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LATERAL LOAD ANALYSIS OF OUTRIGGER AND BELT TRUSS SYSTEMS

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Abstract—In recent time Reinforced concrete framed structures have gained lots of attention especially in urban areas of metropolitan. Lots of research work is going on in the analysis and safe design of R.C high rise structural frames, due to scarcity of land or due to small FSI (floor space index) in the cities buildings are evolving vertically that is multi-storeyed or high rise buildings. Response of high rise buildings are quite different then multi-storeyed buildings because high rise building suffer lots of lateral drift or lateral displacement and their lateral stability is a great concern in seismic and wind design keeping in view the lateral stability of high rise building. Seven models of RC structural frames with different configuration in ETABS have been made; the main aim of the study is to find out which structural configuration is more stable against the lateral forces. Outriggers and belt trusses of different type and different materials at different locations have been in cooperated in the building models so as to improve the lateral stability.

Keywords— R.C structural frames, story drift, lateral displacement, outriggers, belt trusses.

I. INTRODUCTION

In today's world tall buildings are essential for human life, due to lack of space high-rise buildings became very famous in past century, pervious era design of buildings were restricted but now with the help of technology the designing of tall buildings become easy and less time consuming.

On the other hand when the high of the building increases the structure will become weak in both wind and seismic loads. To overcome this weakness against wind and seismic different systems such as core walls and bracings are invented

OUTRIGGERED FRAME SYSTEMS

Outriggers are structural elements, introduced to resist lateral loads outriggers connect from the core walls to the edge columns. To make outriggers more efficient they are made single story deep, outriggers are placed mechanical equipment floors to avoid blocking the usage of normal floors.

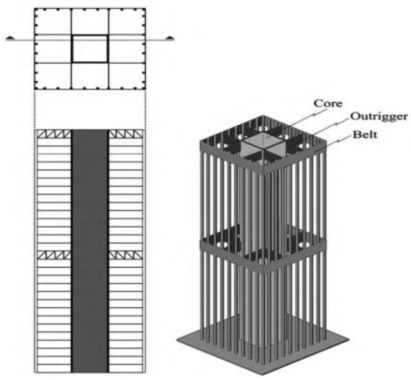


Fig.1: Outrigger & belt truss system

II. OBJECTIVES OF THE STUDY

- The most important purpose of the project is to evaluate the response of high rise structural R.c frames when subjected sever lateral force
- To understand the modelling of high rise building in ETABS with F.E.M modelling technique.

- To compute the reaction of the structure when a vertical stiffener in the form of middle shear barrier been worn in the construction.
- To perform linear stationary study (Equivalent static), static wind analysis, linear active study (Response spectrum analysis).
- To recognize the recital of building when outriggers and restraint truss worn in the building at different locations at different high.
- To realize the effect of unlike equipment such as concrete, structural steel when they have been use to build outriggers and belt truss.
- To know the performance of the construction by studying following parameters
    - Lateral displacement
    - Story drift
    - Base Shear

III. METHOD OF ANALYSIS

Four types of analysis have been performed on the building models namely:

1. Linear static analysis (Equivalent static method) – Seismic analysis
2. Static Wind analysis
3. Linear dynamic analysis (Response spectrum analysis) – Seismic analysis
4. Dynamic Wind Analysis- Gust Factor method

IV. TYPES OF MODELS

Model 1 –A model without Core wall and bracings
Model 2–This Model contains Concrete center wall and concrete outriggers Extending from center wall to the extreme boundaries of the structure [forward and backward outriggers]
Model 3 – Model with Concrete core wall and belt truss (concrete) throughout the story
Model 4 – Model with Concrete Core wall and box section Steel outriggers Extending from core wall to the extreme edges of the building [forward and backward outriggers]
Model 5 – Model with Concrete core wall and belt truss (box section Steel) throughout the story
Model 6 – Model with Steel wall and box section Steel outriggers
Model 7 – Model with Steel wall and belt truss (box section Steel) throughout the story

V. MODELLING

Model definition

Material Properties:

Young's modulus of (M40) concrete = 31622.78 Mpa, Young's modulus of (M50) concrete = 35355.34 Mpa
Density of R.cc = 25 KN/m^3, Poisson's ratio of concrete = 0.2, Modulus of elasticity of brickwork = 3500x103KN/m^2
Density of brick masonry = 20 KN/m^3, Poisson's ratio of masonry = 0.15, Assumed dead load intensities
Floor finishes = 1.5 KN/m^3, L.L = 3 KN/m^2

Member Properties:

