DYNAMICPERFORMANCE ANALYSIS OF OUTRIGGER AND OUTRIGGER WITH BELT TRUSS SYSTEM IN COMPOSITE HIGH RISE BUILDING”

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Abstract - *In high rise building the outrigger is used as one of the structural system to effectively control the excessive drift due to lateral loads induced due to earthquake or wind, and to analyse the risk of the structural and non-structural damage and how it can be minimized. When the height of the structure increases, the building stiffness becomes more important and introduction of the outrigger beams between the shear walls and external columns is often used to provide sufficient lateral stiffness to the structure. The objective of study is to optimize outrigger and outrigger with belt truss system location and to assess the efficiency of each outrigger used in the structure. In 60–storey three dimensional model outrigger and outrigger with belt truss system are subjected to wind and earthquake load, analyzed and compared to find the lateral displacement reduction related to the outrigger and belt truss system location.*

Key Words: Outriggers, Lateral loads, Displacement, Base Shear, Lateral Stiffness,Belt truss system.

1.INTRODUCTION

Human race had always fascinated for height and throughout our history, we have constantly sought to reach for the stars, from the ancient pyramids to today’s modern skyscraper. Today, there has been a demonstrated competitiveness that exists in human race to proclaim to have the tallest structure in the world. In late 19th century the tall structures were emerged in the U.S.A. They constituted so-called “American Building Type,” meaning is that most important tall buildings were built in the U.S.A. However, now a day’s there is a worldwide architectural phenomenon in the development of tall buildings which has evolved rapidly in recent years.

As the population increases in the metropolitan cities the availability of land for shelter is diminishing. Hence to overcome these problems multistorey’s buildings are most prominent and efficient solution. In development of tall buildings we have to take an account of various aspects such as requirements, technology, and construction regularities and so on. For designer as the building height increases the challenges will also increases and self-weight of the building, live load acting, and earthquake loads and along with wind forces are significant factors that will affect the design.

For mutistoreys building we have to ensure safe working environment against the dynamic actions. An earthquake is an unexpected moment of the earth’s crust which originates below the ground surface. When an earthquake occurs the structures moves vertically and horizontally caused by the ground motion induced by earthquake.

A structure is to be designed to resist the lateral forces which occur to it. In order to achieve this lateral resisting system should be introduced to the structures such as moment resisting frames, infilled frames, shear walls, framed tubes, trussed tubes, super frames, tube in tube, bundle tubes, outriggers etc.

1.1 OUTRIGGER

The outrigger and belt truss system acts very important role to resist the lateral loads in the structure. In the structure the external columns are tied to the central core wall with stiffened outriggers and belt truss at one or different levels. This system is rigidly fixed to the core and simply connected to the exterior columns. When central core tries to bend, the belt trusses act as lever arms which directly transfer axial stresses into the perimeter columns, so that the columns act as struts to resist the lateral deflection of the core. Hence the core fully develops the horizontal shear and the belt trusses transfer the vertical shear from the core to the outrigger frame. Thus, the structure is made to act as a single unit similar to cantilever tube.

Outriggers are stiff elements connected to a structure core or to outer columns. Outriggers improve the stiffness against overturning by developing a tension-compression couple in perimeter columns when a central core tries to bend, generating restoring moment acting on the core at the outrigger level.

