Comparison of Seismic Analysis Response of Multi-Storied Building with and without Liquid Damper in various Seismic Zones using STAADPRO

Prof Sanjay K. Bhadke[1], Reecha R. Meshram[2]

[1] *Assistant professor, Dept. of Civil engineering, Tulsiramji Gaikwad-Patil College of Engineering and Technology, Nagpur, Maharashtra, India*

[2]*Research Scholar, of Dept. of Civil engineering, Tulsiramji Gaikwad-Patil College of Engineering and Technology, Nagpur, Maharashtra, India*

Abstract:*The project aim is to study the effectiveness of structure with and without using Tuned Liquid Dampers (TLD) in reducing the seismic vibration of a building when it is subjected to horizontal sinusoidal excitation. Tuned liquid damper is a device which is also known as passive damping device that consists of tanks filled with liquid to suppress the horizontal vibration of structures using the moving effect of water. Usually tuned liquid damper are connected on the top of main structure. In the present work, the structure with and without tuned liquid damper buildings of 30 storey structural model are considered. Also a comparison on the basis of liquid damper and parameters such as base shear, storey drift , joint displacement etc considered. The necessity of with and without tuned liquid damper structures are analysed in various seismic zone. Zone analysed are zone 2 and zone 4 respectively. The analysis is carried out by Staadpro v8i ss6 software.*

Key Words**: 30 storied building, tuned liquid damper, seismic zones 2 and 4, staadpro v8i.**

1. Introduction

An earthquake is the shaking of ground surface, which cannot be predictable like other natural calamities. Earthquake causes the vibration of structure, which can damage the structure and affect people. Hence, structure constructed in highly seismic zone areas should be designed in such a way that the vibration occurring over the structure can be reduced. Various methods have been developed to minimize the vibration caused by earthquake. The methods include shear walls, base isolator, dampers, etc. Among these dampers are widely in use. Dampers are also further classified as tuned mass damper and tuned liquid dampers and many other.

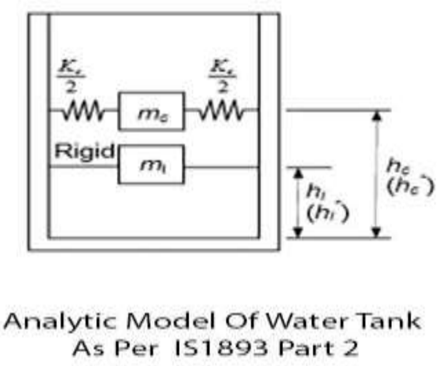

Figure 1. Analytical Model of Water Tank

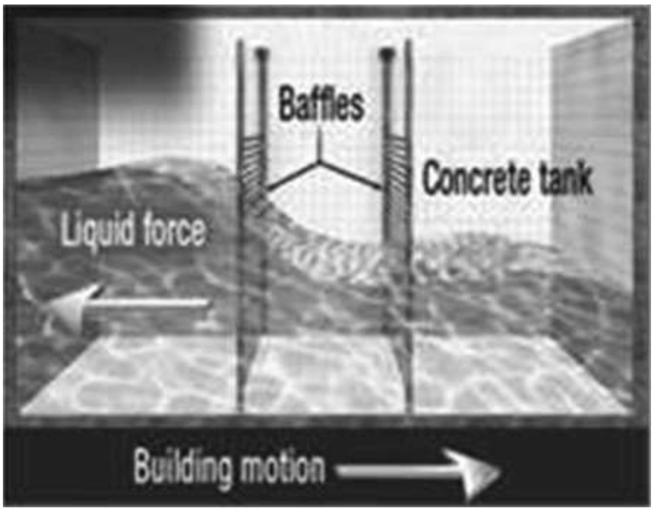

Figure 2. Motion of liquid damper during vibration

1.1 Tuned Liquid Damper(TLD)

In these project, tuned liquid dampers have to analyzed which can be provided on the top of RC structure. Again the tuned liquid dampers are classified as follow:

1.1.1. Tuned Sloshing Liquid Dampers(TSLD): These type of damper is partially filled with liquid mostly water but can also filled with sugar solution or oil. Liquid impacts sidewalls of container generating damping force. Due to simple construction, sloshing dampers are often meant by the term tuned liquid dampers in literature and papers.

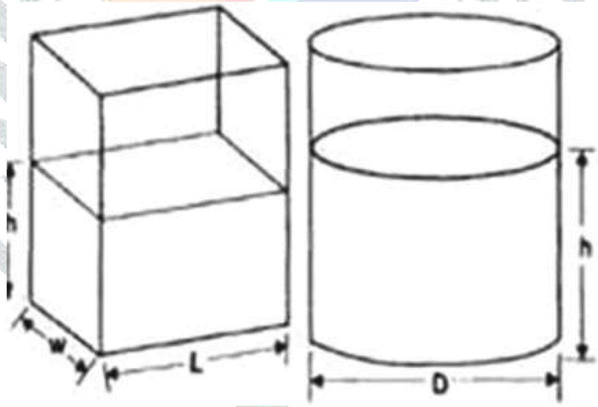

Figure 3. TSLD

1.1.2 Tuned Liquid Column Dampers(TLCD):A tuned liquid column damper is a U-shape damper containing liquid with open or closed container. They are rectangular or circular in shape provided on the top surface of building. Liquid flows from one vertical column to the other creating horizontal damping force due to impact on vertical walls and friction between liquid and tube. Liquid motion in TLCD can be well determined by hydraulic laws. Due to this TLCD are well investigated and. For some time similar dampers are used in naval architecture for ship stability and are called antiroll tanks. In this case, special pipes connect two tanks along sides of the ship.

