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Blast Response of Elevated Water Tank Staging with Metallic Damper

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Abstract: - In the present paper work an attempt has been made to study the dynamic behaviour of the elevated water tank staging by using x-plate metallic damper subjected to blast induced ground vibrations. The main objective of this study is to reduce the damage of the elevated water tank by providing structural response control devices. The water tank staging is modelled in SAP 2000 and non-linear time history analysis is carried out to know the performance of the metallic damper under four different intensity blast induced ground motions and comparing the performance of structure without damper case. After the completion of analysis, the results show that by using metallic damper bending moment, shear force and displacements are comparatively reduced when compared to the without damper case. From this study observed that metallic x-plate damper is effectively reduced the structural responses under blast excitations.

1. Introduction

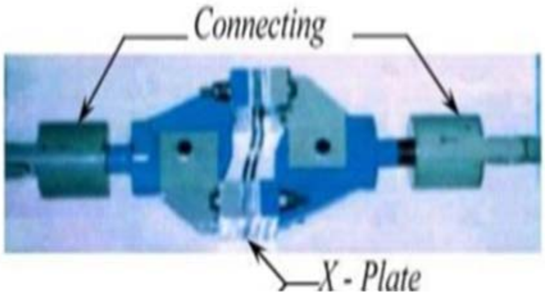
Elevated water tanks are very important structures to supply water for public utility and firefighting demand. These are expected to be serviceable during and after severe earthquakes and blast explosions. The elevated water tanks have huge amount of mass concentrated at the top, and it is resting on the slender supporting structure so it is more vulnerable against lateral forces due to earthquake and blast loads. It is important to consider dynamic motion of water with respect to tank as well as tank motion with respect to ground. During the blast explosion greater amount of energy is produced and this energy is causes to structural damage. Many of the elevated water tanks are collapsed due to poor staging performance during the earthquake and blast. To reduce the structural damage by introducing the energy taking devices such as dampers and base isolators. In this paper to control the displacement, displacement control dampers are used and it gives additional stiffness to the structure.

In recent years, many researchers investigated the effectiveness of dampers on elevated water tank staging. Panchal and jangid [1] worked on the seismic response of liquid storage steel tanks isolated with using variable frequency pendulum isolators and compared with friction pendulum systems. Shekari.et.al, [2] worked on the seismic behavior of cylindrical base isolated liquid storage structures and concluded that by using isolation system the dynamic behavior of tanks during earthquake ground motions can be considerably decreases. Seleemah.et.al, [3] base isolation was indicated to be more efficient for slender tanks as compared with broad tanks under seismic loads. Mohammed Zain kanga et.al, [4] concluded low damping isolator is found to be more effective in response reduction ability than high damping isolator and LRB is more effective in decreasing structural accelerations and story drifts. Manchalwar and Bakre [5] studied on the performance of RC structure equipped with steel and aluminum x plate damper. Manchalwar and Bakre [6] worked on the optimal placement of metallic damper based on concept of generic algorithm. Nirmala G.et al, [7] worked on the vibrational mitigation of water tank staging equipped with x- plate metallic damper. Nirmala G and atulkumar studied [8] studied behavior of the water tank staging with steel and aluminum x- plate damper.

2. X-Plate metallic damper

X-Plate metallic damper is one type of damper which configuration is in X shape and this damper made up of steel and aluminum. The XPD provides to reduce the deformation and it is very efficient in the reduction of energy. This XPD consists of multiple x-plate connections. The number of metallic plates is depending on the structural system type to exhaust the input external energy. The XPD provides additional stiffness and damping to the system.

The various researchers studied on the x-plate damper and analyze the effectiveness of the damper. Manchalwar and Bakre [9] investigated on the steel and aluminum metallic x-plate damper on reinforced concrete structures and they found the x- plate dampers are very efficient to reduce the seismic and blast performance. In BARC (Bhabha atomic research center), IIT Mumbai tested many experiments to evaluate the x-plate damper performance.



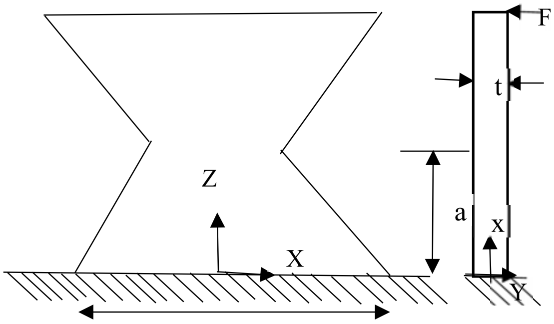


Fig.1. X-plate metallic damper

Properties of metallic X-plate damper: -

$$F_y = \frac{\sigma_y b t^2}{6a} n \quad (1)$$

$$q = \frac{2\sigma_y a^2}{Et} \quad (2)$$

$$K_d = \frac{F_y}{q} \quad (3)$$

$$K_d = \frac{Ebt^3}{12a^3}\, n \quad (4)$$

Where, F_y is the yield force, K_d is the initial stiffness of X-plate damper, q is the yield displacement. a, b and t are indicating the height, width and damper thickness. σ_y and E are yield stress and young's modulus of the damper.