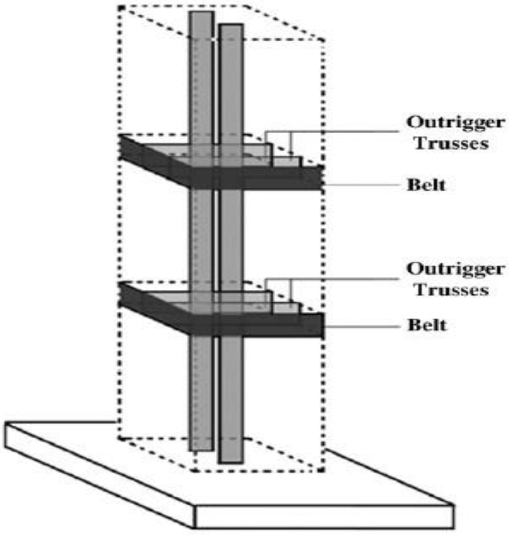


Fig- 1.1: Structure with Outriggers and Outrigger with Belt Truss

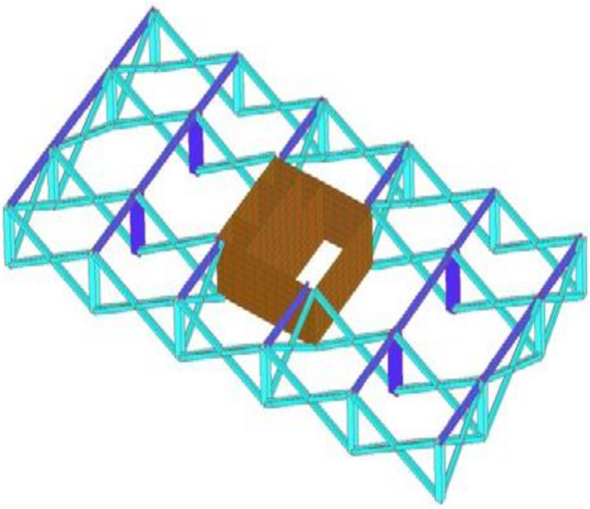


Fig- 1.2: 3D view of Outrigger and belt truss belt truss

1.2 TYPES OF OUTRIGGER TRUSS SYSTEM

Based on connectivity of core to exterior columns, the outrigger truss system may be divided in two ways.

1. CONVENTIONAL OUTRIGGER CONCEPT
2.VIRTUAL OUTRIGGER CONCEPT

1.2.1 CONVENTIONAL OUTRIGGER CONCEPT

The concept of the conventional outrigger is the outrigger trusses are directly connected to the shear walls or braced frames at the core of the structures. The columns are located outboard of the core. Normally the columns are located at the outer edges of the building.

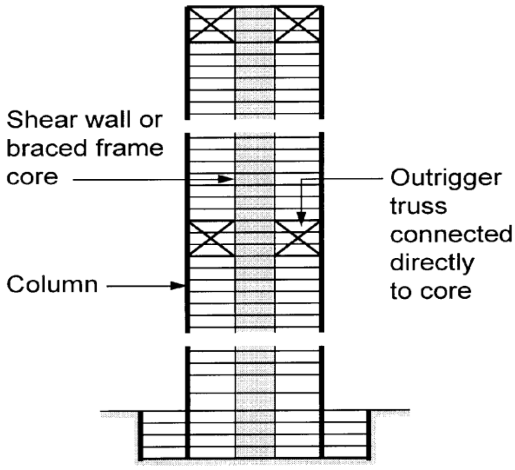


Fig-1.3: Tall building with conventional outriggers

1.2.3 BELT TRUSSES AS VIRTUAL OUTRIGGERS

The basic principle is the same as when belt trusses are used as virtual outriggers. Some of the moment in the core is transformed into a horizontal couple and transferred to the truss chords in the floors at the top and the bottom of the diaphragm and finally converted into vertical forces at the exterior columns.

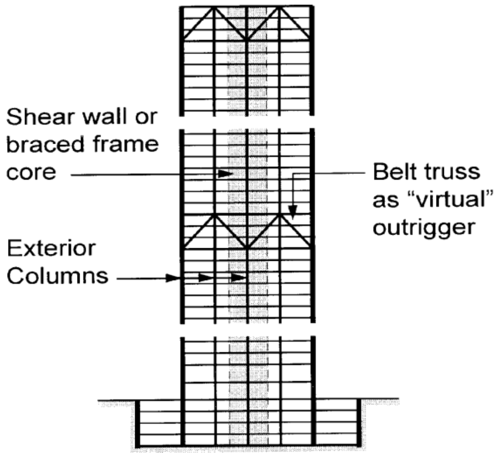


Fig-1.4: Structure with belt trusses as "virtual" outriggers

2. OBJECTIVE

Analysis of the 3D models of the 60 storey building located in zone V for hard soil has been performed and overall seismic evaluation of the structures were carried out using the performance parameters like Base shear, Displacement in each storey obtained from the dynamic analysis using the software ETABS 9.7.3

