

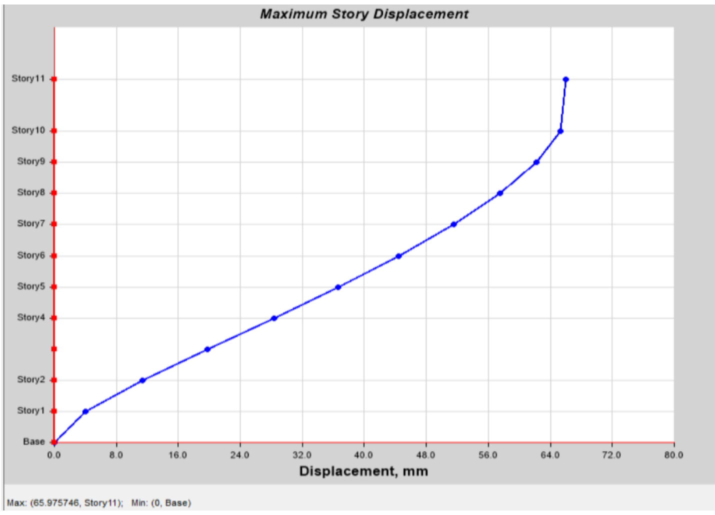


Displacement = + 73.27 mm

Observation – When Rectangular water tank is preferred then it is more reliable to dissipate the energy as compare to Square tank in Y direction.

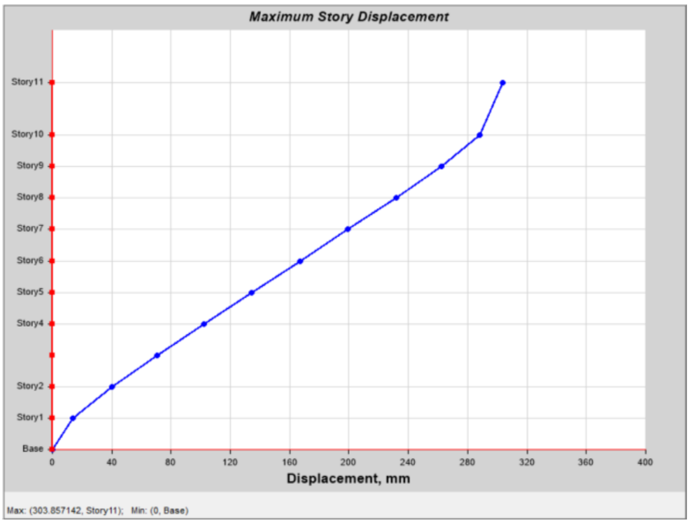
Lateral Displacement for case (6) -

Displacement due to EQ X -



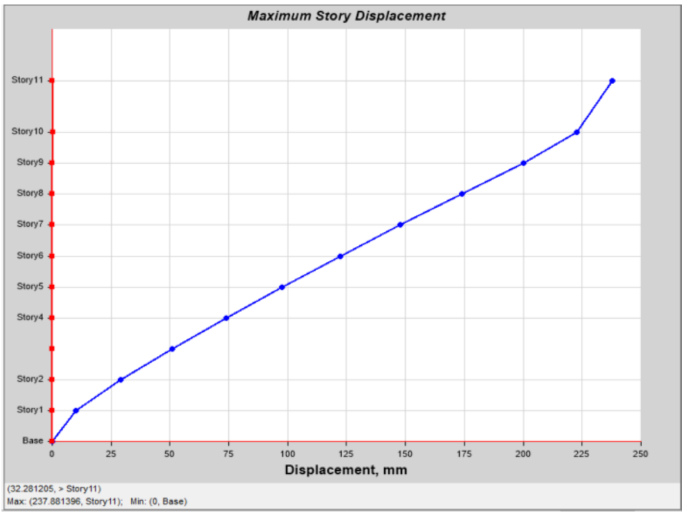
Displacement = + 65.97 mm

Displacement due to Water X -



Displacement = - 303.86 mm

Displacement due to TMD X -

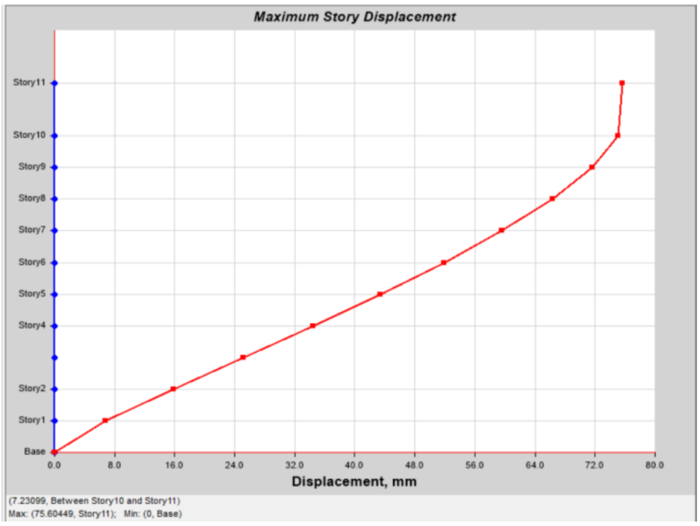


Displacement = - 237.88 mm

Observation – From Case 1 to 8, case No. 6 shows that it is more preferable to take square building with rectangle water tank.

