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INVESTIGATION OF SEISMIC BEHAVIOR OF G+10 BUILDING AT RAIPUR CITY HAVING TOP RECTANGULAR WATER TANK WORK WITH LIQUID DAMPER

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Abstract

Present study deals with the push over analysis multistoried frame structures by using SAP2000 software in G+10 Building with TSLD Damper and without damper. Recent earthquakes in which many concrete structures have been severely damaged or collapsed, have indicated the need for evaluating the seismic adequacy of existing buildings. About 60% of the land area of our country is susceptible to damaging levels of seismic hazard. We can’t avoid future earthquakes, but preparedness and safe building construction practices can certainly reduce the extent of damage and loss. In order to strengthen and resist the buildings for future earthquakes, some procedures have to be adopted. One of the procedures is the nonlinear static pushover analysis which is becoming a popular tool for seismic performance evaluation of existing and new structures. By conducting this push over analysis, we can know the weak zones in the structure and then we will decide whether the particular part is to be retrofitted or rehabilitated according to the requirement.

Keywords: Linear static analysis, Non-linear dynamic analysis, Non-linear static analysis, Pushover analysis, SAP2000, Time history analysis.

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1. Introduction

An earthquake occurs when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. Scientists can’t tell that an earthquake is a foreshock until the larger earthquake happens.

Earthquake are disastrous even in small amount for skyscrapers because they are not only high but there dead load is also high so for making high rise building we tend to keep building weight as lower as possible which in turn make building prone to vibrations. If they fails they leads to failure of their neighboring buildings too.

When Seismic waves are generated in any part of earth due to tectonic plate’s movement the waves which are generated causes to and fro motion of earth. Foundation as it rests over ground also move forward and backward along with ground but the superstructure due to inertia of rest tends to be in its same position and thus integrity of structure fails.

So to avoid failure of building the forces which are transferred to superstructure are to be redistributed and reduced. These are carried out by using Shear wall, Diaphragms, Moment resisting frames, Installation of dampers, Installation of vibration isolation devices, Use of earthquake resistant materials, Base isolators etc.

Investigation of seismic behavior is required because the structure fails during earthquake which leads to loss of property as well as lives. Therefore engineer needs to develop a method so that when any building is susceptible to vibration they can bear them. We are using tunes mass damper in form of tuned sloshing liquid damper for reducing effect of earthquake vibration on multistory structure Tuned liquid damper in form of rectangular tank filled with plain tap water is used for vibration control in multi storey building. The frequency of liquid sloshing motion is set by adjusting the length, depth of tank and it is tuned with frequency of structure.

Abhijeet A. Maske et. al. [5] has done the push over analysis to identify weak zones in the structure and then decide whether the particular part is to be retrofitted orrehabilitated according to the requirement. They have performed their analysis onmultistoried frame structures by using most common software SAP2000 (version 14). To achieve this objective,two framed buildings with 5 and 12 stories respectively were analysed. The results obtained from this studyshowed that properly designed frames perform well under seismic loads.

J. P. Kadali et. al. [6] discussed about “Special Moment Resisting Frames”. Reinforced concrete special moment frames are used as part of seismic force-resisting systems in buildings that are designed to resist earthquakes. The poor performance of Ordinary Moment Resisting Frame (OMRF) in past earthquakes suggested special design and detailing to warrant a ductile behaviour in seismic zones of high earthquake (zone III, IV & V). Special proportioning and detailing requirements result in a frame capable of resisting strong earthquake shaking without significant loss of stiffness or strength.

Rakshith K J et. al. [7] studied the base shear, story acceleration, story drift and column and beam forces due to earthquake ground excitation, applied to superstructure of the building by installing base isolated devices at the foundation level and then compared the different concerts between the fixed base condition and base isolated condition by using ETABS 2016v software. They have considered G+14 symmetrical RCC building as test model.Lead rubber bearing and high damping rubber bearing is used as base isolation structure in study. Nonlinear time history analysis is used on both fixed and base isolated buildings.

Procedure has developed by A. S. Moghadam et. al [8] for elastic spectrum analysis of the building to obtain the target displacements and load distributions for pushover analyses. Then two-dimensional inelastic static analyses are conducted on the lateral load resisting elements of interest. To investigate the efficiency of this method for different types of eccentric buildings, three systems are studied. The first model is a ductile moment resisting frame building. The second model is a set-back building and the last one is a wall-frame structure. Each building is subjected to ten spectrum compatible time history records as ground motion excitations at the base. Building frames are designed for ductility of structure by Sneha P. Meshram et. al [9]. Ductility is assured by considering Special Moment Resisting Frames and its performance is compared with nominally ductile frame i.e. with Ordinary Moment Resisting Frames.