Depth of RC slab = 125mm, Interior Column size = 500mmX1000mm (M50) ,Column size = 500mmX 750mm (M50)
Beam size = 400mmX600mm (M40) ,Thickness of brick masonry wall = 230mm ,Thickness of RC shear wall = 400mm (M40)
Outriggers:
Concrete bracings = 300mmX1000mm (M40), Steel bracings = ISA 150X150X14mm

Load Calculations:

Wall load R.L= 3.2 KN/m, Wall load on other floors=12.5 KN/m

Seismic Data:

Zone, Factor = 0.36 [Zone V]
I. Factor = 1.5
Response Reduction Factor = 5 (SMRF)
Soil type = Type II [M-soil]

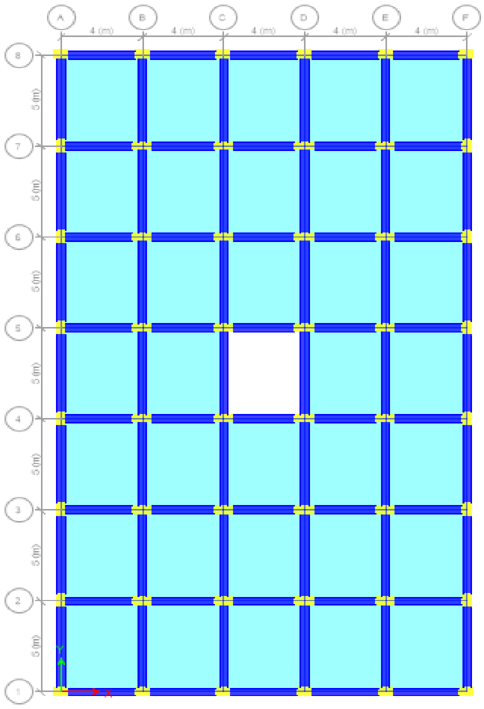


Fig.2: Plan layout

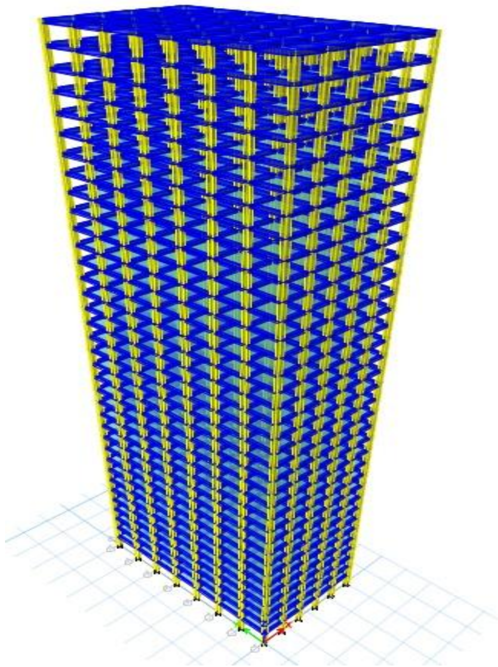


Fig. 1: 3D view of building (Model 1)

Fig.4: Sectional Elevation of building (Model 1)

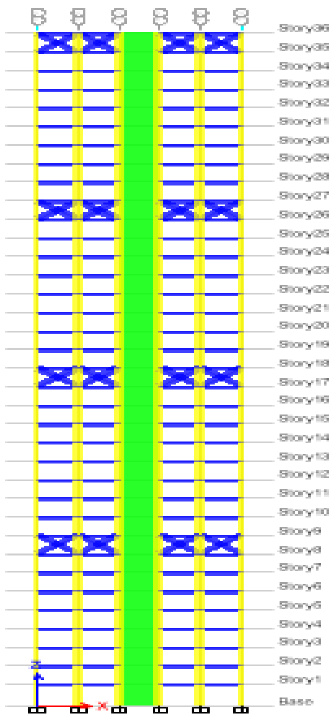


Fig.5: Sectional Elevation of building (Model 2)

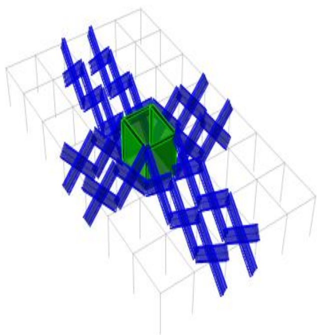


Fig.6: Perspective view Of a storey outrigger Location (Model 2)