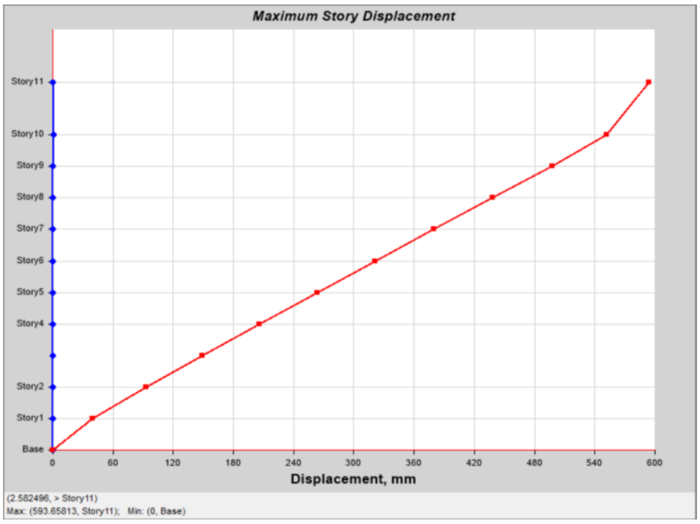
Lateral Displacement for case (6) -

Displacement due to EQ Y-



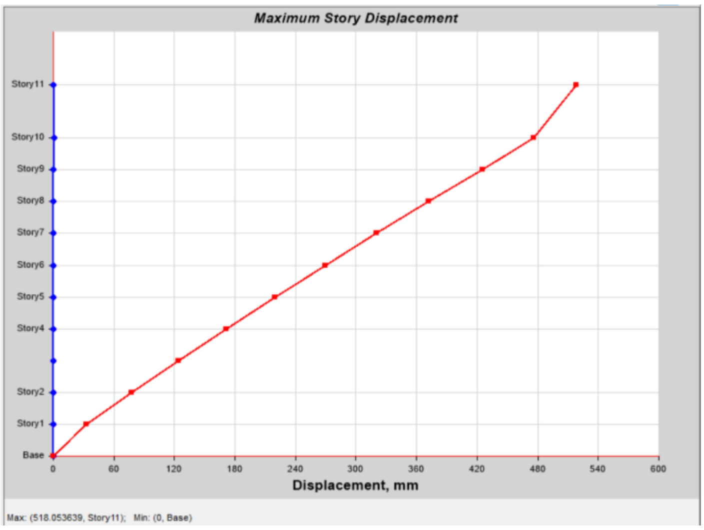
Displacement = + 75.60 mm

Displacement due to Water Y -



Displacement = - 593.65 mm

Displacement due to TMD Y -

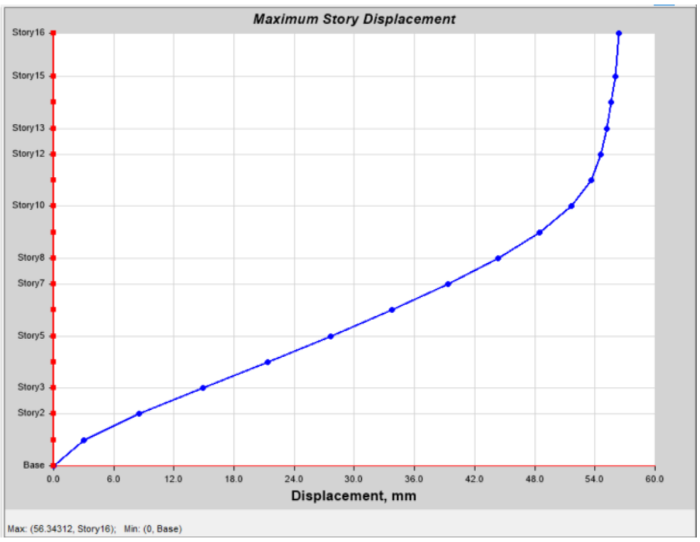


Displacement = - 518.05 mm

Observation – Resultant displacement among case 1 to 8 is found lesser one in case 6.