1.1 Damping

The ability of any structure to dissipate energy, experienced by structure during dynamic loading is damping. The system energy is slowly reduced which is caused by motion on earth crust or due to wind. Rate which amplitude of vibration decreases depend on damping properties and damping criteria.

Types- the various types of dampers used in structures to reduce vibration effects are

1) Viscous damper- it is silicon based fluid piston cylinder arrangement damper used for absorbing seismic energy as well as wind energy
2) Viscoelastic Damper Elastomer with metallic plates is used which convert mechanical energy to heat energy as damping of energy. It also withstands wind vibration along with earthquake.
3) Friction Damper- various steel plates sliding over each other separated by friction pad are used which dissipate vibration by absorbing them in order to reduce the friction between the plates.
4) Magnetic damper-it has two racks, two pinions of copper disk and earth magnet which is used in dynamic vibration absorber.
5) Tuned mass damper- it is located in particular position in any structure to minimize amplitude of vibrations up to a certain limit.
6) Lead injection Damper LED-it has lead filled inside two chamber cylinder and when vibration occur lead from one chamber move to other.

1.2 Tuned Liquid Damper (TLD)

It is a passive control device; Tuned Liquid Damper is a type of TMD in which in place of mass Liquid i.e. water is used for vibration control. We usually try to make light weight structure which is more vulnerable to oscillation so liquid mass damper are used to prevent the to and fro motion of structure up to a certain limit. When frequency of tank motion is close to one of the natural frequencies of tank fluid, large sloshing amplitudes can be expected. If both frequencies are reasonably close to each other, resonances will occur. Generally tuning the fundamental sloshing frequency of the TLD to the structures natural frequency causes a large amount of sloshing & wave breaking at the resonant frequencies of the combined TLD-Structure system, this dissipate a significant amount of energy.

1.3 Structure idealization

The equation for motion for TLD in single degree of freedom is

$$m_s\, v_s + c_{ss} v_s + k_s v_s = -m_s a_g + F$$

where m=mass, k=stiffness, c=damping

Fundamental sloshing frequency of TLD is

$$F_w = \frac{1}{2\pi}\sqrt{\frac{\pi g \tanh(\frac{\pi h}{L})}{h}}$$

Where g= gravity, L= length of tank, h= height of water

Natural frequency according to linear wave theory

$$\omega n2=\frac{g(2n-1)\pi \tanh\,(2n-1)\pi r}{a}$$

For nonlinearity $\omega d=\omega n\{1.037(\frac{Ae}{a})^{0.0035}\}$ for Ae<3% of tank dimension

$$\omega d=\omega n\{1.59(\frac{Ae}{a})^{0.125}\}$$ for Ae>3% of tank dimension

Mass of water

$$md = M\frac{8\tanh\{(2n-1)\pi r\}}{r(\pi(2n-1))^3} = M\frac{0.83 tanhx 3.2r}{3.2r}$$

2. Mathematical Formulation

2.1 Pushover Analysis Study

Various forces are applied to structures with nonlinear properties and graph between displacement and lateral force is drawn to define the Capacity curves and Demand Curves in form of acceleration displacement graph. Pushover use equivalent SDOF models for vibration effect along with response spectra. The base shear, storey drift displacement, acceleration are the main forces which are calculated in pushover analysis.

2.2 Calculation of base shear

Table-1 Equivalent static force analysis

Sl.No	**Type of Load**	**Dimension**				**Unit Weight**	**Load**
		NO	L	B	T		
1	**Dead Load Calculation**						
A	Slab	1	12	12	0.125	25	450
B	Beam	8	12	0.3	0.45	25	324
C	Column	16	3	0.45	0.45	25	243
D	External Wall	8	12	0.23	3	20	1324.8
2	**Live Load**						
	25% of Area of Floor	1	2	12	12	0.25	72
3	**Floor Finish**	1	1	12	12	1	144
	Weight of 1^{ST} to 10^{TH} Floor						**2557.8**
	Weight of Roof						846
	Total Weight					W	26424

2.3 Calculation of Lateral Forces

Storey lateral forces and shear forces are calculated and tabulated in the following table.