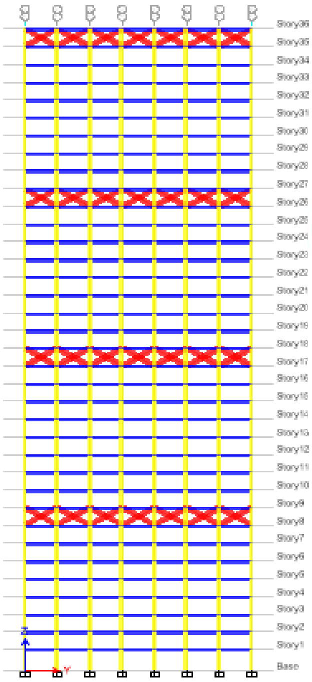


Fig.7: Sectional Elevation of building (Model 3)

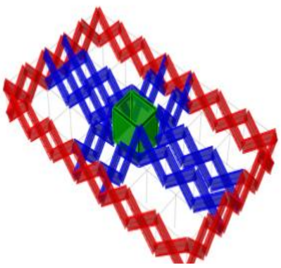


Fig.8: Perspective view of a storey showing outrigger and Belt truss (Model 3)

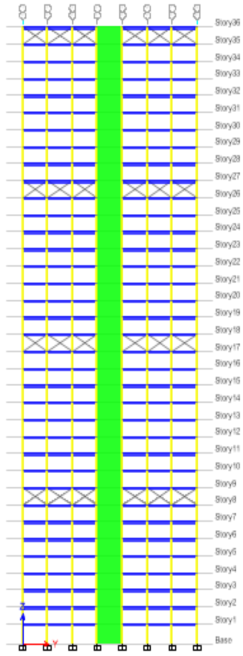


Fig.9: Sectional Elevation of building (Model 4)

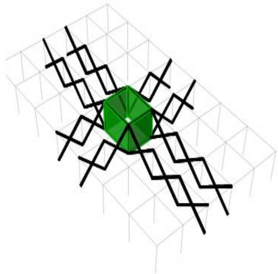


Fig.10: Perspective view of a storey showing outrigger (steel)-Model 4

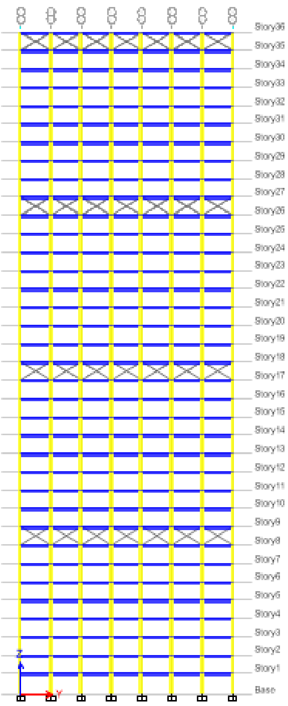


Fig.11: Sectional Elevation of building (Model 5)

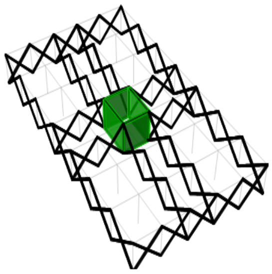


Fig.12: Perspective view of a storey showing outrigger & belt truss (steel) (Model 5)

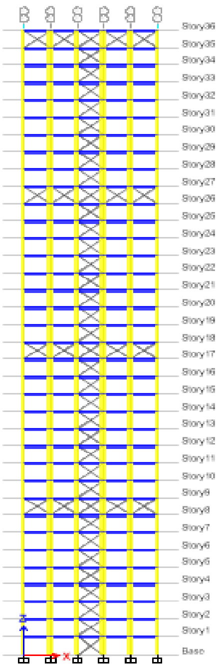


Fig.13: Sectional Elevation of building (Model 6)

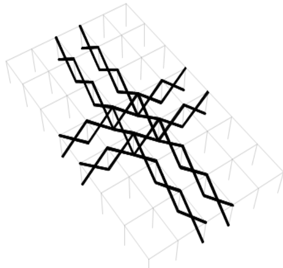
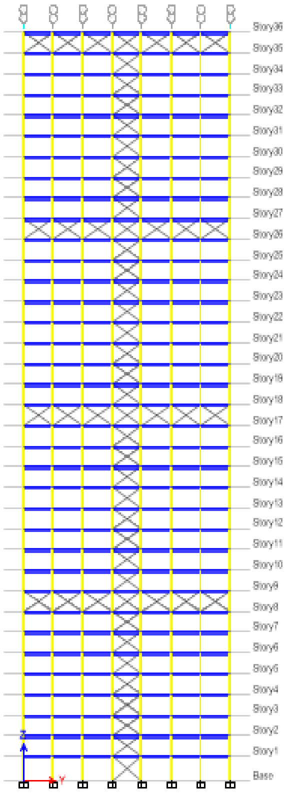