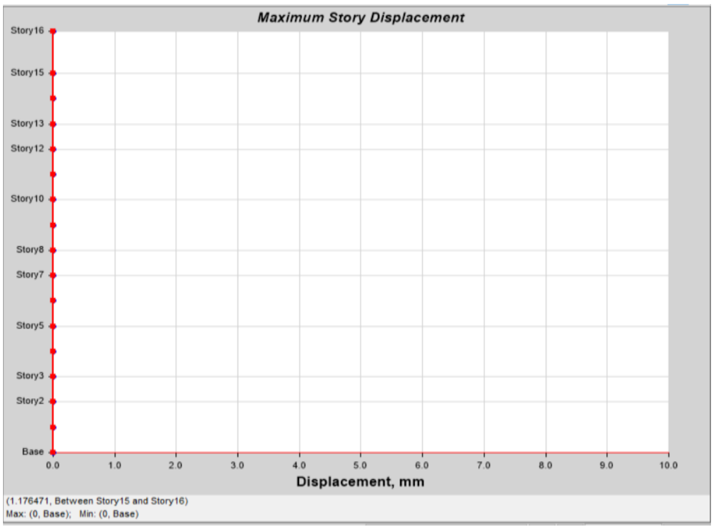
Lateral Displacement for case (7) -

Displacement due to EQ X -



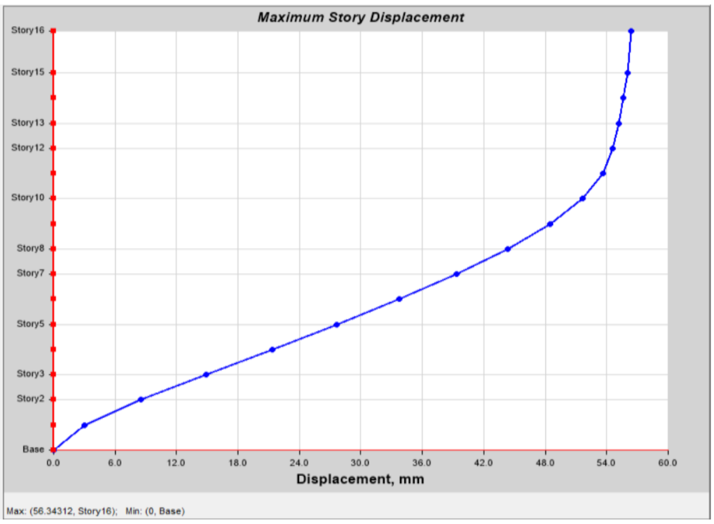
Displacement = + 56.34 mm

Displacement due to Water X -



Displacement = - 0 mm

Displacement due to TMD X -

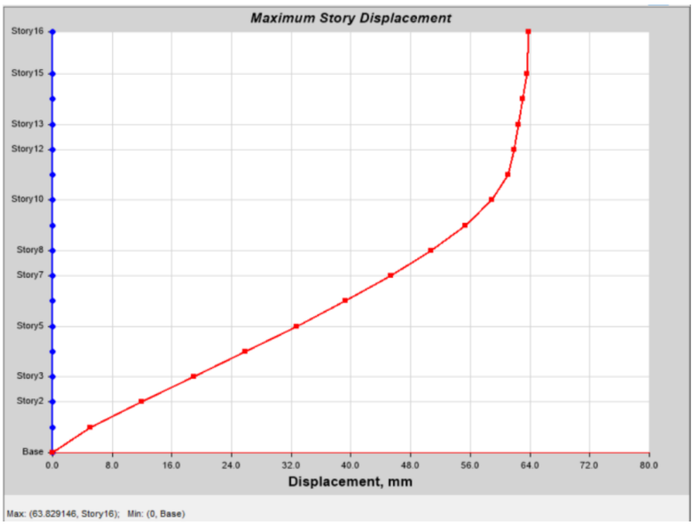


Displacement = +56.34 mm

Observation – No. of storey increases as compare to previous case hence lateral displacement in X direction is reduced for same intensity of load.

