

STUDY OF THE RESPONSE OF HIGH-RISE BUILDING USING OUTRIGGERS WITH VISCO-ELASTIC DAMPER

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Abstract – In developing country like India having such a high population, and unavailability of land, the high-rise building is a possible solution. This gives rise to some challenges in its structural stability due to critical loading conditions that arise due to earthquake and predominantly due to wind. Control of the lateral deformation and inter storey drifts is the major challenge to overcome in the execution of high-rise buildings subjected to these lateral loads. The outrigger belt truss system is commonly used structural system for controlling the excessive drift due to lateral load effectively. For high-rise buildings, particularly in seismically active zone, this system can be selected to meet structural safety requirements. This study is carried out on an eighty storeyed building having a floor plan of 30m x 30m along with varying location of outrigger belt truss system. Non-linear Time-history analysis is carried out for obtaining results. Parameters like maximum storey displacement, Inter Storey Drift and base shear is considered.

Keywords— Outrigger Belt Truss System, Visco Elastic Damper, Non-Linear Time history analysis.

I. INTRODUCTION

The outrigger and belt truss system is one of the commonly used structural system for high-rise buildings to effectively control the excessive lateral deformation. (Caused by earthquake and wind excitations) Outriggers are stiff, deep beam which connects the central core of the structure to the exterior columns which helps in keeping the columns in their position in turn reducing the sway. Outrigger belt truss systems connects all exterior columns to the central core. Consequently, the exterior columns and belt truss system resist the rotation of central core and also decrease the lateral deformation and bending moment at base of the structure. A new concept, building having energy-dissipation story system, in which dampers combined with braces were substituted for outrigger bracings, had been proposed by Zhou et al. (2007). ^[2] The outrigger belt truss system facilitates the activation of all the exterior columns that contributes in resisting the overturning moment. Due to this the moment in the core supporting system reduces that minimizes the drift and reduction in tension and uplift force at the foundation level.

2 OBJECTIVE OF STUDY

This study is specifically concentrated to achieve the following objectives:

- i. To study the performance of a high-rise building with outrigger belt truss systems and dampers as an energy dissipation Systems.
- ii. To determine the optimum location of energy-dissipation story in high-rise buildings that yields maximum benefits in the engineering design parameters.
- iii. To obtain the response of a high-rise building under different ground motion in terms of parameter- storey displacement, inter storey drift, base shear & time period.

DYNAMIC CHARACTERISTICS OF VISCOELASTIC DAMPER

Viscoelastic dampers provide both a velocity dependent force and a displacement dependent elastic restoring force. They are typically made of copolymers or glassy substances. Viscoelastic is a material that exhibit both Viscous as well as elastic characteristics.

The dynamic properties of the viscoelastic damper are characterized by:

- (a) The shear loss modulus G''
- (b) The shear storage modulus G'
- (c) The loss factor $\eta = G''/G'$.

The shear loss modulus controls the specific energy dissipation capacity of the damper. High value of G'' indicate high energy dissipation capacity of damper. The shear storage modulus affects the change in stiffness of the structural system to which the damper is added. The loss factor η is a measure of the suitability of the damper as a damping medium.

- 1) Stiffness of Damper, $k' = \frac{G'A}{h}$
- 2) Damping Coefficient, $c = \frac{G'' Ah}{\omega h}$

Where, Ah is area of VE material; h is thickness of VE material and ω is vibration frequency. ^[3]

II. MODELING AND ANALYSIS

The model considered for analysis is an 80 Storey High-rise Building having 30m x 30m plan dimension. Outriggers Belt Truss systems are provided at different positions by varying height of the building. Viscoelastic Damper having Stiffness (k) 800 KN/mm and damping coefficient 560.85 KN/mmS⁻¹ is used as Energy Dissipater. Dimensions of main structural members are as shown in table below:

TABLE- I (Main Dimensions of the Building) (All dimensions are in mm)

Storey	Beam Sections	Column Section	Shear Wall	Slab
1-20	450 x 850 (M60)	1000 x 1000 (M60)	600 mm thick (M60)	175 mm thick (M60)
21-40	450 x 750 (M50)	900 x 900 (M60)		
41-60	450 x 650 (M50)	800 x 800 (M60)		
61-80	350 x 500 (M50)	700 x 700 (M60)		