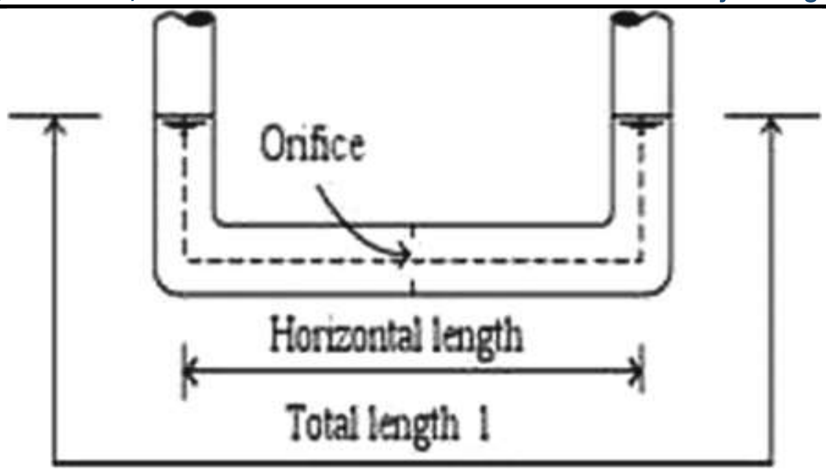

Figure 4. TLCD

1.1.3 Modified Tuned Liquid Column Dampers(MTLCD): It is modified form of tuned liquid column dampers. Placing two tuned liquid column damper in perpendicular directions damping effect in both main vibration directions will be assumed. Such system is known as double tuned liquid column damper.

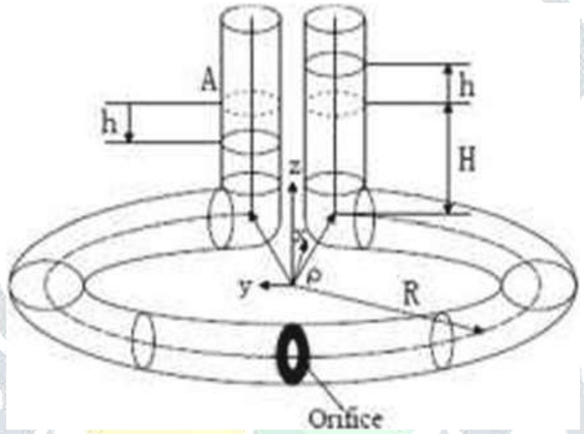

Figure 5. MTLCD

1.2 Parameters affecting the behaviour of TLD

There are different parameters that affect the behaviour of TLD in building are as follows:

1.2.1 Tuning ratio: Tuning ratio is the ratio of frequency of TLD to the frequency of the building.

1.2.2 Mass ratio: Mass ratio is the ratio of the mass of the liquid in TLD to the mass of the building.

1.2.3 Depth ratio: Depth ratio is the ratio of the depth of the tank to the length of the tank in the direction of sloshing.

1.2.4 Shape of tank: The shape of the tank can be circular, rectangular, etc. Different shape of tank describe different sloshing behaviour.

1.2.5 Position of tank: Position of tank affect the TLD. It can be placed at top, corner, edge. For best result it is kept on terrace.

2. Literature Review

1] Arsha A. Deleep and Varsha Susan Thomas "Comparison of seismic response of multi-storied building with and without liquid damper," Advances in civil engineering-Springer.(2020)**:**

The paper suggest the comparison between multistoried reinforced concrete structure with liquid dampers using different types of liquid. Liquid using other than water gives different response during an earthquake. It also suggest that using other liquid such as sugar solution and oil decreases the displacement. Also the base shear value and joint displacement were reduced. Regular RC structure was consider for analysis. As a result we can conclude that by using different liquid substance we found different variation.

2] Mr. Aakash B.R, Mr.Shubhesh B, Mr.Prashant S, Analysis of tuned liquid damper in controlling earthquake response of a building", International research journal of engineering and technology(2018**):**

The paper tell us about the analysis of tuned liquid damper in controlling earthquake response of building. The tuned liquid damper are low cost and the maintenance and installation is also easier. There is no restriction to unidirectional vibration. The water in tanks can be utilized in emergency situation. Also the natural frequency can be adjust by adjusting the depth of water.