Table 1. Sectional properties of the water tank

Capacity of the tank (ML)	Tank diameter (m)	Size of column (mm)	Bottom beam (mm)	Brace beam (mm)
0.6	11.38	400 x 400	350 x 750	300 x 550

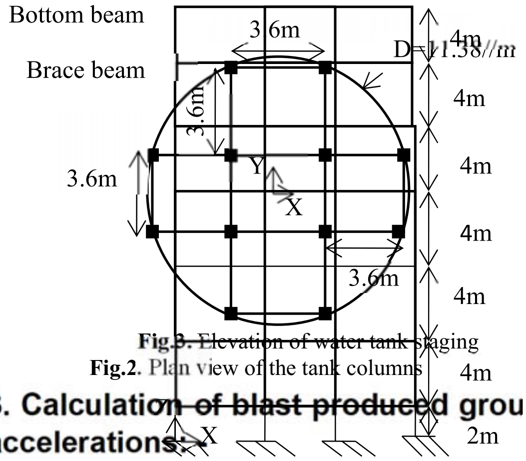


Fig.3. Elevation of water tank staging

Fig.2. Plan view of the tank columns

3. Calculation of blast produced ground accelerations: -

based on the earlier research by Hinman [10], Carvalho and Battista [11] are proposed the one exponential decaying function for blast induced ground vibrations in terms of ground acceleration in the form of equation.

$$\ddot{x}_g(t) = -\frac{1}{t_d} v e^{\frac{-t}{t_d}} \quad (5)$$

In the above equation $\ddot{x}_g(t)$ is the ground acceleration, t_d is the arrival time of wave calculated by t_d = R/C, C is the velocity of wave and R is the d charge point distance for present study it is taken as 100 m. v (m/s) is peak particle velocity which is proposed by Kumar et al., [12]

$$v = \frac{f^{0.642} SD^{-1.463}}{\gamma_D} \quad (6)$$

Where f is the uniaxial compressive strength of granite rock deposit, SD is the scaled distance SD = R/$\sqrt{Q}$, Q is the charge weight in this present study it is taken as 10-ton, 25-ton, 50-ton, 75-ton. γ_D average mass density of granite is 26000 kg per cubic meter, young's modulus of granite rock is 73.9 Gpa these are taken from Kumar et al., [12]

4. Problem statement: -

To evaluate the blast progress of the water tank structure by using x- plate steel damper for this study 12 column 24m height staging has been selected and modeled in SAP 2000. Plan and elevation of the elevated water tank is taken from the Suraj O. Lakhade [13] which is shown in fig. 2&3. In this study M20 concrete and Fe 500 steel is used. For design dead loads and live loads are considered as per IS 875- 1983 0f part 1 & 2.

5. Performance of the structure: -

To assess the efficiency of the steel x-plate damper, the non-linear time history analysis has been conducted in SAP 2000 under four blast ground vibrations. The yield strength and stiffness of the damper 43.2kN and 23288.4kN/m respectively.

5.1 Axial force, Shear force and Bending moment comparison: -

From the analytical results, the response parameters axial force, shear force and bending moment of water tank as shown in table 2,3 and 4 respectively. After analyzing results, it is noticed that axial force gradually decreased, shear force and bending moment values are effectively reduced when compared without x-plate damper case.

Table 2 Axial and comparison for 12 column 24m staging.

Column number	Blast charge weight	Axial force (kN)	
		Without damper	With XPD
14	10 Ton	117.1	75.4
	25 Ton	227.3	272.3
	50 Ton	380.4	1141.4
	75 Ton	511.5	433.0
8	10 Ton	1402.7	1044.9
	25 Ton	2722.1	3765.7
	50 Ton	4555.8	14412.8
	75 Ton	6124.7	5769.06

Table 3 shear force comparison for 12 column 24m staging.