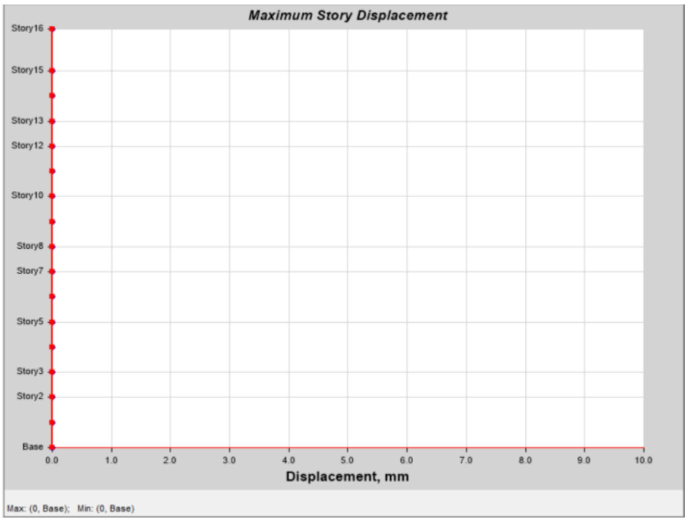
Lateral Displacement for case (7) -

Displacement due to EQ Y-



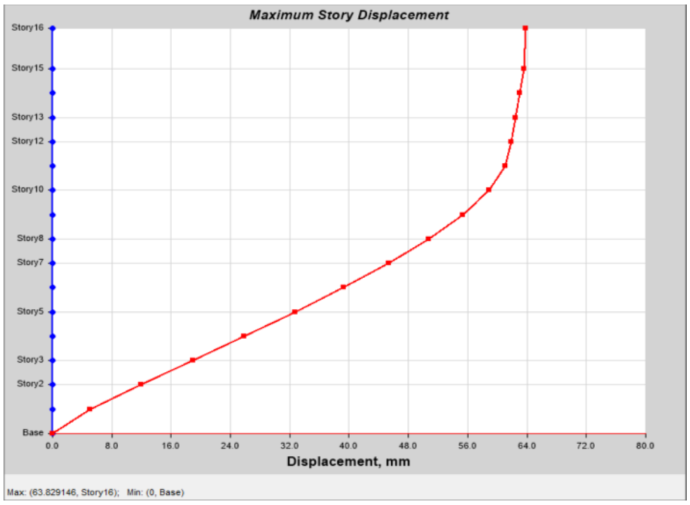
Displacement = + 63.82 mm

Displacement due to Water Y -



Displacement = - 0 mm

Displacement due to TMD Y -

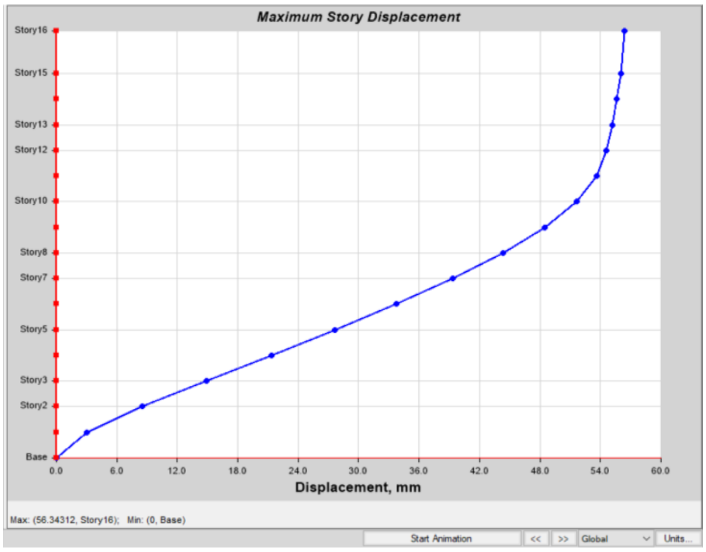


Displacement = + 63.82 mm

Observation - No. of storey increases as compare to previous case hence lateral displacement in Y direction is reduced for same intensity of load.