2.1 NEED FOR PRESENT STUDY

- Several studies were carried out on structure by taking shear wall, bracings systems as a lateral load resisting for dynamic analysis.
- In several studies outrigger system were only used as a lateral resisting system.
- Based on literature review there is a scope to compare the outrigger struts with outrigger struts and belt trusses.

2.1 METHODOLOGY

In the present study, 60 story building was considered with the plan area of 42m x 42m in both x and y direction of 7 no. of bays. The typical floor height is considered as 3m throughout the structure and total height of the structure is 180m. The beams, columns, shear walls were assumed as concrete structure and outrigger as steel structure.

2.2 MODEL DETAILS

Case 1: RC bare frame having shear wall in hard and medium soil for zone IV and V

Case 2: RC bare frame having shear wall with outrigger struts and belt trusses in hard soil at zone V (OB-H-V)

- Outrigger struts and belt trusses at multi storeys (OB-H-V) in 15-30-45
- Outrigger struts and belt trusses at multi storeys (OB-H-V) in 30-45-60
- Outrigger struts and belt trusses at double storeys (OB-H-V) in 15-30
- Outrigger struts and belt trusses at double storeys (OB-H-V) in 15-45
- Outrigger struts and belt trusses at double storeys (OB-H-V) in 30-45
- Outrigger struts and belt trusses at double storeys (OB-H-V) in 30-60
- Outrigger struts and belt trusses at double storeys (OB-H-V) in 45-60
- Outrigger struts and belt trusses at single storey (OB-H-V) in 15
- Outrigger struts and belt trusses at single storey (OB-H-V) in 30
- Outrigger struts and belt trusses at single storey (OB-H-V) in 45
- Outrigger struts and belt trusses at single storey (OB-H-V) in 60

Case 3: RC bare frame having shear wall with outrigger struts in hard soil at zone V (O-H-V)

- Outrigger struts at multi storeys (O-H-V) in 15-30-45
- Outrigger struts at multi storeys (O-H-V) in 30-45-60
- Outrigger struts at double storeys (O-H-V) in 15-30
- Outrigger struts at double storeys (O-H-V) in 15-45
- Outrigger struts at double storeys (O-H-V) in 30-45
- Outrigger struts at double storeys (O-H-V) in 30-60
- Outrigger struts at double storeys (O-H-V) in 45-60
- Outrigger struts at single storey (O-H-V) in 15
- Outrigger struts at single storey (O-H-V) in 30
- Outrigger struts at single storey (O-H-V) in 45
- Outrigger struts at single storey (O-H-V) in 60

2.3 MODELS PLAN AND ELEVATION:

Case 1: Section of RC bare frame having shear wall in hard and medium soil for zone IV and V

