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ADEQUACY OF BELT-TRUSS AND OUTRIGGER SYSTEMS WITH VISCOUS DAMPER IN 3D RC FRAME FOR SEISMIC LOADING

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ABSTRACT- *Seismic forces are one of the most dominant forces to which civil structures will be subjected and designing of structures to resist these forces represents a challenging task. There are essentially two ways to improve the seismic performance of the structures. One method is to improve the deformation capacity of the structural members, which is not always possible in practical situations and another method is to add dampers or base isolators to increase the seismic performance of the structures. Based on this G+23 Storeyed 3D RC frame model with the different locations of Viscous damper, belt-truss and outrigger system are considered in this study. Following which the FE Analysis involving the modal, equivalent static and response spectrum analyses are performed and results are obtained interms of Time period, Base Shear, storey displacement and Storey drift which all are tabulated and discussed.*

KEYWORDS- Modal Analysis, Equivalent Static Analysis, Response Spectrum, Time Period, Displacement, Storey Drift.

1. INTRODUCTION

Tall buildings have always inspired people to dream big and enhance technology to make their ideas more widely accepted. Due to the accelerated growth of urban technical capabilities, towering buildings are now a more suitable option for both residential and commercial construction. Tall structures are frequently employed residential, commercial, or office purposes. Business strategies are used in response to the city's rapid population growth and the necessity to keep everyone safe as much as possible. Earthquakes are a phenomenon that commonly happens throughout the world. The boundaries of these tectonic plates are the region that sees more frequent and severe Earthquakes since earthquakes are caused by the movement of tectonic plates. The seismic zones are divided based on these tectonic borders. Both structures and living things sustain a great deal of damage during earthquakes. The Earthquakes can be described as a wave-like motion that is moving through the crust of the earth. The earthquake's powerful ground vibrations are to blame for the building's damages. As the height of the structure increases, the impact of lateral forces like wind and Earthquake also increases. This is because the effect of an earthquake on a structure is modelled as a dynamic lateral force. As a result, a high-rise building with an RC frame might not be able to withstand the lateral strains caused by an earthquake. Different structural technologies have been used in tall buildings that make structures resistant to lateral loads such as wind and Earthquake.

2. LITERATURE REVIEW

This paper [1] worked on a high-rise steel-frame building construction subjected to seismic pressure in this study report to determine the best site for an outrigger. The fundamental idea of this work is to analyze the outcomes of lateral displacements and storey drift using non-linear time history and response spectrum methods. The analysis of 20 and 25 storey models was done by taking into account the ground accelerations of many real earthquakes from earlier studies on drift and displacement. They have taken the buildings height from the top at 0.44 and 0.5 times, respectively. By using non-linear time history analysis, it was determined that high storey 14 and 16 were the best locations for outriggers and belt-trusses. Therefore, the researcher maybe confident that outrigger's ideal site must be at high level. In this paper it has been discussed using viscous dampers in RC framed buildings, the responses have been considerably decreased. In this paper [11] the most effective structure is selected amongst the models and time history analysis is carried out, the paper intends to study the optimal damping ratio of the viscous dampers in the braced frames. Up to 90% decrease in the time period of maximum pseudo spectrum acceleration and about 70% reduction in the base shear is observed. Buildings with square columns are performing well in terms of response of the structure when compared to the rectangular columns irrespective of the floor plan.

3. OBJECTIVES

The objectives of this dissertation are,

1.To study the Effectiveness of Viscous Damper, Outrigger system and Belt-truss on 3D-RC Frame with liftcore wall by varying their positions.

2.To perform FE Analysis involving Modal, Equivalent Static and Response Spectrum Analyses all the models to obtain Natural frequency, Mode shape, Base shear, Displacement and Drift.

4. OUTRIGGER, BELT-TRUSS AND VISCOUS DAMPER.

4.1 OUTRIGGER AND BELT-TRUSS:

Outriggers aid to resist lateral loading and improve the stiffness and strength of a building's ability to overturn. They are horizontal members and strong beams that connect the interior core and shear wall of the structure to the outermost columns. Tall buildings are protected by an outrigger system when they are subjected to lateral stresses caused by an earthquake or wind. Column prevents the shear wall from rotating. As a result, the lateral displacement at the top and base of the movement would be significantly reduced.