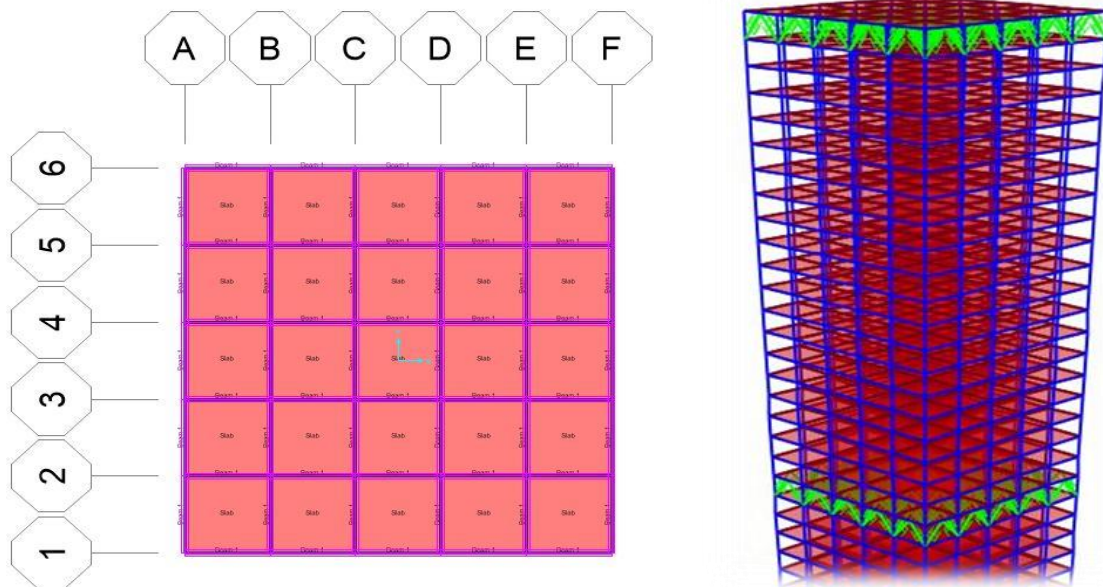


Fig. 1 Layout of Building and Outrigger Belt Truss System in a high-rise building

MODEL ARRANGEMENT WITH DIFFERENT POSITION OF OUTRIGGERS

Various models were run to determine optimum position of outrigger belt truss system which are at 0%, 25%, 50%, 75% and 100% height of the high rise building. Model arrangements are as below:

- 1) MT0 – Model without Outrigger Belt Truss system.
- 2) MT25-50 Model with Outrigger Belt Truss provided at 25% and 50% of the height of the building (I.e. at 20th storey and at 40th storey).
- 3) MT25-75 Model with Outrigger Belt Truss provided at 25% and 75% of the height of the building (I.e. at 20th storey and at 60th storey).
- 4) MT25-100 Model with Outrigger Belt Truss provided at 25% and 100% of the height of the building (I.e. at 20th storey and at 80th storey).

- 5) MT50-75 Model with Outrigger Belt Truss provided at 50% and 75% of the height of the building (I.e. at 40th storey and at 60th storey).
- 6) MT50-100 Model with Outrigger Belt Truss provided at 50% and 100% of the height of the building (I.e. at 40th storey and at 80th storey).
- 7) MT75-100 Model with Outrigger Belt Truss provided at 75% and 100% of the height of the building (I.e. at 60th storey and at 80th storey).

III. RESULTS AND DISCUSSION

NON-LINEAR TIME HISTORY ANALYSIS

For Seismic analysis, different types of ground motions are considered and Non-Linear Time History Analysis is carried out for different model arrangements discussed above. Near Fault Ground motions of Imperial Valley, California El Centro Array #5 (EQ11) and El Centro Array #7 (EQ21) are used.

TABLE IIIIIV
Results of near fault ground motion

Model	EQ11			EQ21		
	Top Storey Displacement (mm)	Reduction (%)	Top Storey Acceleration (m/sec ²)	Top Storey Displacement (mm)	Reduction (%)	Top Storey Acceleration (m/sec ²)
MT0	352.880	-	0.3963	327.901	-	0.3542
MT25-50	348.492	1.2434	0.3982	324.378	1.0744	0.3658
MT25-75	346.129	1.9131	0.3928	322.302	1.7075	0.3440
MT25-100	344.584	2.3509	0.3788	320.632	2.2168	0.3390
MT50-75	348.000	1.3829	0.3936	323.956	1.2031	0.3496
MT50-100	346.500	1.8079	0.3777	322.324	1.7008	0.3559
MT75-100	344.157	2.4719	0.3737	321.937	1.8188	0.3492