Fig.14: Perspective view of a storey showing outrigger (steel) and Brace core wall (Model 6)



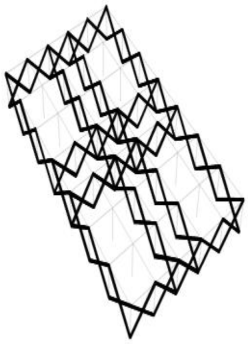


Fig.16: Perspective view of a storey showing outrigger and belt truss (steel) and Brace core wall (Model 6)

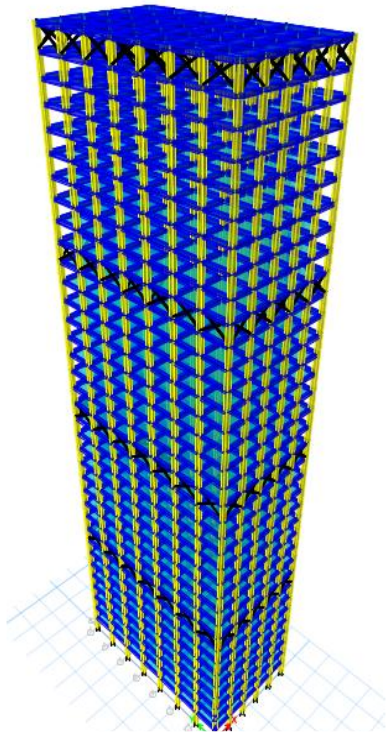


Fig.17: 3D view of building (Model 7)

Fig.15: Sectional Elevation of building (Model 7)

VI. RESULTS AND DISCUSSION

The results of base shear, lateral displacements, storey drifts, and natural period of vibration and overall performance for the different building models are presented and compared.