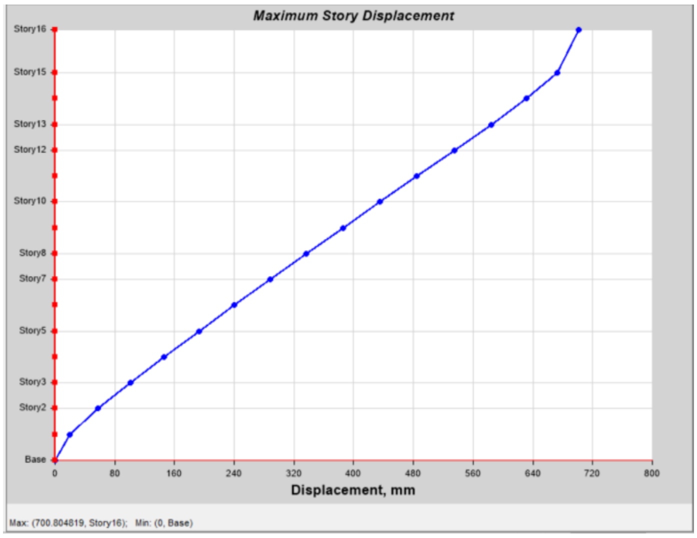
Lateral Displacement for case (8) -

Displacement due to EQ X -



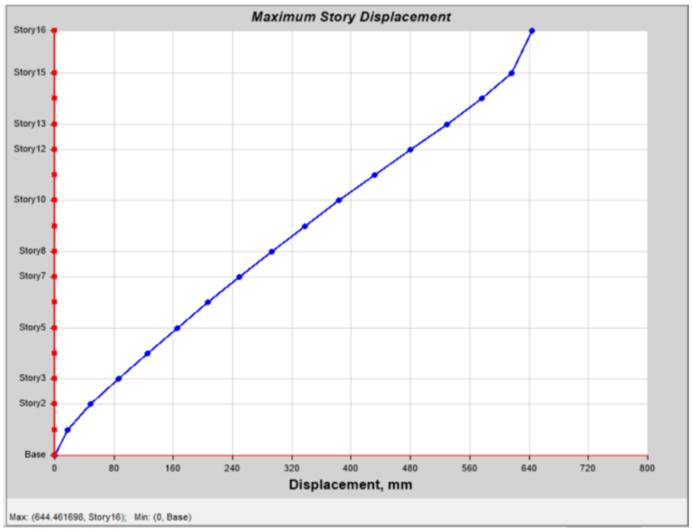
Displacement = + 56.34 mm

Displacement due to Water X -



Displacement = - 700.80 mm

Displacement due to TMD X -

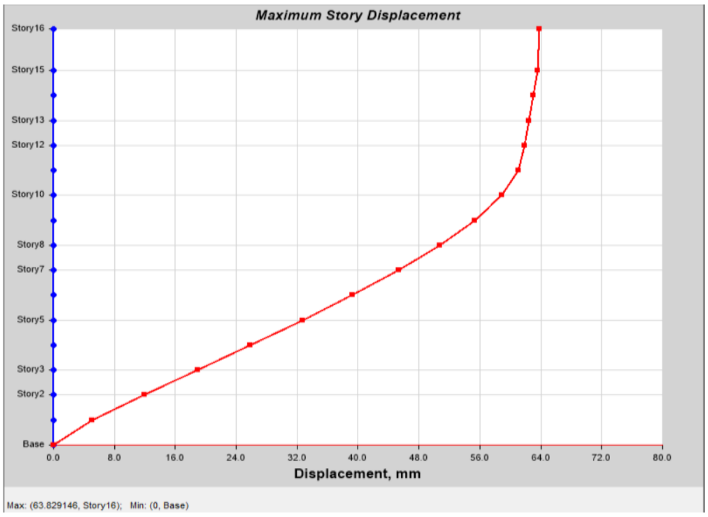


Displacement = - 644.46 mm

Observation – Resultant displacement in X direction is changes when compare to case 4 because the shape of water tank is change.

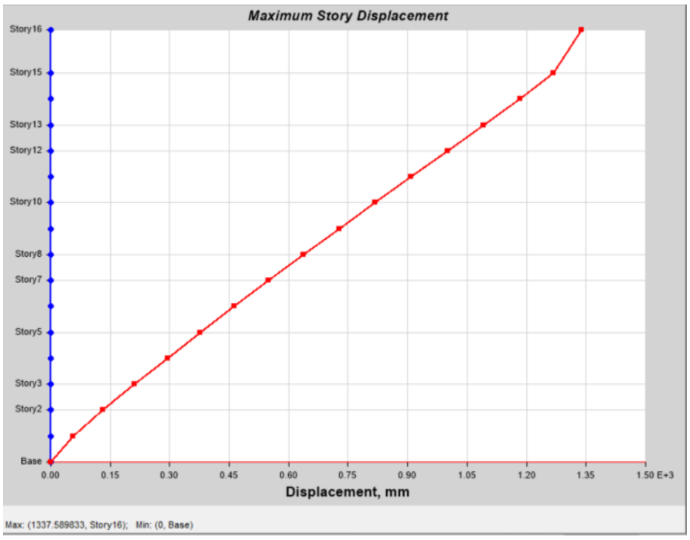
Lateral Displacement for case (8) -

Displacement due to EQ Y-



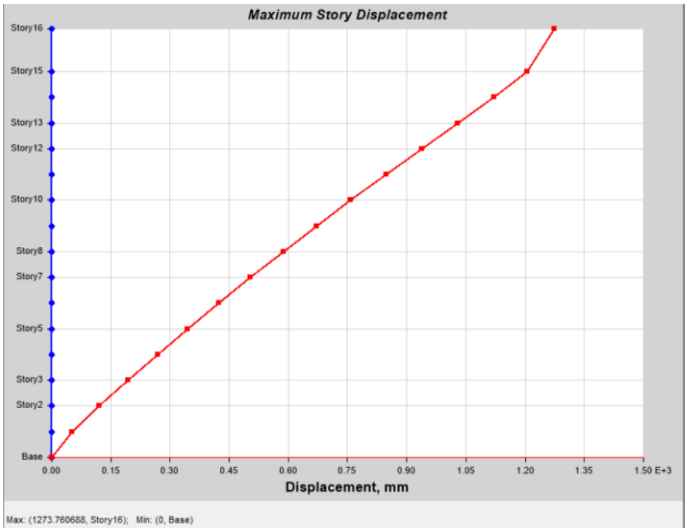
Displacement = + 63.83 mm

Displacement due to Water Y -



Displacement = - 1337.58 mm

Displacement due to TMD Y -

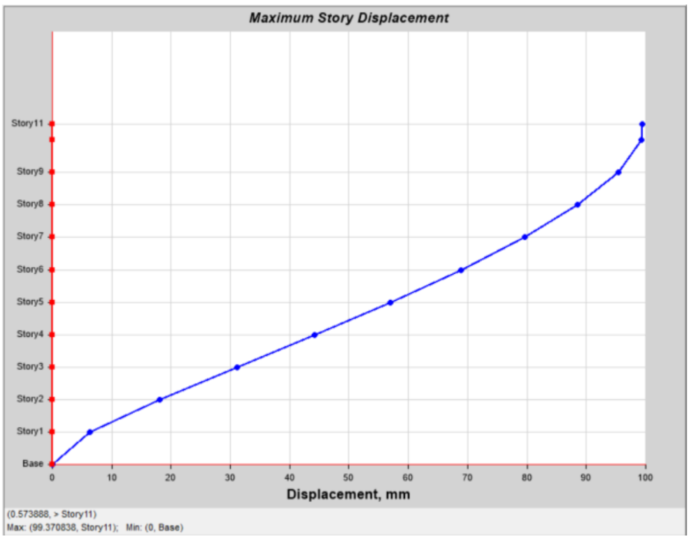


Displacement = - 1273.76 mm

Observation – Resultant displacement in Y direction is changes when compare to case 4 because the shape of water tank is change.