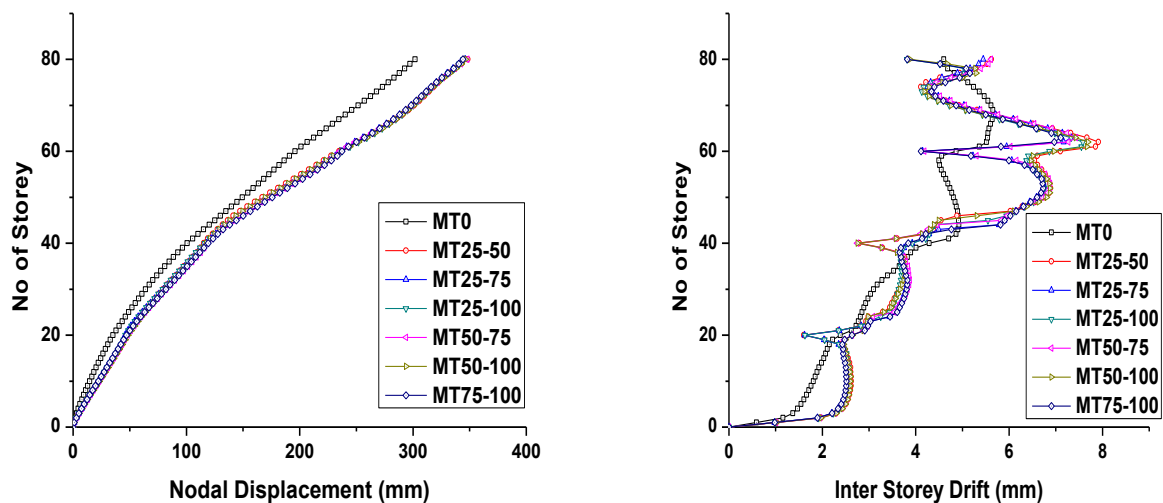


Fig. 4 Graph of Nodal Displacement and Inter Storey Drift for El Centro Array #5 (EQ11)

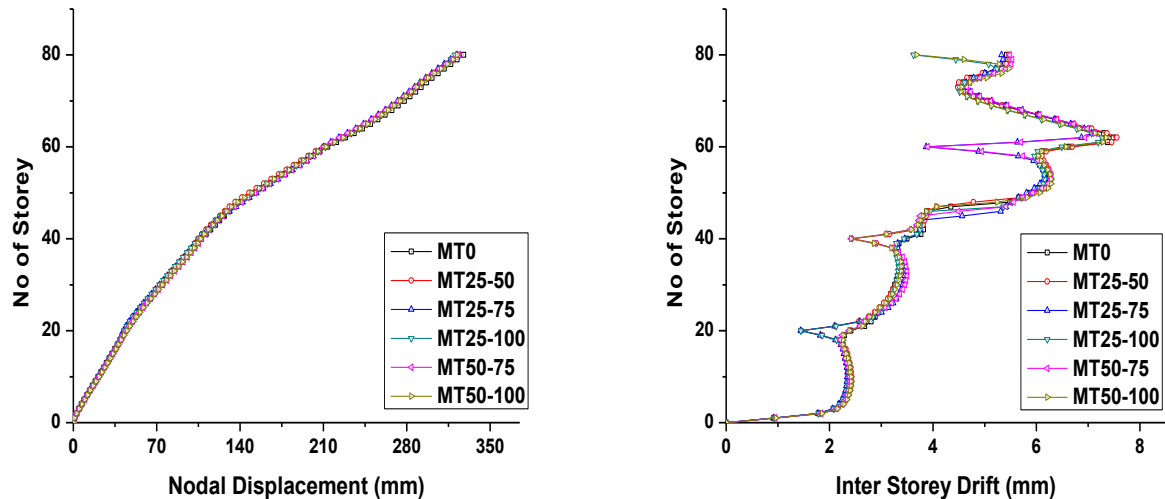


Fig. 5 A Graph of Nodal Displacement and Inter Storey Drift for El Centro Array #7 (EQ21)

Far Fault Ground motions of Canoga Park - Topanga Canyon (CNPX) and Northridge-Saticoy (STCX) are used for Non-linear Time history analysis and following results are observed:

TABLE VV (Results of near fault ground motion)

Model	CNPX			STCX		
	Top Storey Displacement (mm)	Reduction (%)	Top Storey Acceleration (m/sec ²)	Top Storey Displacement (mm)	Reduction (%)	Top Storey Acceleration (m/sec ²)
MT0	58.802	-	0.345	49.873	-	0.407
MT25-50	57.520	2.180	0.322	48.983	1.784	0.381
MT25-75	57.452	2.295	0.328	49.048	1.654	0.387
MT25-100	57.026	3.020	0.303	48.484	2.785	0.358
MT50-75	57.453	2.294	0.330	48.943	1.864	0.390
MT50-100	57.050	2.979	0.309	48.369	3.015	0.365
MT75-100	56.998	3.067	0.305	48.474	2.805	0.360