Column number	Blast charge weight	Shear force (kN)	
		Without damper	With XPD
14	10 Ton	116.8	78.1
	25 Ton	226.8	276.8
	50 Ton	379.6	1146.0
	75 Ton	510.3	438.1
8	10 Ton	139	101.0
	25 Ton	269.7	356.5
	50 Ton	451.4	1395.0
	75 Ton	606.9	550.7

Table 4 Bending moment comparison for 12 column 24m staging

Column number	Blast charge weight	Bending moment (kN m)	
		Without damper	With XPD
14	10 Tons	352.38	310.01
	25 Tons	683.80	947.91
	50 Tons	1144.45	3565.78
	75 Tons	1538.55	1425.8
8	10 Tons	215.40	156.60
	25 Tons	417.99	552.84
	50 Tons	699.58	875.9
	75 Tons	940.48	853.68

5.2 Displacement comparison: -

To estimate the effectiveness of the metallic x-plate damper, nonlinear time history analysis is conducted and plotted the time history graphs between displacement (KN) and time (sec). Graphs are plotted for four different blast induced ground accelerations. From the results, the x-plate damper is very effectively reduced the displacements when compared to the no damper case shown in Fig.4..

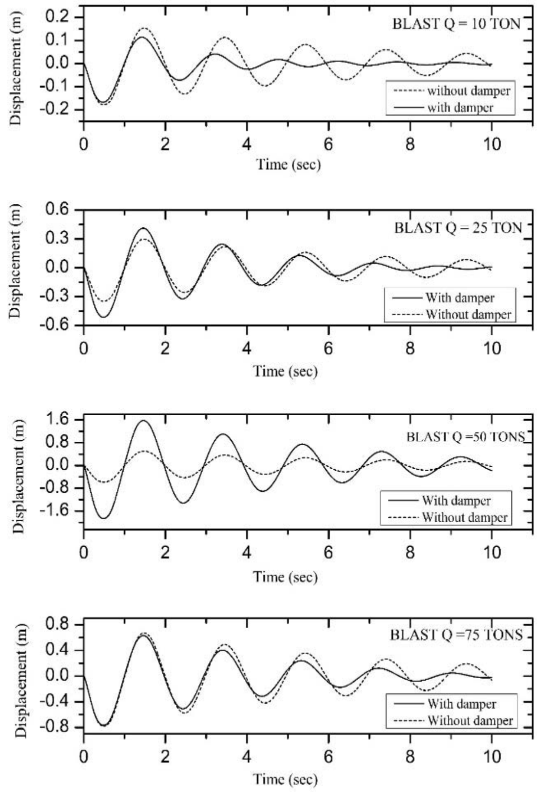


Fig.4. Displacement vs time of metallic steel damper for 12 column 24m staging

5.3 Hysteresis loop: -

Hysteresis loop indicates energy dissipation of damper in the structure it is related to the axial force and displacement. By using steel metallic damper, the energy will be efficiently reduced when subjected to the blast vibrations shown in fig.5.

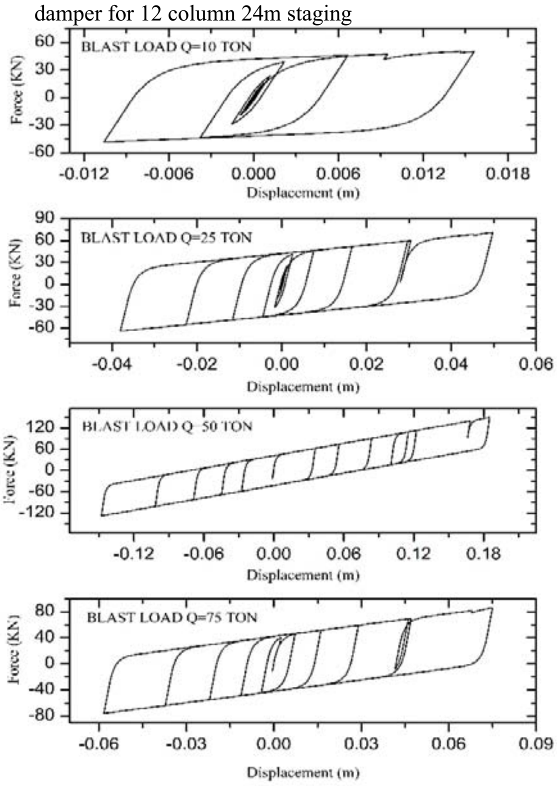


Fig.5. hysteresis loop of 12 column 24 m staging

6. Conclusion: -

In the present study, blast response of water tank is analyzed with metallic damper and without damper. For this study 12 column 24 m is considered, Modeling of water tank and nonlinear time history analysis is performed in SAP 2000. The main aim of this study to reduce the damage of the water tank when subjected to blast induced ground motions. By using metallic dampers axial force, shear force and bending moment values are effectively reduced for 10 ton and 75-ton blast loads. For 25 ton and 50-ton blast loads the responsive parameters are slightly increases as compared to the without damper. From the results, concluded that top story displacement values are reduced about 25-30% in metallic damper case.

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