3]N.V.Jacob,M.M.Varkey,J.Michael,N.M.Reji,Er.V.Philip,Er.A.Mathew, Study of combined action of coupled tuned liquid and mass damper on earthquake response of buildings", International research journal of engineering and technology(2018)**:**

The paper tell us about the combine action of tuned liquid dampers and mass damper on earthquake response of building. Also the primary requirement of earthquake resistant building is to have safety and minimum damage to the structure. For that the structure must have proper strength, stiffness and ductility. So to examine these work the combination of tuned liquid and mass damper is determined.

4] Akshatha N.S, Vahini.M, Analysis of multi-storey buildings using water tank as a liquid damper using E-tabs", International journal of engineering and technology(2017)**:**

These paper suggest about the analysis of multi-storey buildings using water tank as liquid damper using ETABS. Also the depth of water tank used as tuned liquid damper reduces the structural vibration.

3. Objectives

The primary objective of these project can be summarized as follow:

1. To understand the structural behavior of high rise building subjected to seismic load.
2. To model multi-storied rc buildings with and without liquid dampers.
3. To study the performance analysis of building with and without liquid dampers.
4. To compare the seismic response of building in various zone using STAADPRO V8i.
5. To compare building with tuned sloshing liquid damper.
6. Compare the structure considering base shear, displacement. etc.

4. Research Methodology

1. In these study multi storied building of 30th stories subjected to seismic load is analyzed.
2. Analysis is carried out for zone 2 and zone 4 using IS 1893;2002 in Staadpro Vi8 ss6 software.
3. Efficiency of multi stories structures with respect to the storey drift, shear, displacement are found out for both types of model or buildings for both zones.
4. Further analysis is extended with incorporation of rectangular liquid damper or tuned sloshing damper.
5. Location of the damper is on the roof or top floor of structure.
6. Based on the Results obtained ,the discussion and conclusions will be made by indicating the effect of liquid damper.

5. Parameters considered

In the current study, analysis of G+29 multi-stories building in zone 2 and zone 4 for seismic forces is carried out. 3D model prepared for multi-storied building is in Staadpro.

5.1. 3D Model type

Model 1- Without considering damper.

Model 2- With considering damper.

5.2. Structural Member

Table 1. Data of structural members

Thickness of slab	0.175
Beam	0.3*0.6
Column	0.6*1.2

5.3. Details of materials

Table 2. Materials details

Utility of Building	Residential building
Number of storey	G+29
Storey Height	90m
Bay width along X-direction	2.5m
Bay width along Y-direction	3m
Seismic Zone	2 and 4
Soil type	Medium(Type 2)
Response reduction	5
Importance factor	1

5.4. Specification of damper used

Table 3. Damper specification

Damper	Tuned liquid damper
Type	Rectangular damper
Position	Top of building
Size	7*5

5.5. Model of structure using staadpro

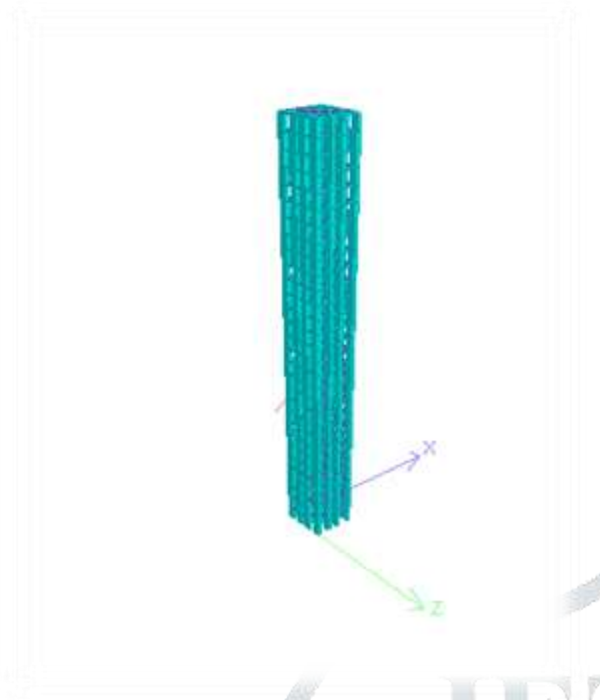

Fig.6.Model 1 without damper

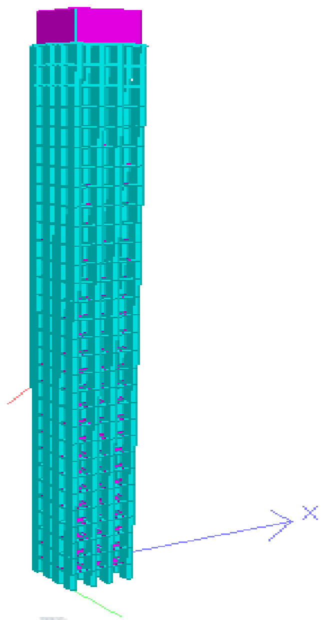

Fig.7.Model 2 with damper

6. Design analysis

6.1.Seismic Load Analysis

According to IS 1893:2002:

Table 4. Data for Seismic load analysis

Abbreviation	Description	Value	
Z	Zone factor	Zone 2	Zone 4
		0.12	0.24
I	Importance factor	1.0	
R	Response reduction factor	5.0	
Ta	Fundamental time period	0.09h /√d RC frame with brick infill	
Ah	Design horizontal seismic co-efficient	Ah = (z/2) * (i/r) * (sa/g)	
Vb	Design seismic base shear	vb= ah * w w= Seismic weight of building	

7. Results

7.1. Comparison of structure with and without liquid damper (Zone 2)

a. Top Joint Displacement(mm): After analyzing the structure with and without considering liquid damper in zone 2 following results for top joint displacement obtained.