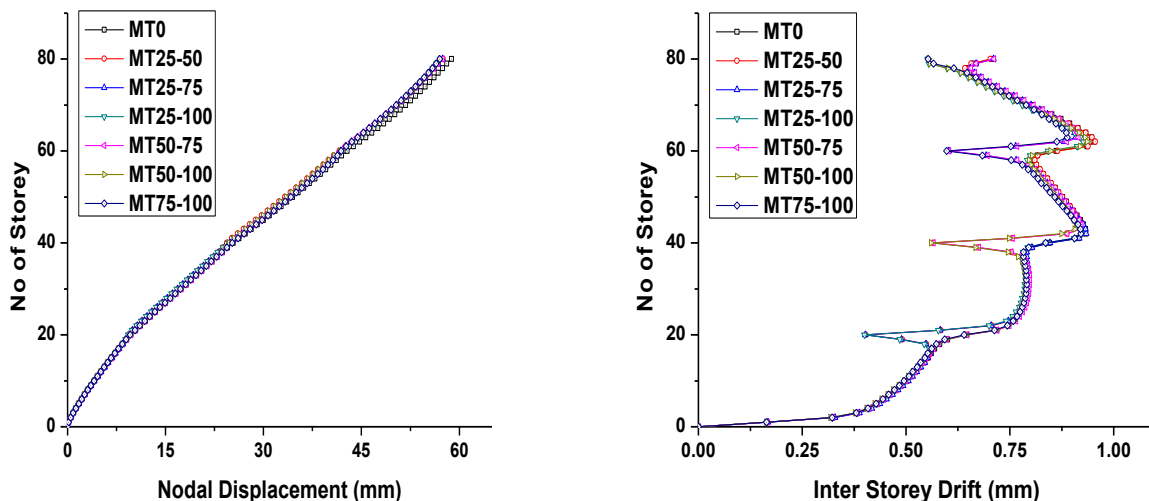


Fig. 6 A Graph of Nodal Displacement and Inter Storey Drift for Canoga Park ground motion (CNPX)

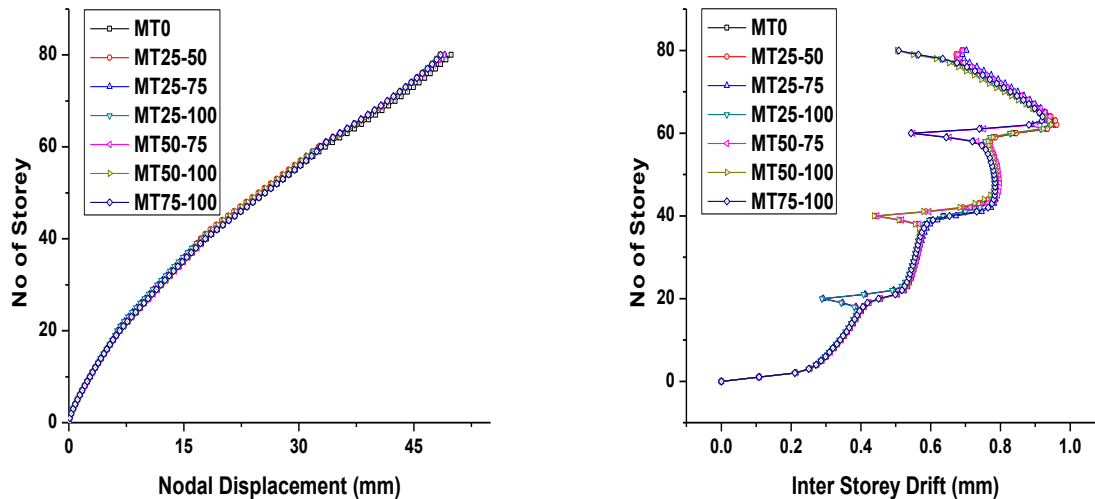


Fig. 6 A Graph of Nodal Displacement and Inter Storey Drift for Northbridge ground motion (STCX)

IV. CONCLUSIONS

The use of Viscoelastic Dampers in Outrigger Belt Truss System for a high-rise building increases its stiffness and performance of the building under lateral forces. Following conclusions can be drawn from the study:

- I. Outrigger belt truss system with viscoelastic dampers can increase the performance of the building while subjected to different Ground motions by reducing the lateral deformation of the building.
- II. Inter-Storey drift also reduces at a floor having these structural system. Up to 30% reduction in particular storey drift is observed in these analysis.
- III. By providing Outrigger Belt-Truss System at different positions, top floor displacement and top storey acceleration reduces by 10 and 8 percent respectively.
- IV. Lateral deformation observed in case of Near Fault ground motion is high compared to Far Fault ground motion.

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