Lateral displacement

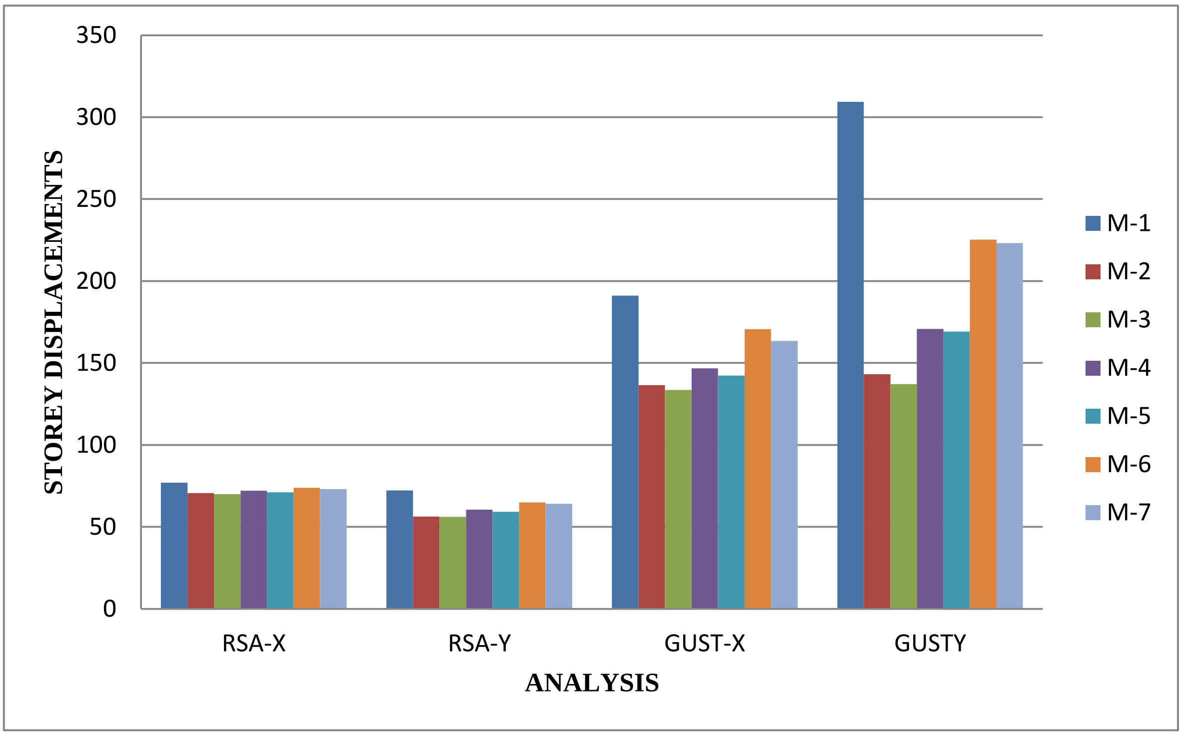


Chart 1: Comparison of maximum storey displacement for all Models

MODEL	Model description	Response Spectrum Analysis		Dynamic Wind Analysis	
		RSA-X	RSA-Y	GUST-X	GUST-Y
1	Bare Frame	76.993	72.304	191.137	309.28
2	Concrete Core Wall & Outrigger	70.624	56.336	136.529	143.13
3	Concrete Core Wall, Outrigger and Belt truss	69.944	56.098	133.58	137.147
4	Concrete Core Wall, Outrigger(steel)	72.012	60.49	146.678	170.836
5	Concrete Core Wall, Outrigger(steel) and Belt truss(steel)	71.071	59.189	142.335	169.157
6	Steel Core Wall, Outrigger(steel)	73.823	64.895	170.623	225.239
7	Steel Core Wall, Outrigger(steel) and Belt truss(steel)	73.067	64.079	163.526	223.078

Table 1: Maximum Displacement by Response Spectrum Analysis and Dynamic Wind

Storey Drift

The maximum storey drifts for various building models along longitudinal and transverse direction obtained from response spectrum and dynamic wind analysis from ETABS are shown in table below

MODEL	Model description	Response Spectrum Analysis		Dynamic Wind Analysis	
		RSA-X	RSA-Y	GUST-X	GUST-Y
1	Bare Frame	0.000856	0.000927	0.002079	0.004096
2	Concrete Core Wall & Outrigger	0.000842	0.000714	0.001528	0.001861
3	Concrete Core Wall, Outrigger and Belt truss	0.000847	0.000717	0.001517	0.001801
4	Concrete Core Wall, Outrigger(steel)	0.000837	0.000749	0.001635	0.002177
5	Concrete Core Wall, Outrigger(steel) and Belt truss(steel)	0.000837	0.000748	0.00161	0.002196
6	Steel Core Wall, Outrigger(steel)	0.000848	0.000844	0.001879	0.003025
7	Steel Core Wall, Outrigger(steel) and Belt truss(steel)	0.000856	0.000859	0.001833	0.003082