FLOOR LEVEL (i)	**Wi(kN)**	**Hi(m)**	**WiHi^2(KN-M2)**	**Story force Qi= Vb*WiHi2/ƐWiHi^2**	**SHEAR FORCES (Vi)**
11	846	33	921294	223.9338348	223.9338348
10	2557.8	30	2302020	559.5392637	783.4730985
9	2557.8	27	1864636.2	453.2268036	1236.699902
8	2557.8	24	1473292.8	358.1051288	1594.805031
7	2557.8	21	1127989.8	274.1742392	1868.97927
6	2557.8	18	828727.2	201.4341349	2070.413405
5	2557.8	15	575505	139.8848159	2210.298221
4	2557.8	12	368323.2	89.52628219	2299.824503
3	2557.8	9	207181.8	50.35853373	2350.183037
2	2557.8	6	92080.8	22.38157055	2372.564607
1	2557.8	3	23020.2	5.595392637	2378.16
			ƐWiHi2=9784071		

3. Modeling in SAP 2000

3.1 Modeling in SAP2000 without TLD

Defining properties of RC frame, material frame, slab sections and support condition.

File menu→ New Model→ choose 3D frame in dialogue box.

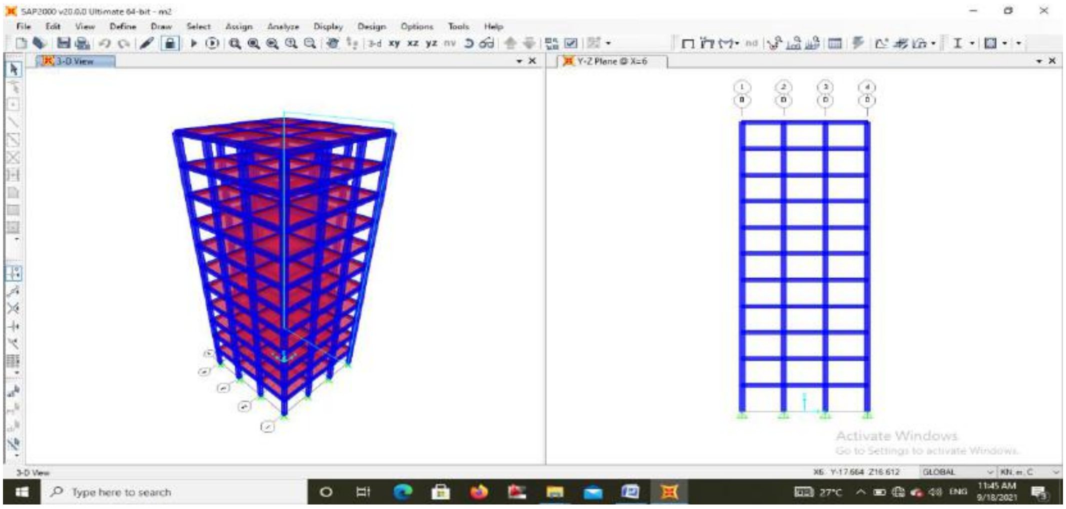

Fig.1 Modeling in SAP2000 without TLD

3.2 Modeling in SAP2000 with TLD

Tank frame is modeled using columns of same size as that of building which is then in filled with concrete wall panels.