In a structure, the number of outriggers can range from one to many, depending of the building. To improve their ability to withstand lateral stresses they are also paired with belt-trusses and shear bands. Outriggers distribute rotating forces from the building core to the outermost columns when a structure is subjected to lateral loading. This process converts horizontal forces into vertical forces, such as tensile and compressive forces. This outside column is utilized effectively, and the structure's overall deflection is decreased.

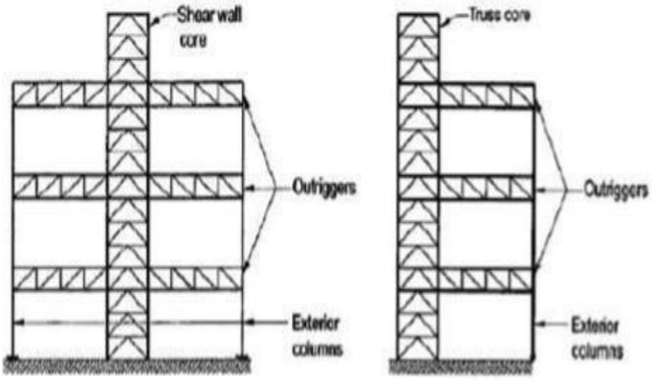


Fig 1. Outriggers and belt-truss system

4.2 VISCOUS DAMPERS:

Viscous dampers are initially used in the military and aerospace industry. They were adapted for use in structural engineering in the late 1980s and 1990s. They typically consist of a piston head with orifices contained in a cylinder filled with a highly viscous fluid, usually a compound of silicone or a similar type of oil. Energy is dissipated in the damper by fluid orifice when the piston head moves through the fluid. The fluid in the cylinder is nearly incompressible, and when the damper is subjected to a compressive force, the fluid volume inside the cylinder is decreased as a result of the piston head area movement. A decrease in volume results in a restoring force. This restoring force is undesirable and is usually prevented by using a run-through rod that enters the damper, is connected to the piston head, and then passes out the other end of the damper. Another method for preventing the restoring force is to use an accumulator. An accumulator works by collecting the volume of fluid that is displaced by the piston rod and storing it in the make-up area. As the rod retreats, a vacuum that has been created will draw the fluid out.

The Viscous damper for structures outwardly resembles the shock absorber on an automobile, but operates at a much higher output. Structural dampers are significantly larger than automotive dampers, and are constructed of stainless steel and other extremely durable materials as required to furnish a life of at least 40 years. Silicone oil, which is inert, non-flammable, non-toxic, and stable for incredibly long period of time, serves as the damping fluid. The viscous damper's seals are patented high-tech designs with no leaks that are based on aerospace fluid elements.

Fig 2. Viscous Damper

5. BUILDING DETAILS

The building has 5 bays in both the directions each of 6m width. 12 models of G+23 with storey height 3m each are considered.

Type of structure	Special moment resisting RC frame
Grade of concrete	M 30
Grade of reinforcement	Fe 500
Number of stories	G+23
Each floor height	3m
Column size	600 x 600mm
Beam size	450 x 600mm
Density of concrete	25 kN/m^3
Live Load on Floor	3 kN/m^2
Live load on Roof	3 kN/m^2

Floor finish	1 kN/m^2
Importance factor	1.2
Zone	V
Response reduction factor	5
Boundary condition	Fixed
Bracings	ISMB400
Viscous damper	FVD250