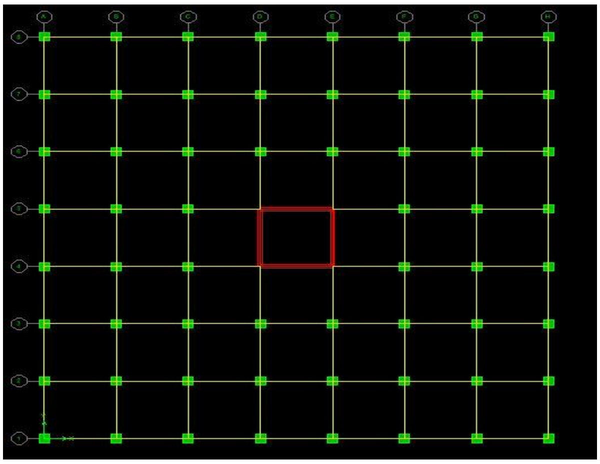


Fig 2.1: Typical plan view for model of bare frame of hard soil for zone V

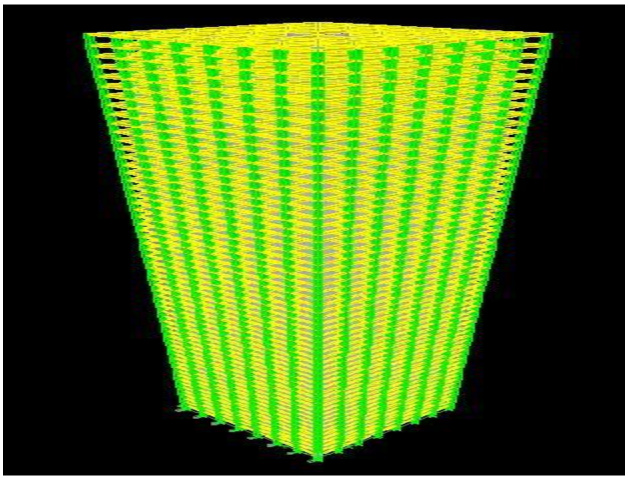


Fig-2.2: 3D view for model of bare frame of hard soil for zone V

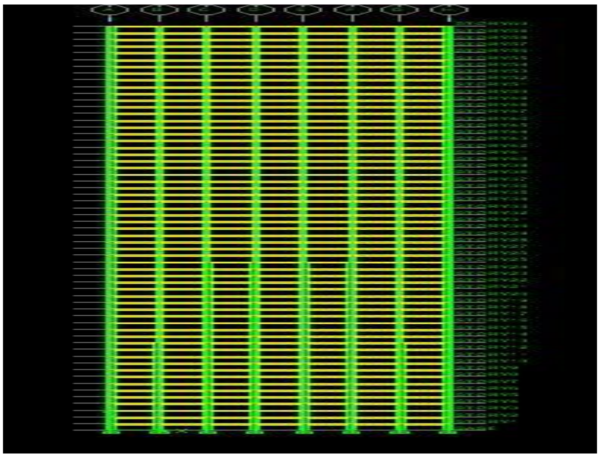


Fig- 2.3: Elevation of bare frame of hard soil for zone V at section 1-1

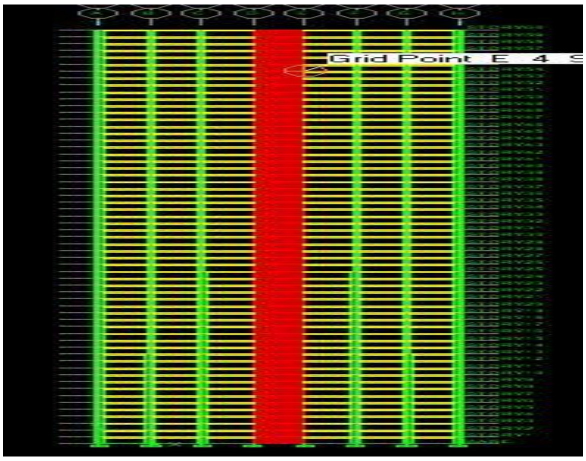


Fig -2.4: Elevation of bare frame of hard soil for zone V at section 4-4

Case 2: Section of RC bare frame having shear wall with outrigger struts and belt trusses in hard soil at zone V (OB-H-V)