Table 5.Result for joint displacement

Storey Height	Without Damper	With Damper
0	0.00000	0.00000
3	0.00626	0.00568
6	0.02011	0.01846
9	0.03784	0.03494
12	0.05780	0.05355
15	0.07826	0.07360
18	0.10187	0.09472
21	0.12540	0.11672
24	0.14975	0.11397
27	0.17479	0.16287
30	0.20044	0.18685
33	0.22660	0.21132
36	0.25318	0.23619
39	0.28009	0.26140
42	0.30723	0.28685
45	0.33449	0.31246
48	0.36178	0.33814
51	0.38900	0.36380
54	0.41603	0.38935
57	0.44276	0.41470
60	0.46910	0.43975
63	0.49492	0.46640
66	0.52011	0.48856
69	0.54456	0.51213
72	0.56816	0.53501
75	0.59080	0.55709
78	0.61237	0.57828
81	0.63279	0.59848
84	0.65199	0.61759
87	0.66999	0.63555
90	0.68699	0.65196

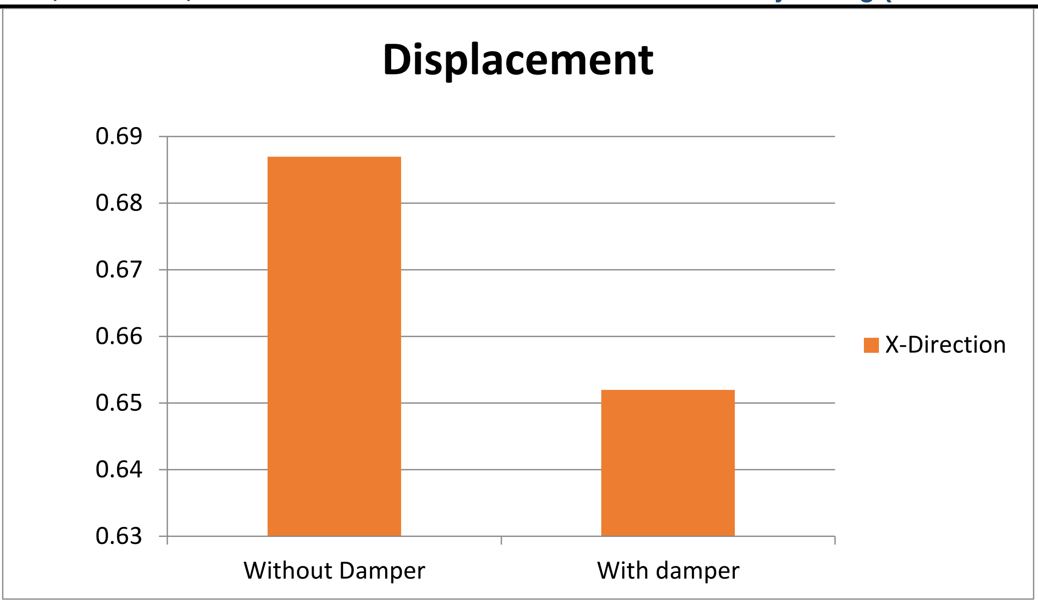

Fig 8. Comparison of Top joint displacement without and with damper(zone 2)

b. Base Shear(KN): The maximum expected lateral load on the base are as follows:

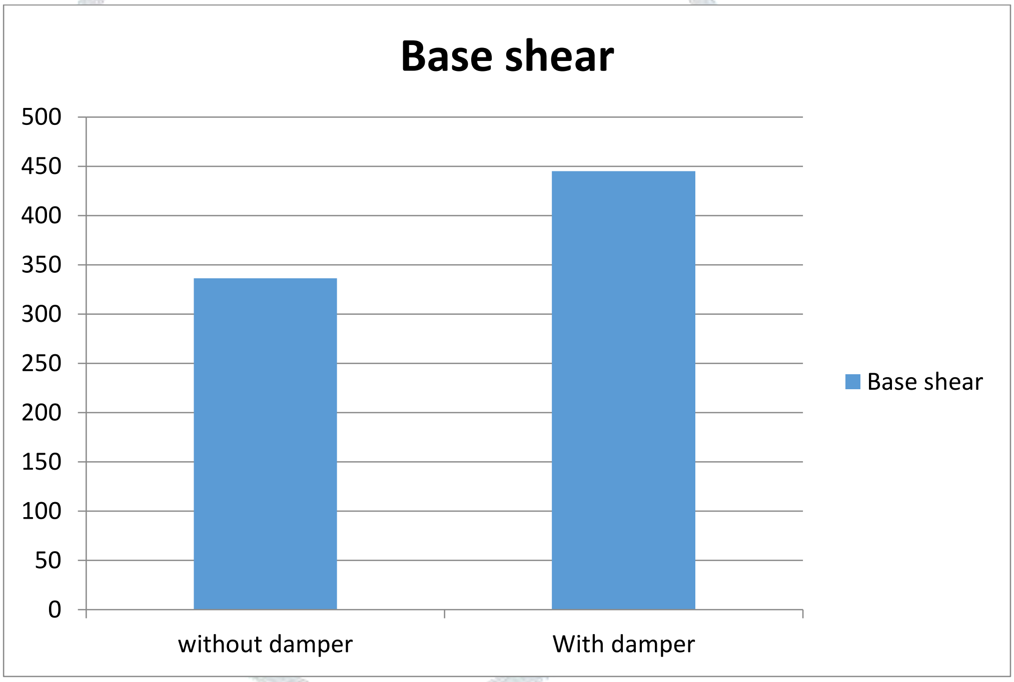

Fig 9. Comparison of base shear

c. Storey Drift(mm): After analyzing the structure with and without considering liquid damper in zone 2 following results for storey drift obtained.

Table 6.Result for storey drift

No. Of Storey	Without Damper	With Damper
0	0.0000	0.0000
1	0.0000	0.0000
2	0.0052	0.0045
3	0.0062	0.0057
4	0.0200	0.0186
5	0.0215	0.0201
6	0.0226	0.0211

7	0.0235	0.0220
8	0.0243	0.0228
9	0.0254	0.0234
10	0.0257	0.0240
11	0.0262	0.0245
12	0.0266	0.0249
13	0.0269	0.0252
14	0.0271	0.0255
15	0.0273	0.0256
16	0.0274	0.0257
17	0.0275	0.0257
18	0.0270	0.0256
19	0.0267	0.0254
20	0.0263	0.0250
21	0.0258	0.0247
22	0.0252	0.0242
23	0.0245	0.0236
24	0.0236	0.0229
25	0.0226	0.0221
26	0.0216	0.0212
27	0.0204	0.0202
28	0.0192	0.0191
29	0.0180	0.0179
30	0.0170	0.0165

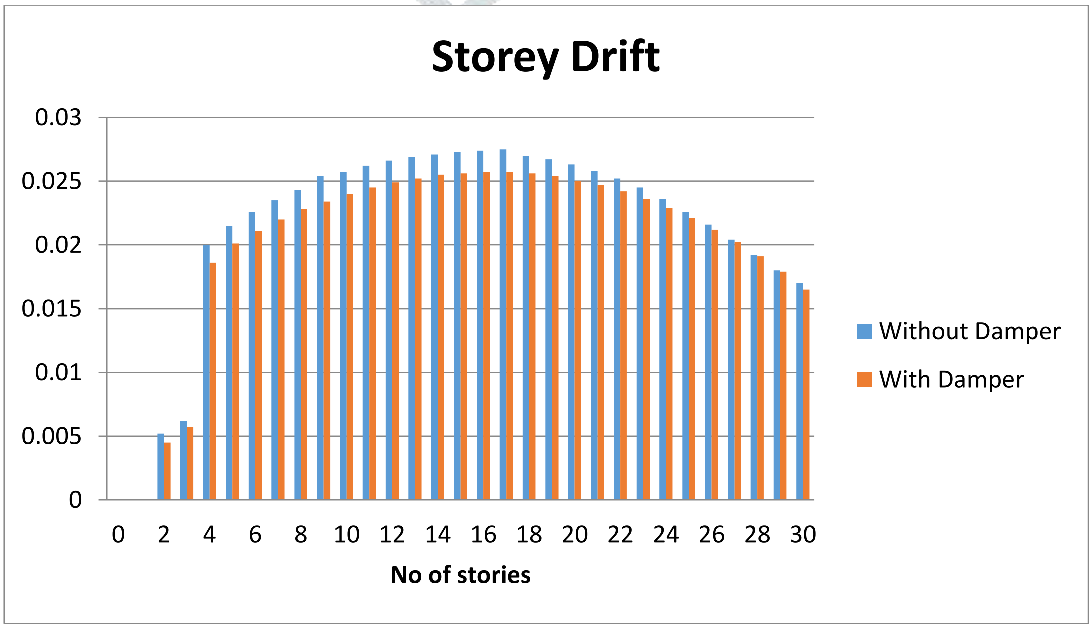

Fig 10. Comparison of Storey drift without and with damper(zone 2)

7.2. Comparison of structure with and without liquid damper (Zone 4)

a) **Top Joint Displacement(mm):**After analyzing the structure with and without considering liquid damper in zone 4 following results for joint displacement obtained.