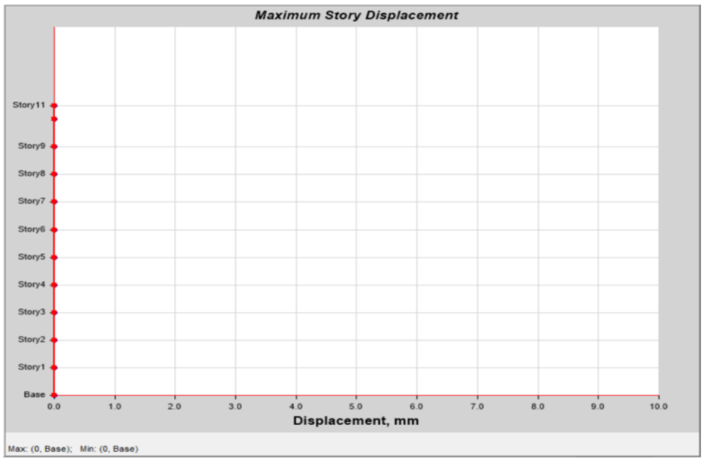
Lateral Displacement for case (9) -

Displacement due to EQ X -



Displacement = + 99.37 mm

Displacement due to Water X -



Displacement = - 0 mm

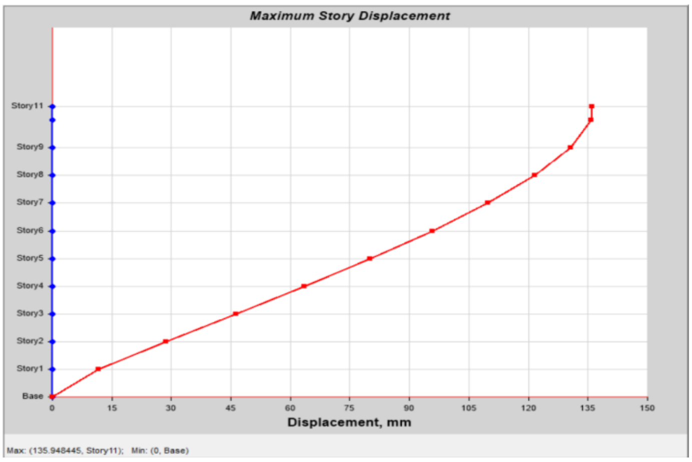
Displacement due to TMD X -

Displacement = + 99.70 mm

Observation – When we compare the results with case 4 then it shows that rectangle shape building with rectangle water tank is showing higher displacement in X direction.

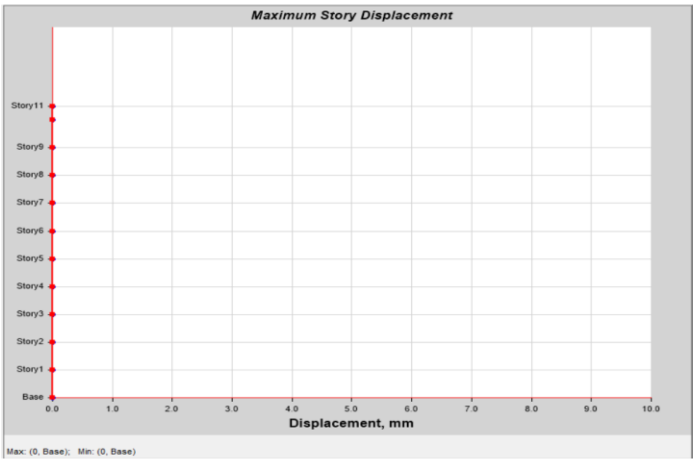
Lateral Displacement for case (9) -

Displacement due to EQ Y-



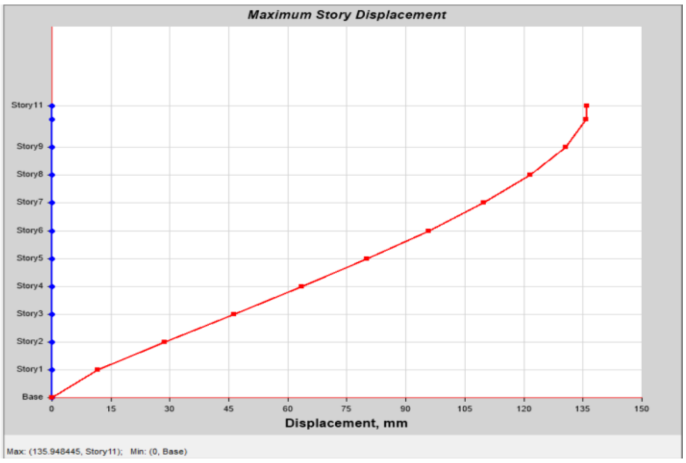
Displacement = + 135.94 mm

Displacement due to Water Y -



Displacement = - 0 mm

Displacement due to TMD Y -

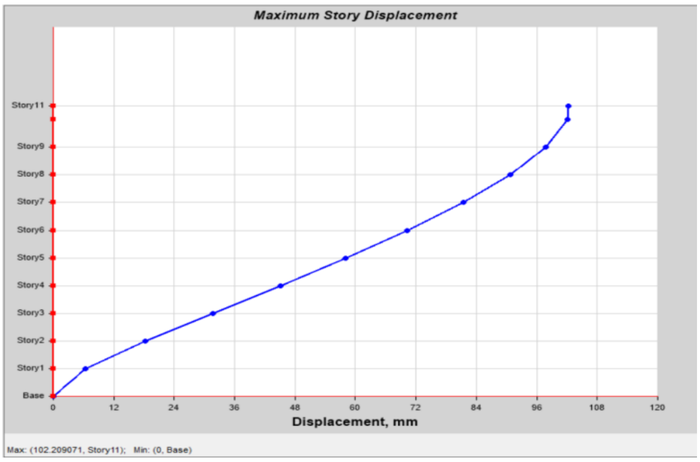


Displacement = + 135.94 mm

Observation – When we compare the results with case 4 then it shows that rectangle shape building with rectangle water tank is showing higher displacement in Y direction.