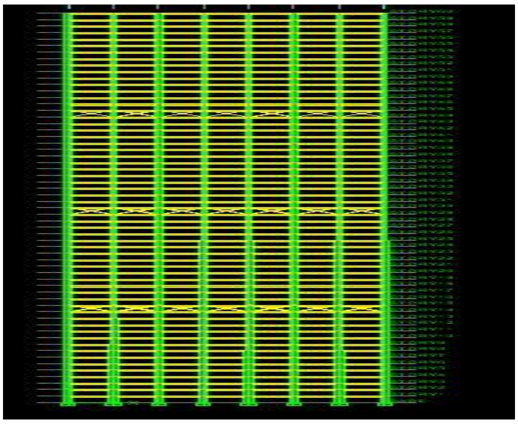


Fig- 2.5: Elevation of multi OB-H-V on 15-30-45 stories at section 1-1

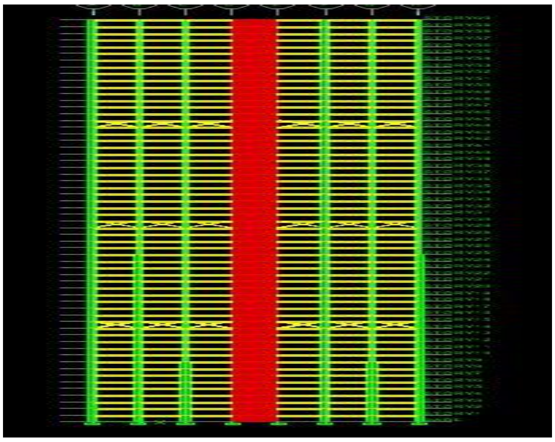


Fig -2.6: Elevation of multi OB-H-V on 15-30-45 stories at section 4-4

Case 3: Section of RC bare frame having shear wall with medium soil at zone V (O-H-V)

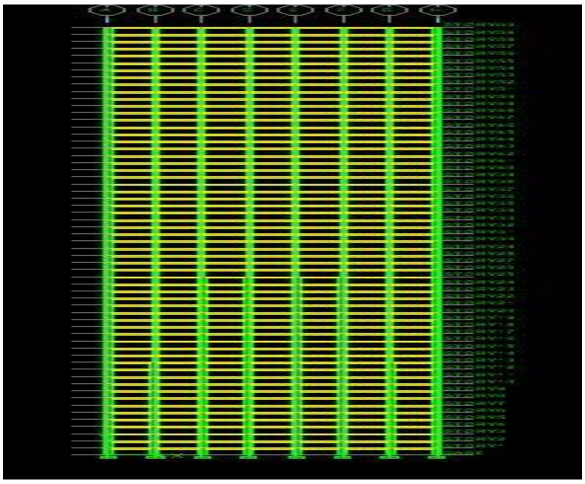


Fig- 2.7: Elevation of multi O-H-V on 30-45-60 stories at section 1-1

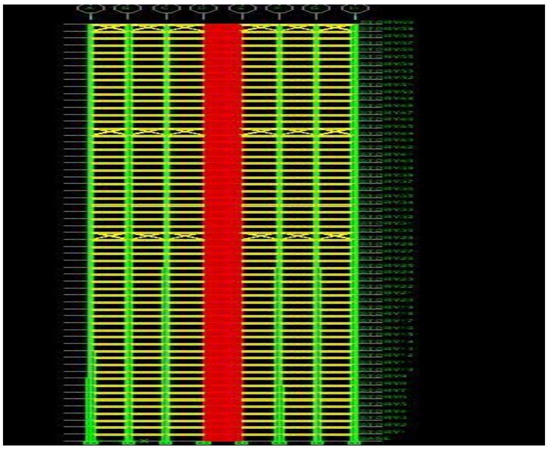


Fig -2.8: Elevation of multi O-H-V on 30-45-60 stories at section 1-1

3. RESULTS AND DISCUSSIONS:

This chapter presents the results of seismic analysis carried out on a 60th storey bare frame in which outriggers and outrigger with belt truss system were introduced as a lateral load resisting systems. The results of base shear and displacement are discussed in detail and presented with the reference of relevant tables and charts.

3.1 ANALYSIS RESULTS

Table-3.1: Preliminary data.