Table 7.Result for joint displacement

Storey Height	Without Damper	With Damper
0	0.00000	0.00000
3	0.01259	0.01251
6	0.04054	0.04022
9	0.07635	0.07567
12	0.11676	0.11560
15	0.16030	0.15853
18	0.20623	0.20373
21	0.25417	0.25081
24	0.30385	0.29949
27	0.35507	0.34958
30	0.40766	0.40088
33	0.46142	0.45320
36	0.51618	0.50637
39	0.57177	0.56018
42	0.62800	0.61446
45	0.68467	0.66899
48	0.74160	0.72357
51	0.79859	0.77799
54	0.85543	0.83205
57	0.91193	0.88552
60	0.96787	0.93819
63	1.02305	0.98983
66	1.07725	1.04022
69	1.13026	1.08912
72	1.18186	1.13633
75	1.23183	1.18161
78	1.27996	1.22475
81	1.32602	1.26558
84	1.36982	1.30397
87	1.41119	1.33997
90	1.44934	1.37397

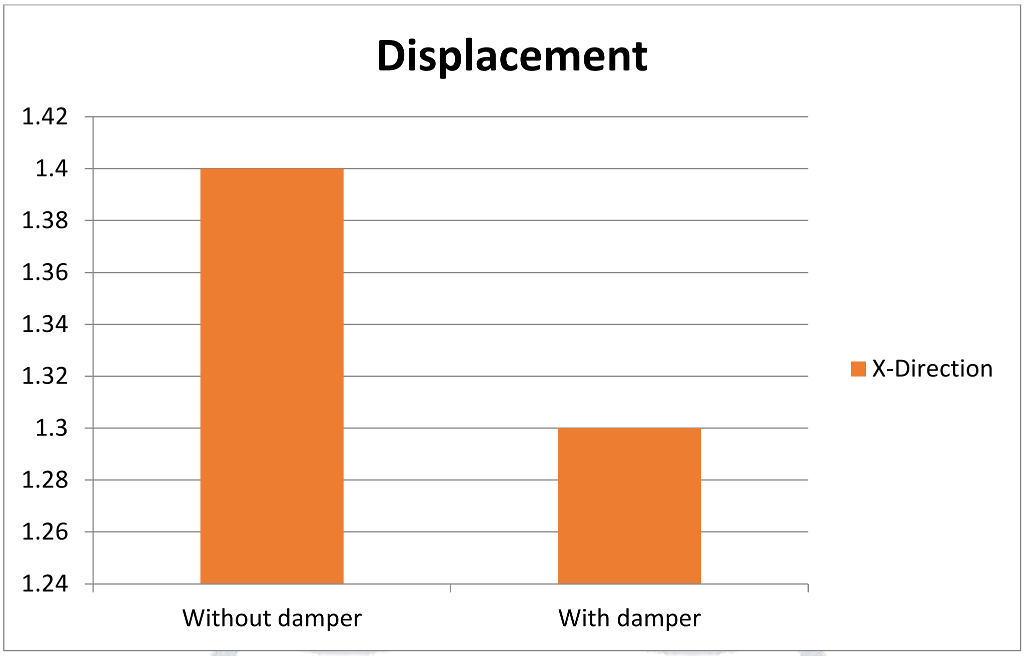

Fig 10. Comparison of Top joint displacement without and with damper(zone 4)

b) Base Shear(KN): The maximum expected lateral load on the base after considering with and without damper has been carried out are as follows:

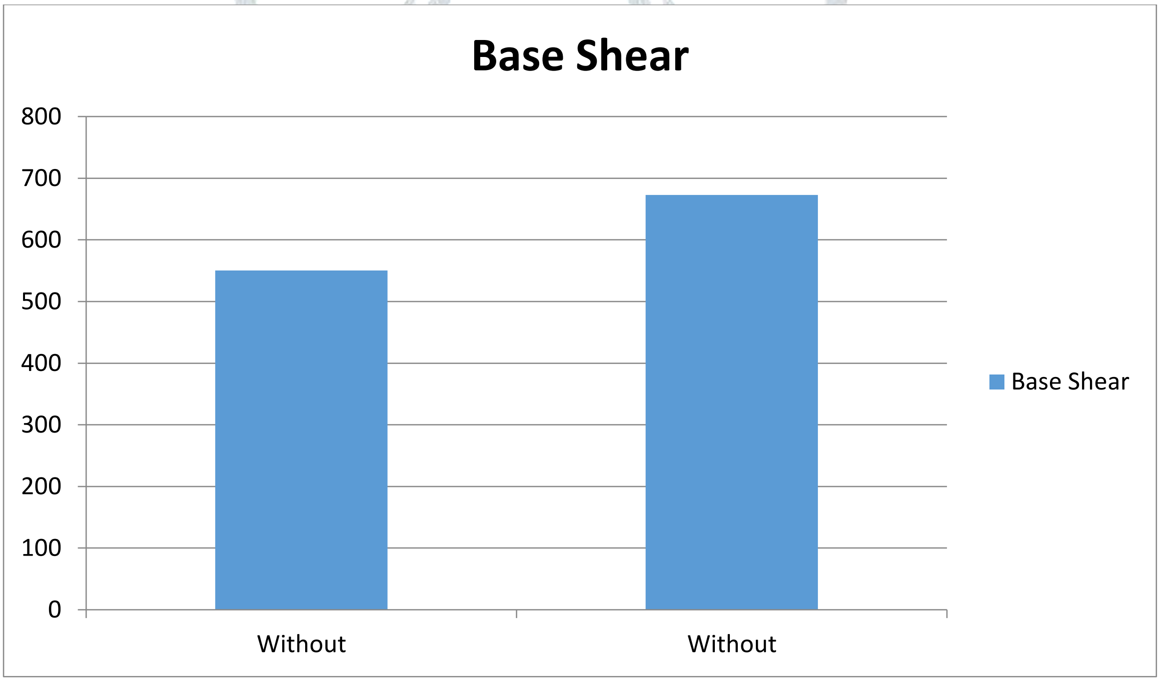

Fig 11. Comparison of base shear

c) Storey Drift(mm): After analyzing the structure with and without considering liquid damper in zone 4 following results for storey drift obtained.

Table 8.Result for storey drift

No. of Storey	Without Damper	With Damper
0	0.0000	0.0000
1	0.0000	0.0000
2	0.0125	0.0125
3	0.0279	0.0277

4	0.0358	0.0355
5	0.0404	0.0399
6	0.0435	0.0429
7	0.0459	0.0452
8	0.0479	0.0470
9	0.0497	0.0487
10	0.0512	0.0501
11	0.0526	0.0513
12	0.0538	0.0523
13	0.0548	0.0532
14	0.0556	0.0538
15	0.0562	0.0543
16	0.0567	0.0545
17	0.0569	0.0546
18	0.0570	0.0544
19	0.0568	0.0541
20	0.0565	0.0538
21	0.0559	0.0527
22	0.0552	0.0516
23	0.0542	0.0504
24	0.0530	0.0489
25	0.0516	0.0472
26	0.0499	0.0453
27	0.0481	0.0431
28	0.0461	0.0408
29	0.0437	0.0384
30	0.0412	0.0360

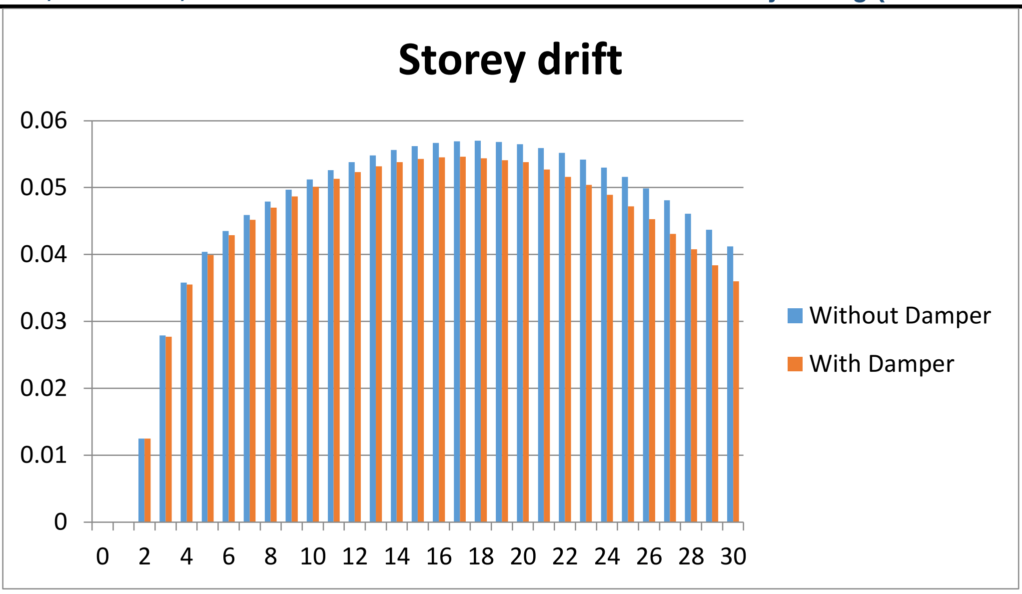

Fig 12. Comparison of Storey drift without and with damper(zone 4)

8. Discussion

In these research paper analysis has been carried out with and without considering liquid damper. From the above comparative graphs results, it has been analysed that when the structure is subjected to seismic load there is an noticeable values in base shear, joint displacement and storey drift. But after the application of tuned liquid damper or rectangular damper on the top of building it has been analysed that there is a reduction in the base shear, joint displacement and storey drift.

9. Conclusion

- Analysis has been carried out considering different zones.
- In zone 2,the difference between the base shear, top joint displacement of structure with and without damper as well as the storey drift is reduced .
- For zone 2,there is an reduction of top joint displacement upto 40%,base shear upto 45% and storey drift upto 15%.
- Also in zone 4,the difference between base shear, top joint displacement and storey drift of with and without liquid damper is also reduced.
- For zone 4,there is an reduction of top joint displacement upto 10%,base shear upto 2% and storey drift upto 7%.
- Hence, it can be conclude that the damper are sustainable to seismic load for structure in low seismic zone than that for the high seismic zone.