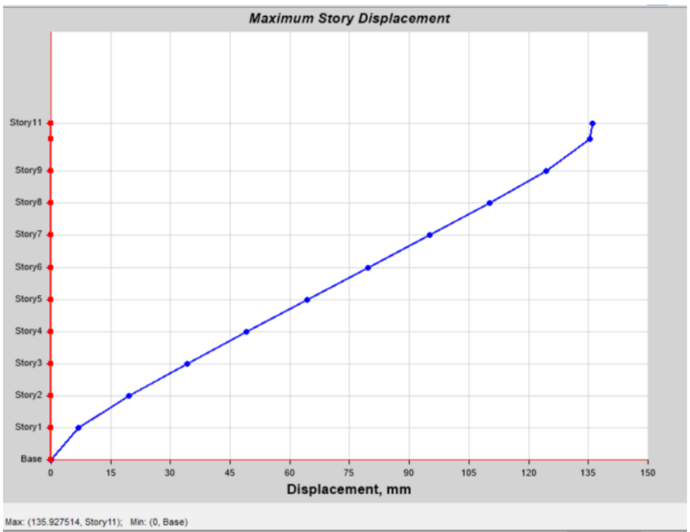
Lateral Displacement for case (10) -

Displacement due to EQ X -



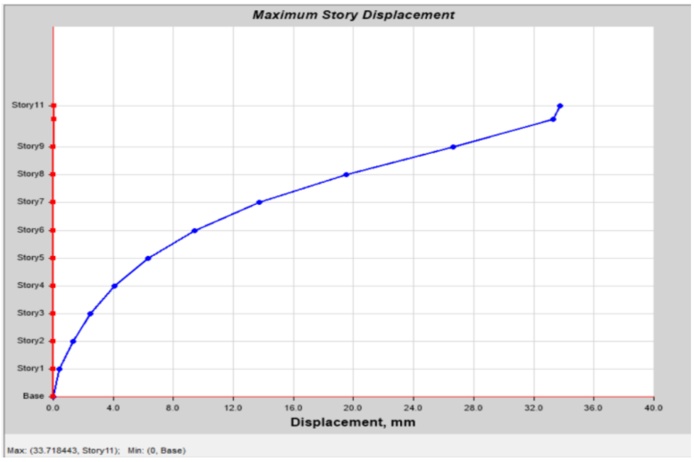
Displacement = + 102.20 mm

Displacement due to Water X -



Displacement = - 135.92 mm

Displacement due to TMD X -

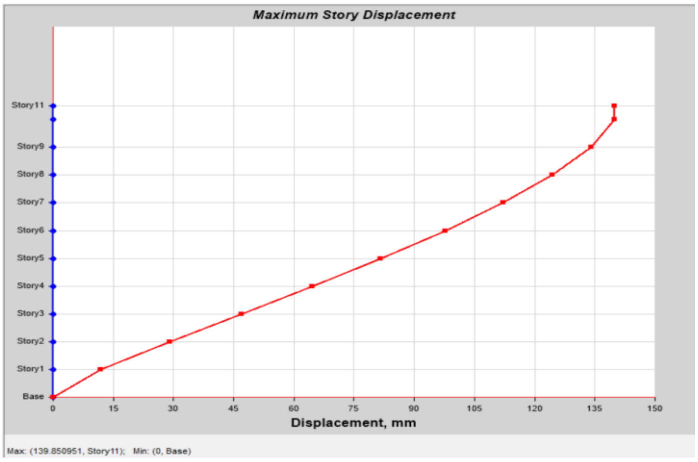


Displacement = - 33.72 mm

Observation – Rectangle shape building with rectangle tank at top floor of building is more effective as TMD.