Table 2: Maximum Storey Drifts by Response Spectrum Analysis and Dynamic Wind

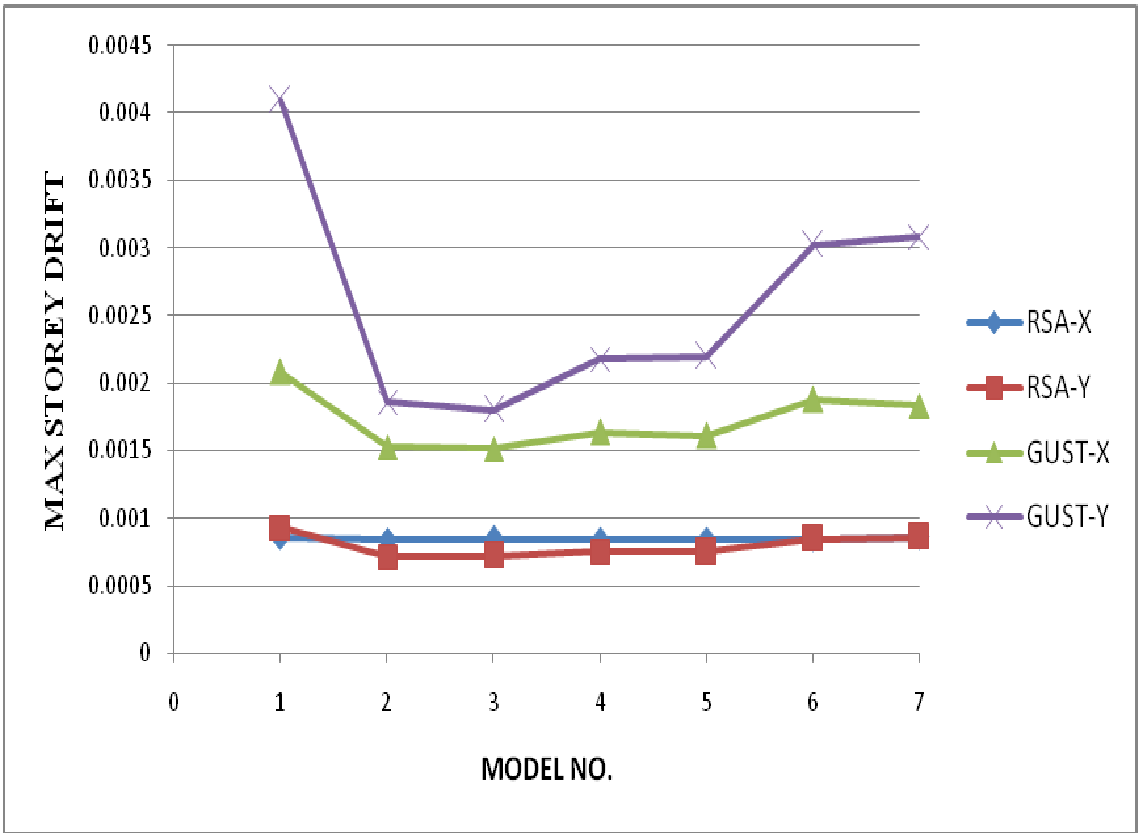


Chart 2: Comparison of Maximum Storey Drifts by Response Spectrum Analysis and Dynamic Wind Analysis

Base shear

MODEL	Model description	Response Spectrum Analysis		Dynamic Wind Analysis	
		RSA-X	RSA-Y	GUST-X	GUST-Y
1	Bare Frame	5457.222	5323.984	13620.29	23922.82
2	A Concrete Core Wall with concrete Outrigger only	7207.344	7964.343	13171.62	21020.6
3	Concrete Core Wall, Outrigger and Belt truss	7489.115	8240.381	13561.95	21106.1
4	Concrete Core Wall, Outirgger(steel)	6690.629	7175.112	13161.6	21106.1
5	Concrete Core Wall, Outrigger(steel) and Belt truss(steel)	6813.233	7358.032	13161.6	21981.88
6	Steel Core Wall, Outrigger(steel)	5920.561	6034.398	13612	22069.45
7	Steel Core Wall, Outrigger(steel) and Belt truss(steel)	6015.331	6115.835	13361.78	22419.76