10. Scope for Future Work

• Analysis shall be carried out in irregular buildings with different soil conditions.

• Analysis shall be carried out with different widths and depth dimensions of the water tank.

• Analysis shall be carried out for different positions of the liquid damper.

• Comparison may be done for all types of dampers through analysis.

Reference

[1]Arsha A.Deleep and Varsha Susan Thomas, "Comparison of seismic response of multi-storied building with and without liquid damper," Advances in civil engineering-Springer.(2020).

[2]Mr. A.B.Rana,Mr. S.Bista, Mr. P.Sunagar, "Analysis of tuned liquid damper in controlling earthquake response of a building",International research journal of engineering and technology(2018).

[3]N.V.Jacob,M.M.Varkey,J.Michael,N.M.Reji,Er.V.Philip,Er.A.Mathew,"Study of combine action of coupled tuned liquid damper and mass damper on earthquake response of buildings", IRJET(2018).

[4]Akshatha N.S, Vahini.M, "Analysis of multi-storey buildings using water tank as a liquid damper using E-tabs", International journal of engineering and technology(2017).

[5] Hong-Nan Li, Ying Jia, Su-yan Wang., "Theoretical and experimental studies on reduction for multi-modal seismic responses of high rise structures by tuned liquid dampers" Journal of Earth and environmental science,volume143,2004.

[6]IS 456: 2000 - plain and reinforced concrete – code of practice (fourth revision).

[7]IS 1893 (Part 1) 2002-Indian Standard Code of Practice Criteria for Earthquake Resistant Design of Structures .

[8]IS: 875 (Part 3) – 1987 (Second Revision), Indian Standard Code of Practice for Design Loads

(other than earthquake) For Buildings and Structures..

[9]Al-Saif, K.A., Aldakkan, K.A., and Foda, M.A., ―Modified liquid column damper for vibration control of structures,‖ International Journal of Mechanical Sciences, vol. 53, no. 7, (2011), pp. 505–512.

[10] Banerji, P. and Samanta, A. Earthquake vibration control of structures using hybrid mass liquid damper. Engineering Structures 33, 1291–1301 (2011).

[11] Chakraborty, S., and Debbarma, R., ―Stochastic earthquake response control of structures by liquid column vibration absorber with uncertain bounded system parameters,‖ Structural Safety, vol. 33, no. 2, (2011), pp. 136–144.

[12] Chakraborty, S., Debbarma, R., and Marano, G. C., ―Performance of tuned liquid column dampers considering maximum liquid motion in seismic vibration control of structures,‖ Journal of Sound and Vibration, vol. 331, no. 7, (2012), pp. 1519–1531.

[13] Faltinsen, O. M., and Timokha, A. N., ―Natural sloshing frequencies and modes in a rectangular tank with a slat-type screen,‖ Journal of Sound and Vibration, vol. 330, no. 7, (2011a), pp. 1490–1503.

[14] Fediw, A.A., Isyumov, N., and Vickery, B.J., ―Performance of a tuned sloshing water damper,‖ Journal of Wind Engineering and Industrial Aerodynamics, 57, (1995), pp. 237-247.

[15] Gao, H., Kwok, K.C.S, Samali, B., ―Optimization of Tuned Liquid Column Dampers,‖ Engineering Structures, Vol. 19, No. 6, (1997), pp. 476-486.

[16] Ikeda, T., ―Non-linear dynamic responses of elastic two-story structures with partially filled liquid tanks,‖ International Journal of Non-Linear Mechanics, vol. 45, no. 3, (2010), pp. 263–278.

[17] Love, J. S., and Tait, M. J., -"A preliminary design method for tuned liquid dampers device match to space restriction, Engineering Structures", (2012).

[18] Love, J. S., Tait, M. J., and Toopchi-Nezhad, H., ―A hybrid structural control system using a tuned liquid damper to reduce the wind induce motion of a base isolated structure,Engineering Structures.

[19] Nanda, B., and Biswal, K. C., ―Application of Tuned Liquid Damper for Controlling Structural Vibration Due to Earthquake Excitations,in Proceeding of Modern Methods and Advances in Structural Engineering and Construction, Zürich, (2011) pp. 983–987.

[20] Love J. S. and Tait M. J., "Multiple Tuned Liquid Dampers device for Efficient and Robust Structural Control devices", Journal of Structural Engineering,ASCE.

[21] Riju Kuriakose , Lakshmi P, “Effectiveness of Tuned Liquid Dampers on High Rise Buildings in Kerala” International Journal of Engineering Research & Technology Vol. 5 Issue 09, September-2016.

[22] Namrata Yannawar, G.R.Patil, “Seismic response behaviour of a three Storey Frame Structure with Tuned Liquid Damper device” International Journal of Innovative Research in Science, Engineering and Technology .

[23]Chidige Anil Kumar , E Arunakanthi, “A Seismic Study on Effect of Water Tank Modelled as TMD” International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 2, February 2017.

[24] Software- Staadpro V8i ss6.