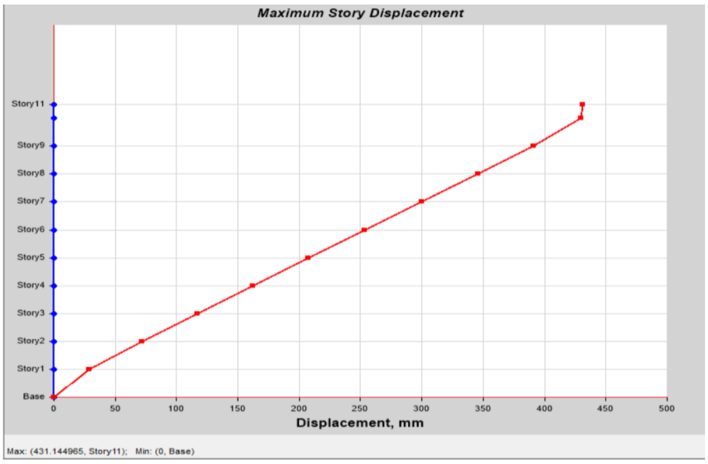
Lateral Displacement for case (10) -

Displacement due to EQ Y-



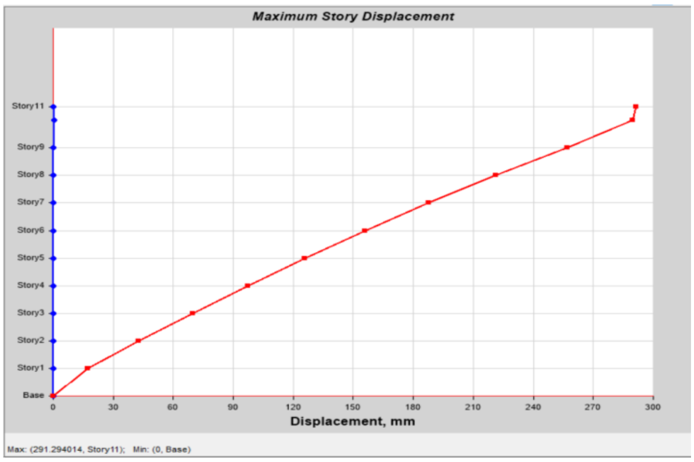
Displacement = + 139.85 mm

Displacement due to Water Y -



Displacement = - 431.14 mm

Displacement due to TMD Y -



Displacement = - 291.29 mm

Observation – The lateral displacement is least in Case 9 10 is found in case No. 10.

4.CONCLUSIONS

The behaviour of frame structure is analysed with full and empty water tank at top and middle of structure to check the possibility of water tank as tune mass damper (TMD). The seismic parameters are obtained by this analysis. Conclusions of the present work are as below.

1. Present study clearly shows that water tank can be applicable as tune mass damper (TMD) in buildings.

2. Water tank effectively contribute to resist lateral load.

3. When tank is empty then only seismic force is contributed in lateral displacement of structure.

4. When water tank is full of water then mass from the tank resist the lateral force acting on the structure due to seismic force.

5. Water tank increases the fundamental time period of the structure.

6. Water tank also increases the base shear of the structure.

7. Water tank at the top of building is more effective as Tune mass damper as compare to middle of the building.

REFERENCES

[1] Fu Chuan (2017). "Transforming Method of TLCD-structure to TMD-structure for Vibration Control". KSCE Journal of Civil Engineering DOI 10.1007/s12205-017-0287-5.

[2] Dr. Vra Saathappan, Manjusha M. (2017). "Analytical Investigation of Water Tank as Tuned Mass Damper Using ETAB 2015". International Research Journal of Engineering and Technology .ISO 9001:2008 certified Journal.

[3] Muhammad Jamil Ahmad, Qasier uz zaman Khan, Syed Muhammad Ali (2016). "Use of water tank as tuned Liquid Damper for (RC)reinforced Concrete Structures."Arab J Sci Eng 10.1007/s13369-2188-1.

[4] Rutuja S. Meshram, S.N.Khante (2016)." Effectiveness of Water Tank as Passive TMD For RCC Building". International Journal of Engineering Research Volume No.5 Issue: Special 3,pp:731-736.

[5] Supradip Saha, Rama Debbarma (2016). "An experimental study on response control of structures using multiple tuned liquid dampers under dynamic loading". Int J AdvStruceng (2017) 9:27–35 DOI 10.1007/s40091-016-0146-5.

[6] Emili Bhattacharjee, Lipika Halder, Richi Prasad Sharma (2013). "An experimental study on tuned liquid damper for mitigation of structural response". International Journal of Advanced Structural Engineering 2013,5.

[7] Pradipta Banergi, Avik samanta (2011). "Earthquake Vibration Controle Of Structures using hybrid mass liquid damper". Engineering structures 33(2011)1291-1301.

[8] Qiao Jin, Xin li, Jing Zhou, Jiong Guan (2007). "Experimental and numerical study on tuned liquid damper for controlling earthquake response of jacket offshore platform". Marine structure 20(2007)238-254.

[9] Sung-Kyung Leea, Eun Chum Parka, Kyung-Won Mina, Sang-Hyun Leea, Ji-Hun Park (2007). "Experimental implementation of a Building Structure with a TunedLiquid Column Damper Based on the Real-Time Hybrid Testing Method".Journal of Mechanical Science and Technology 21 (2007) 885 890.

[10] M. J. Hochrainer (2004). "Tuned liquid column damper for structural control" Acta Mechanical 175, 57–76 (2005) DOI 10.1007/s00707-004-0193-z.
[11] Pradipta Banerji (2004). "Tuned Liquid Dampers for Control Of Earthquake Response" 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada. August 1-6, 2004. Paper No.1666.
[12] Takashi Ikeda (2003). "Nonlinear Parametric Vibrations of an Elastic Structure with a Rectangular Liquid Tank".Nonlinear Dynamics 33: 43–70, 2003.