Table 1: Structural details

6. MODELS

Nomenclature and description of the models

Details	**Nomenclature**
RC bare frame.	BF
RC bare frame with dampers at middle	DM
RC bare frame with dampers at corner	DC
RC bare frame with dampers at middle and Belt-truss at 12^{th} and 24^{th} story	DM2B
RC bare frame with dampers at middle and Belt-truss at 8^{th},16^{th},24^{th} storey	DM3B
RC bare frame with dampers at middle and Belt-truss at 6^{th},12^{th},18^{th},24^{th} storey	DM4B
RC bare frame with dampers at corner and Belt-truss at 12^{th} and 24^{th} storey	DC2B
RC bare frame with dampers at corner and Belt-truss at 8^{th},16^{th},24^{th} storey	DC3B
RC bare frame with dampers at corner and Belt-truss at 6^{th},12^{th},18^{th},24^{th} storey	DC4B
RC bare frame with dampers at middle and Outriggers at 12^{th} and 24^{th} storey	DM2O
RC bare frame with dampers at middle and Outriggers at 8^{th}, 16^{th} and 24^{th} storey	DM3O
RC bare frame with dampers at middle and Outriggers at 6^{th}, 12^{th}, 18^{th} and 24^{th} storey	DM4O
RC bare frame with dampers at corner and Outriggers at 12^{th} and 24^{th} storey	DC2O
RC bare frame with dampers at corner and Outriggers at 8^{th}, 16^{th} and 24^{th} storey	DC3O
RC bare frame with dampers at corner and Outriggers at 6^{th}, 12^{th}, 18^{th} and 24^{th} storey	DC4O

Table 2: **Nomenclature**

Model 1:

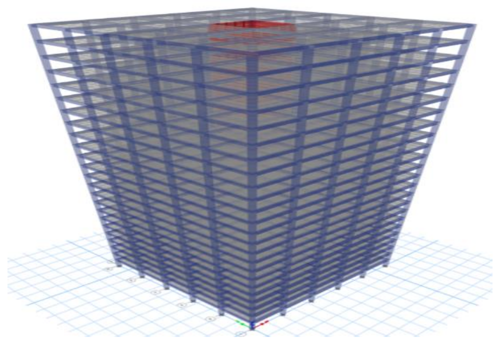


Fig 3. 3D View of RC bare frame

Model 2:

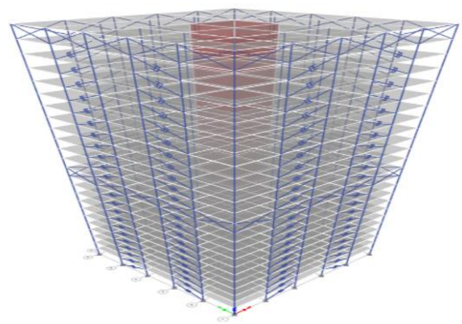


Fig 4. 3D view of DM2B

Model 3:

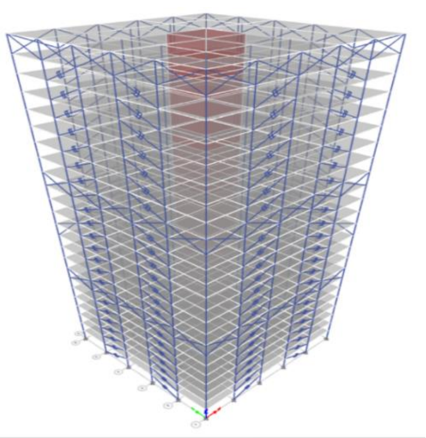


Fig 5. 3D view of DM3B

Model 4:

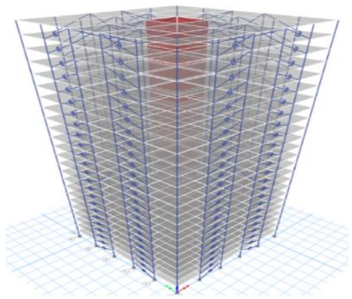


Fig 6. 3D View of DM2O

Model 5:

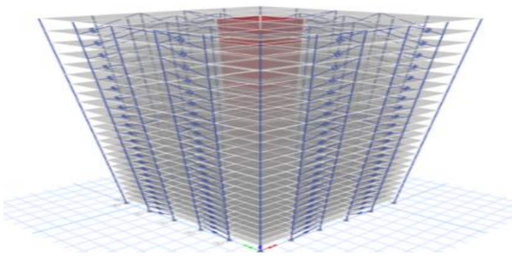


Fig 7. 3D View of DM3O

Model 6:

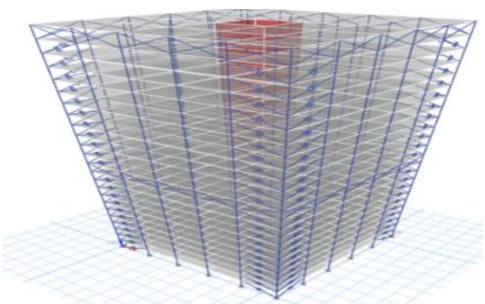


Fig 8. 3D view of DC2B

Model 7:

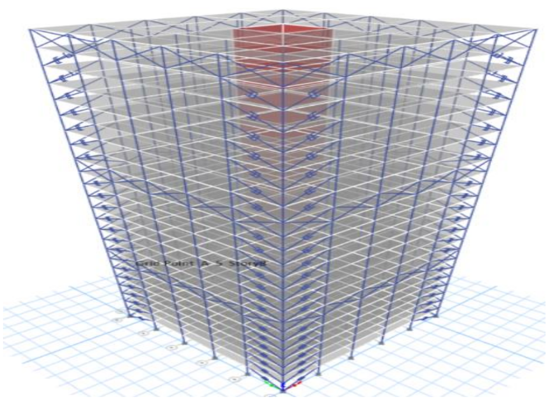


Fig 9. 3D View of DC3B

Model 8:

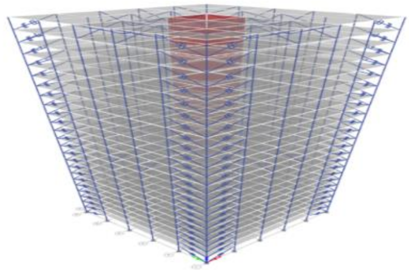


Fig 10. 3D view of DC2O

Model 9:

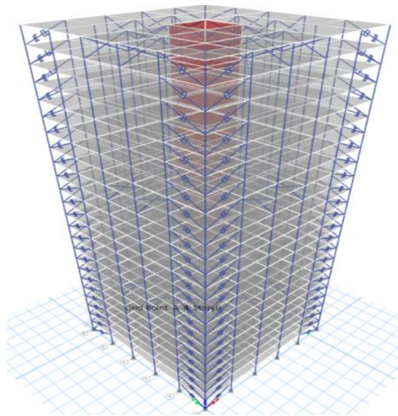


Fig 11. 3D view of DC3O

Model 10:

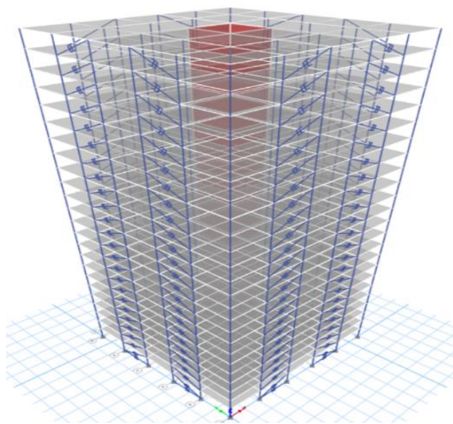


Fig 12. 3D view of DM

Model 11:

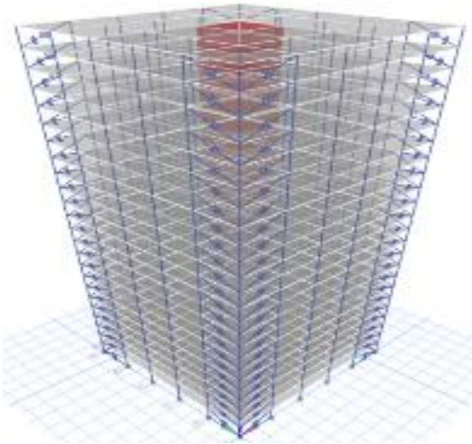


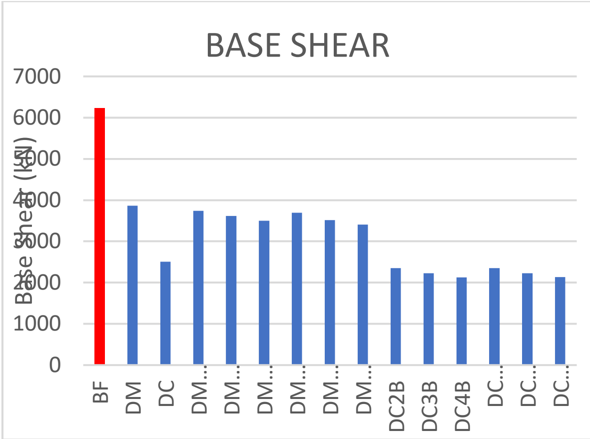
Fig 13. 3D view of DC

7. RESULTS AND DISCUSSIONS

This dissertation study includes the performance evaluation of RC for Modal, Equivalent static and Response spectrum analyses are performed in the FE analysis. In this chapter the results of Time period, Base shear, Storey Displacement and Storey Drift are tabulated anddiscussed

MODEL	Time Period(sec)	
	IS 1893-2016	Modal Analysis
BF		1.830
DM		1.696
DC		1.560
DM2B		1.619
DM3B	1.853	1.570
DM4B		1.543
DC2B		1.484
DC3B		1.441
DC4B		1.404
DM2O		1.595
DM3O		1.535
DM4O		1.497
DC2O		1.483
DC3O		1.442
DC4O		1.410

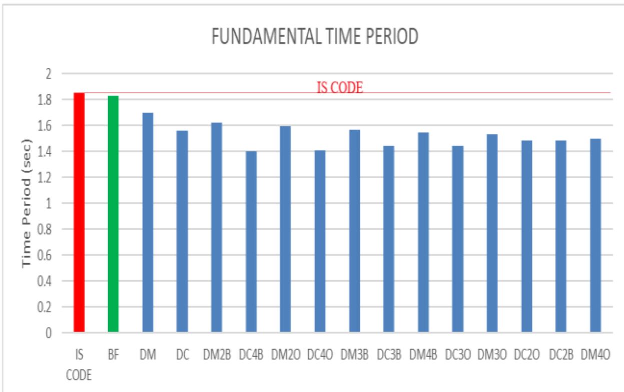
Table 3: Base shear values (kN).



Graph 1: BASE SHEAR

Table 4: Fundamental Time period (sec)

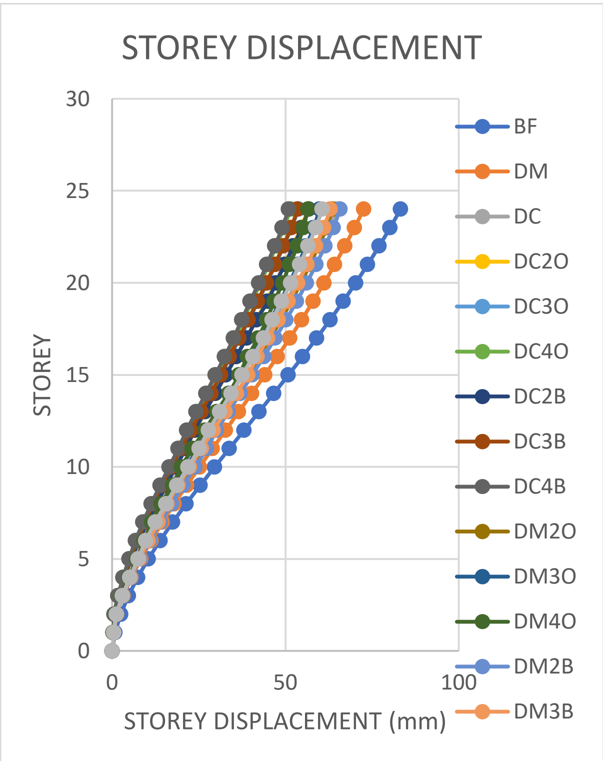
MODEL	Base Shear (kN)
BF	6232.10
DM	3866.22
DC	2505.20
DM2B	3742.01
DM3B	3612.65
DM4B	3496.74
DC2B	2354.58
DC3B	2228.09
DC4B	2121.96
DM2O	3697.40
DM3O	3513.58
DM4O	3407.61
DC2O	2353.16
DC3O	2230.20
DC4O	2130.98