Table 3: The above table shows base Shear by RSA and DSA

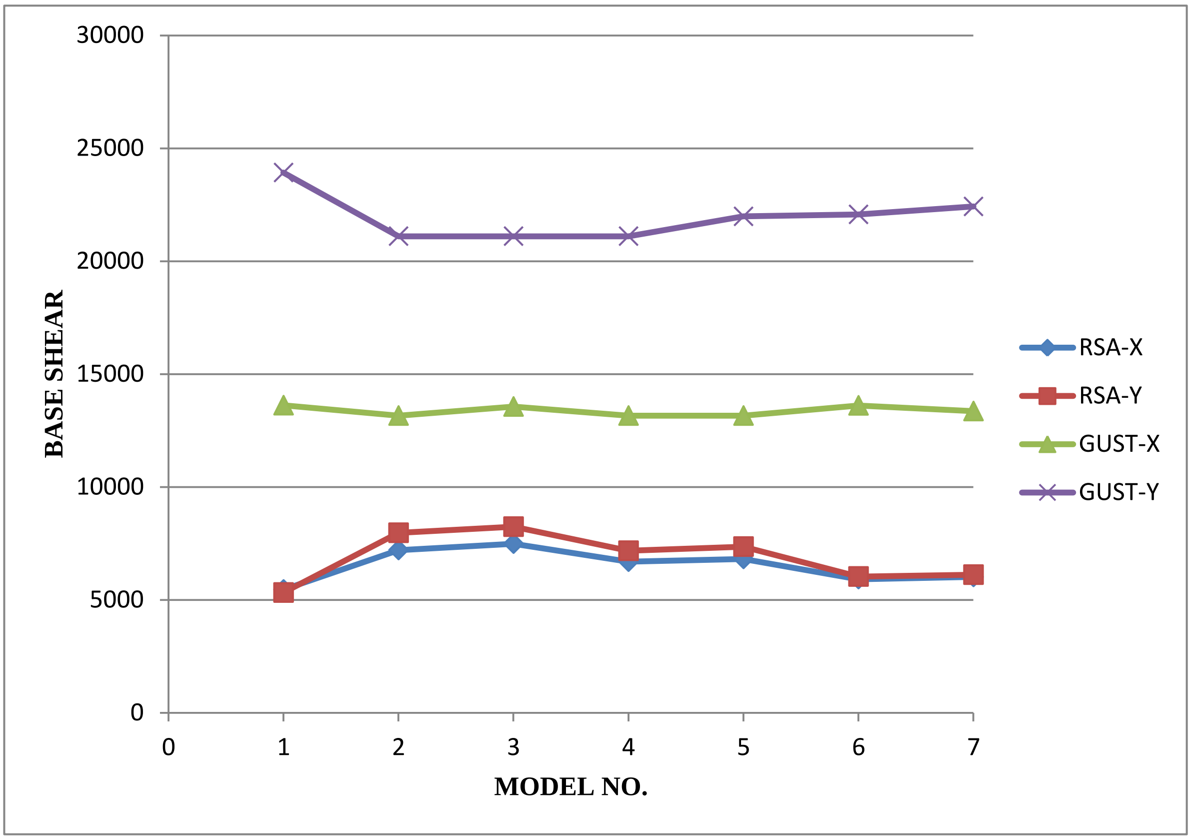


Chart 3: Comparison of Base shear by Response Spectrum Analysis and Dynamic Wind Analysis

Fundamental time period

Table 4: Fundamental period and participation for Model 1

Mode	Period sec	Participation in X (%)	Participation in Y (%)	RZ
1	2.953	0.7442	0	0
2	2.93	0	0.789	0
3	2.392	0	0	0.7939

Table 5: Fundamental period and participation for Model 2

Mode	Period sec	Participation in X (%)	Participation in Y (%)	RZ
1	2.619	0.7036	0	0
2	2.176	0	0.7397	0
3	2.002	0	0	0.8044

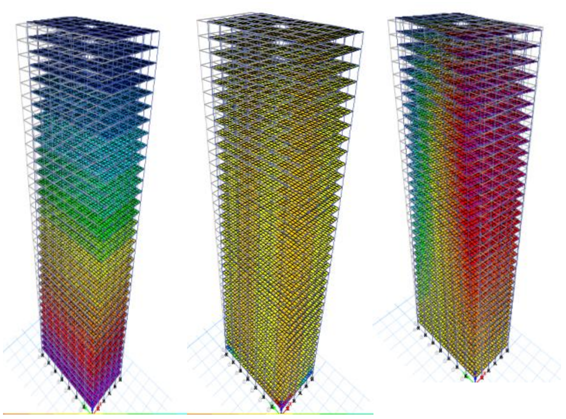


Fig.15: Mode 1, Mode 2, Mode 3 for Model 1

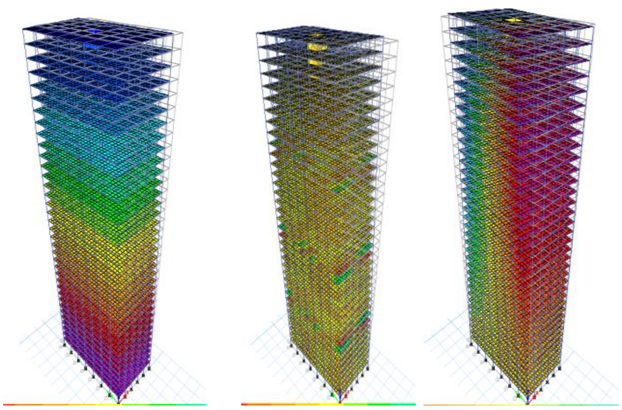


Fig.16: Mode 1, Mode 2, Mode 3 for Model 2

Table 6: Fundamental period and participation for Model 3

Mode	Period sec	Participation in X (%)	Participation in Y (%)	RZ
1	2.603	0.7019	0	0
2	2.171	0	0.7384	0
3	1.927	0	0	0.8167

Table 7: Fundamental period and participation for Model 4

Mode	Period sec	Participation in X (%)	Participation in Y (%)	RZ
1	2.68	0.7054	0	0
2	2.339	0	0.7344	0
3	1.994	0	0	0.8023