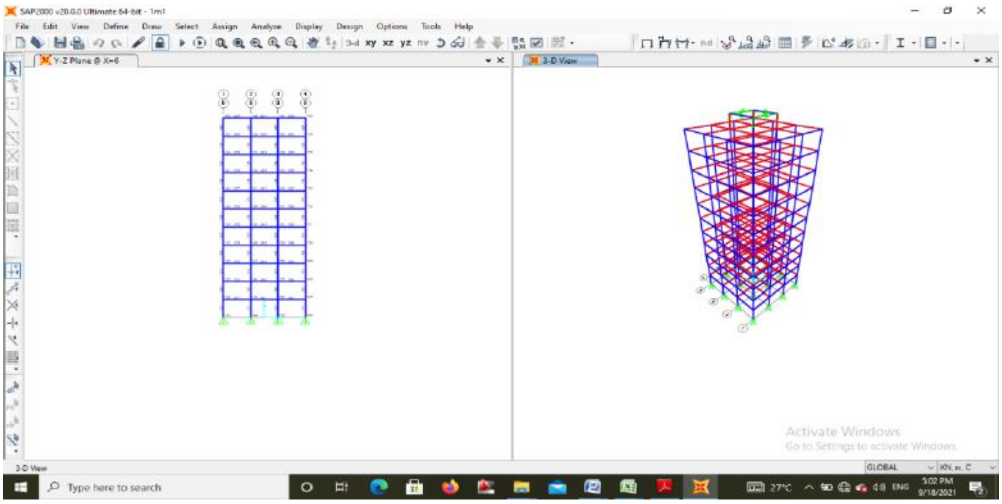

Fig.2 Modeling in SAP2000 with TLD

4. Results and Discussions

4.1 Result of Normal Pushover Analysis without TSLD

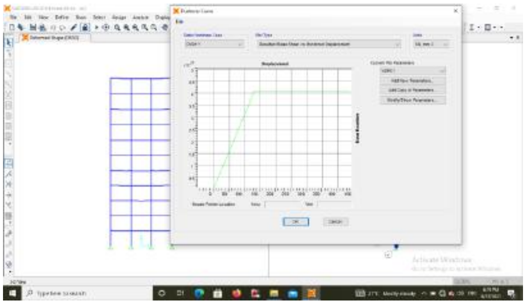

Fig.3 Pushover curve in Deformed Shape

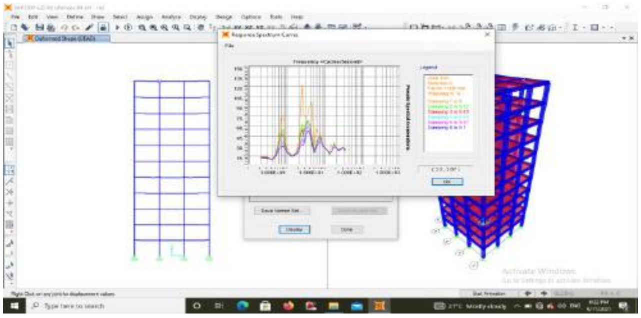

Fig.4 Response Spectrum Frequency Curve

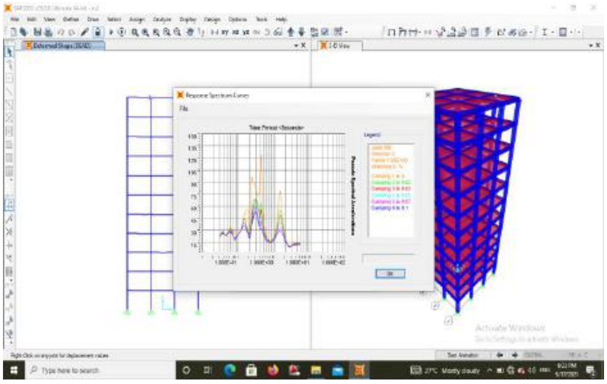

Fig.5 Response Spectrum Time Period Curve

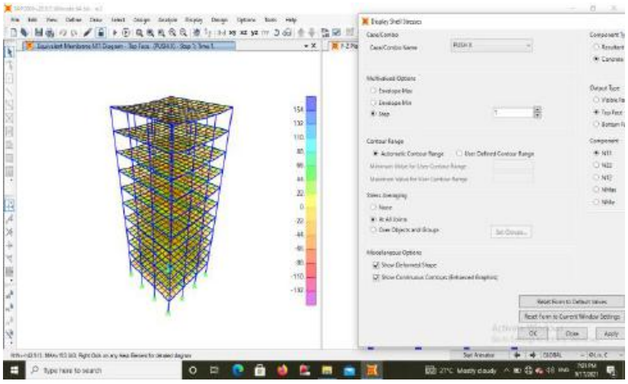

Fig.6 Shell Stresses

4.2 Result of Normal Pushover Analysis with TSLD

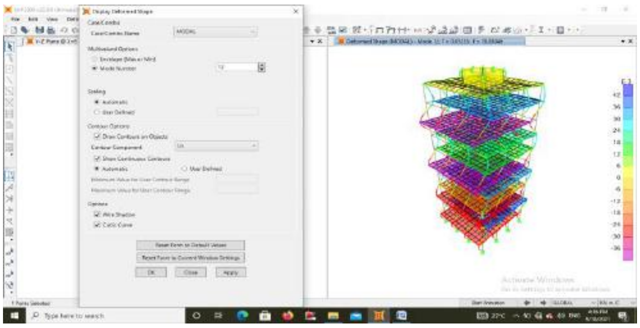

Fig.7 Deformed Shape of building

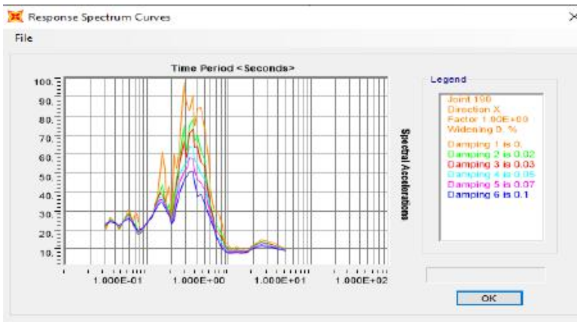

Fig.7 Response Spectrum Curve

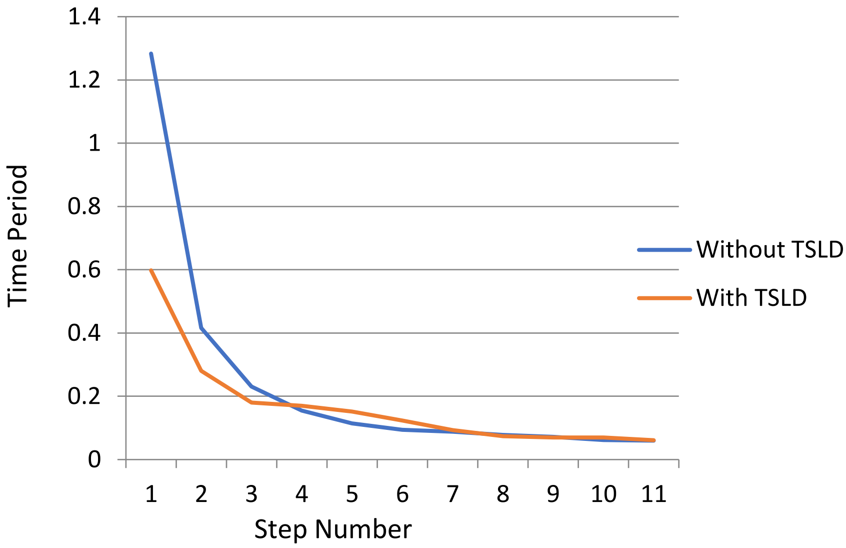

Fig. 8 Variation in Time Period without and with TSLD

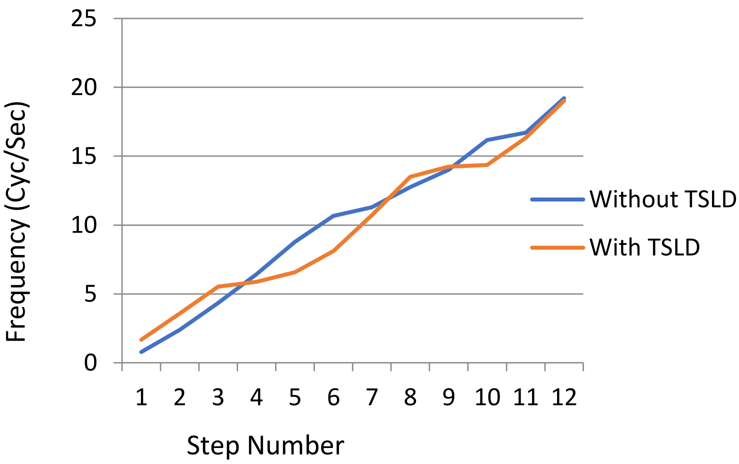

Fig. 9 Variation in Frequency without and with TSLD

It is clear from the above figure that, TLD is most effective when it is tuned to the fundamental natural frequency of structure. Under tuning or over tuning of TLD to fundamental natural frequency of structure puts adverse effect on the damping of the TLD. TLD in controlling the earthquake response of structures is efficient

5. Conclusions

It has been found that, the effect of tuning ratio is found to be critical in the design of TLD. A deviation in tuning by up to 5% is found acceptable. However, beyond this, a sharp reduction in effectiveness is found out. TLD is also found to be more practical and economical for taller buildings. This is due to the fact that the size of each tank of TLD would be much higher for taller buildings and building such large tanks would be more practical than building many number of small tanks. It has been found that, TLD is most effective when it is tuned to the fundamental natural frequency of structure. Under tuning or over tuning of TLD to fundamental natural frequency of structure puts adverse effect on the damping of the TLD. TLD in controlling the earthquake response of structures is efficient. It has been found that though the TLD adds damping to the structure, it is not effective in reducing the response of structures for the extremely short-duration pulse-type motions. However, if the pulse duration is long enough for the peak response to occur after at least two cycles of structural vibration, the TLD becomes progressively more effective. For the longer-duration ground motions, the TLD has been found to be quite effective.

The use of rectangular water tank as tuned sloshed damper system in multi storey building helps in reducing the vibration effect on structure in nonlinear case as well effectively. The pushover curve, time history analysis also shows that the damping in structure vibration occur significantly at top storey buildings and building chances of failure is highly reduced. Base shear is highly reduced in case of TSLD structure as compared to non TSLD structure.

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