Graph 2. Fundamental Time period (sec)

Models	Peak Displacement values (mm)
BF	83.20
DM	72.57
DC	65.13
DM2B	65.79
DM3B	62.95
DM4B	60.61
DC2B	56.69
DC3B	53.52
DC4B	50.89
DM2O	63.61
DM3O	59.88
DM4O	56.54
DC2O	56.69
DC3O	53.81
DC4O	51.54

Table 5. Peak Displacement values (mm)



Graph 3. Storey Displacement (mm)

Models	Peak Drift values x 10^{-6}
BF	1428
DM	1264
DC	1142
DM2B	1144
DM3B	1137
DM4B	1083
DC2B	1006
DC3B	966
DC4B	919
DM2O	1102
DM3O	1092
DM4O	1015
DC2O	990
DC3O	964
DC4O	915

Table 6. Peak Drift values

8. CONCLUSION

1.The time period calculated according to IS 1893-2016 (Part I) does not match with the time period by modal analysis for all models displaying the inefficiency of the code.

2. RC Bare Frame with Belt-truss and Dampers at middle (DMB) has lesser Time Period compared to Outriggers and Dampers at middle (DMO) due to higher stiffness.

3.Similarly, RC Bare Frame with Belt-truss and dampers at corner (DCB) has lesser Time Period compared to Outriggers and Dampers at corner (DCO) due to higher stiffness.

4. Combination of Belt-truss with Dampers at Corner (DCB) is having the least Time Period compared to DMO, DMB, DCO and bare frame due to higher stiffness.

5. RC Bare Frame with Belt-truss and Dampers at middle (BDMB) has lesser Displacement compared to Outriggers and Dampers at middle (BDMO) due to higher stiffness.

6. Similarly, RC Bare Frame with Belt-truss and dampers at corner (DCB) has lesser Displacement compared to Outrigger and Dampers at corner (DCO) due to higher stiffness.

7. Combination of Belt-truss with Dampers at Corner (DCB) is having the least Displacement compared to DMO, DMB, DCO and bare frame due to higher stiffness.

8. RC Bare Frame with Belt-truss and Dampers at middle (DMB) has lesser Storey Drift compared to Outriggers and Dampers at middle (DMO) due to higher stiffness.

9. RC Bare Frame with Belt-truss and dampers at corner (DCB) has lesser Storey Drift compared to Outrigger and Dampers at corner (DCO) due to higher stiffness.

10. Combination of Belt-truss with Dampers at Corner (DCB) has least Storey Drift compared to DMO, DMB, DCO and bare frame due to higher stiffness.

11. There is a sudden decrease in the storey drift at storeys where Outrigger and belt-truss are placed due to the rigidity offered by them.

12. RC Bare Frame with Belt-truss and Dampers at middle (DMB) has lesser Base Shear compared to Outriggers and Dampers at middle (DMO) due to higher stiffness.

13. RC Bare Frame with Belt-truss and dampers at corner (DCB) has lesser Base Shear compared to Outriggers and Dampers at corner (DCO) due to higher stiffness.

14. Combination of Belt-truss with Dampers at Corner (DCB) is having the least Base Shear compared to DMO, DMB, DCO and bare frame due to higher stiffness.

15. Outriggers and Belt-truss placed at H/4 is very effective compared to H/3 and H/4 locations

16. DC4B is turned out to be the most effective of all the models considered.

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