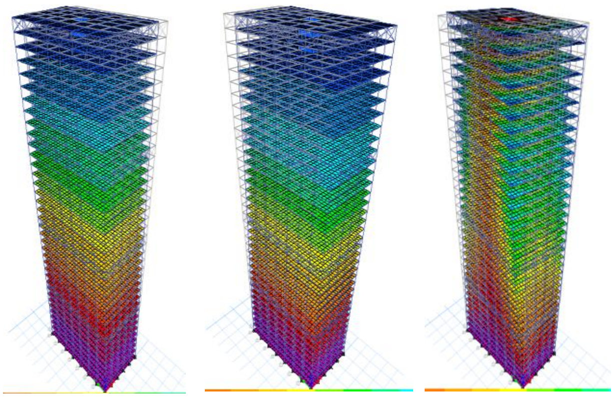


Fig.17: Mode 1, Mode 2, Mode 3 for Model 3

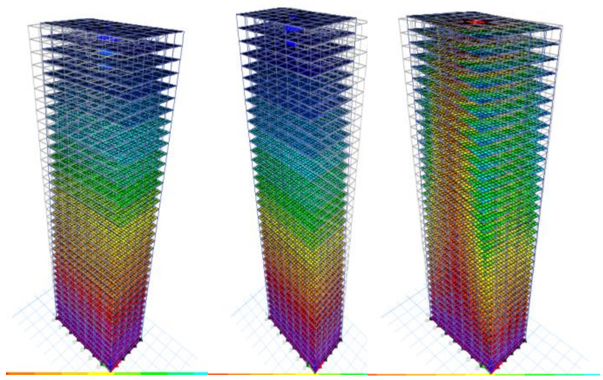


Fig.18: Mode 1, Mode 2, Mode 3 for Model 4

Table 8: Fundamental period and participation for Model 5

Mode	Period sec	Participation in X (%)	Participation in Y (%)	RZ
1	2.648	0.7021	0	0
2	2.292	0	0.7327	0
3	1.9	0	0	0.807

Table 9: Fundamental period and participation for Model 6

Mode	Period sec	Participation in X (%)	Participation in Y (%)	RZ
1	2.783	0.7357	0	0
2	2.599	0	0.7853	0
3	2.361	0	0	0.7951

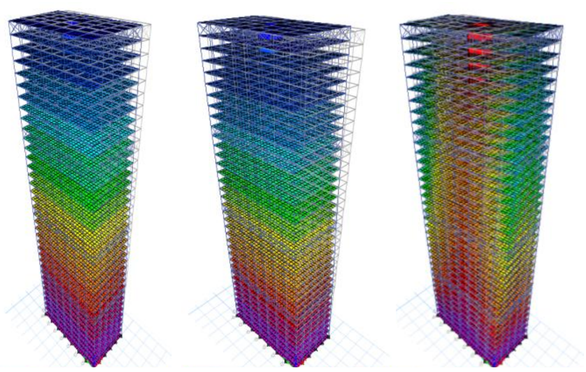


Fig.19: Mode 1, Mode 2, Mode 3 for Model 5

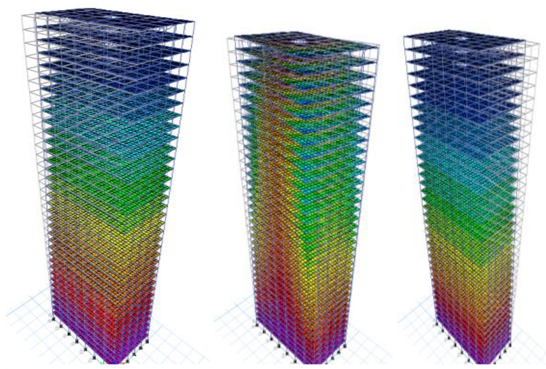


Fig.20: Mode 1, Mode 2, Mode 3 for Model 6

Table 10: Fundamental period and participation for Model 7

Mode	Period sec	Participation in X (%)	Participation in Y (%)	RZ
1	2.75	0.7369	0	0
2	2.569	0	0.7881	0
3	2.216	0	0	0.8079

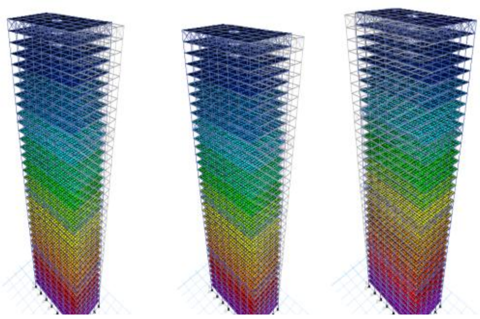


Fig.21: Mode 1, Mode 2, Mode 3 for Model 7

VII. CONCLUSIONS

1. The provision of outriggers and belt trusses in high rise buildings increases the stiffness and stability of the building when compared to the building without outriggers under the action of lateral loads (wind and earthquake loadings)
2. The Concrete Outrigger with belt truss Model shows minimum lateral displacement than the Steel Outrigger with belt truss Model.
3. The Storey drift is minimum at the Outrigger levels
4. Bare frame model is flexible among all the models therefore to make a conventional RC structural frames more effective to resist lateral forces in the form of seismic waves and wind forces, some lateral structural members has to be in cooperated in the building model in the form of shear walls, core walls, bracings.

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