Plan	42m x 42m
Column to column spacing in x & y direction	6m
Support condition	Fixed
Column sizes	
1-8 floors	1150mm x 1150mm
9 floor	1100mm x 1100mm
10-13 floor	1000mm x 1000mm
14-25 floor	950mm x 950mm
26-60 floor	850mm x 850mm
Beam sizes	300mm x 700mm
Slab thickness	150mm
Shear wall	350mm
Outrigger sizes	250 x 250mm
Grade of concrete	M50
Grade of steel	Fe 415

3.1 DISPLACEMENT RESULTS

Table 3.2: Single O-H-V Displacement in mm

DISPLACEMENT IN mm				
O-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15	168	112	71	71
30	167	112	72	72
45	170	114	74	74
60	176	117	76	73
Bare frame	177	117	77	77

Table 3.3: Double O-H-V Displacement in mm

DISPLACEMENT IN mm				
O-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15-30	159	106	68	68
15-45	161	104	68	68
30-45	161	107	70	70
30-60	166	111	72	72
45-60	170	113	74	74

Table 3.4: Multi O-H-V Displacement in mm

DISPLACEMENT IN mm				
O-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15-30-45	152	102	66	66
30-45-60	161	107	70	70

Table 3.5: Single OB-H-V Displacement in mm

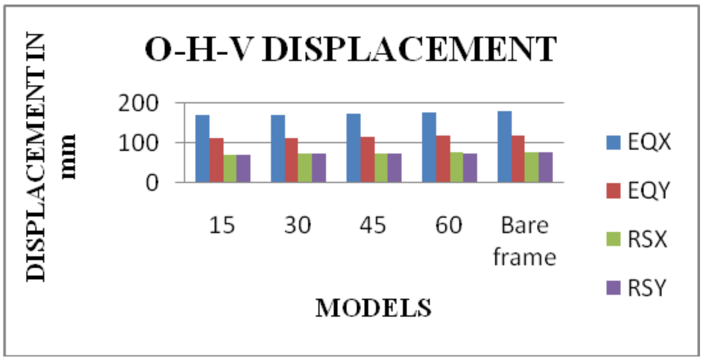
DISPLACEMENT IN mm				
OB-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15	166	111	70	70
30	166	11	72	72
45	169	113	73	73
60	176	118	76	76
Bare frame	177	118	76	76

Table 3.6: Double OB-H-V Displacement in mm

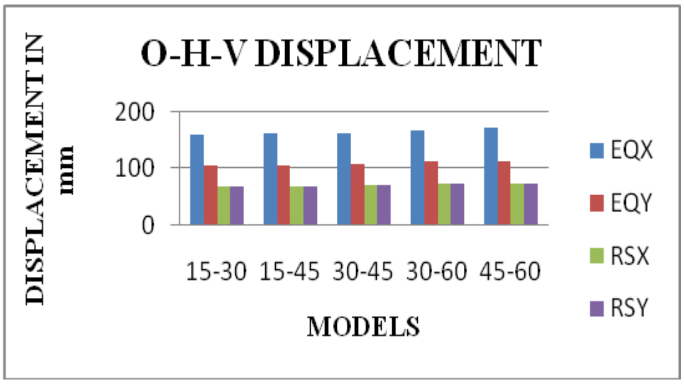
DISPLACEMENT IN mm				
OB-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15-30	155	103	66	66
15-45	158	102	68	68
30-45	158	106	69	69
30-60	165	110	72	72
45-60	169	113	73	73

Table 3.7: Multi OB-H-V Displacement in mm

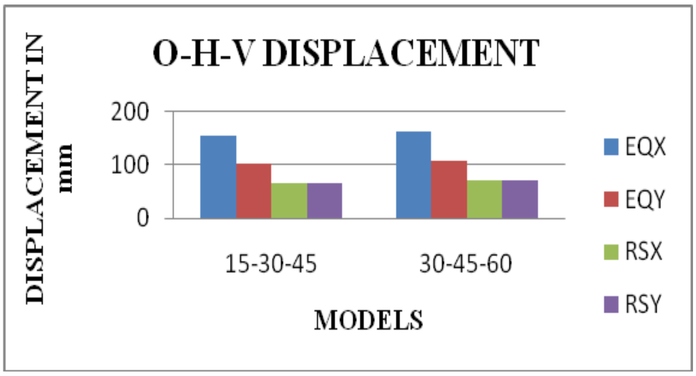
DISPLACEMENT IN mm				
OB-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15-30-45	148	98	64	64
30-45-60	156	105	69	59



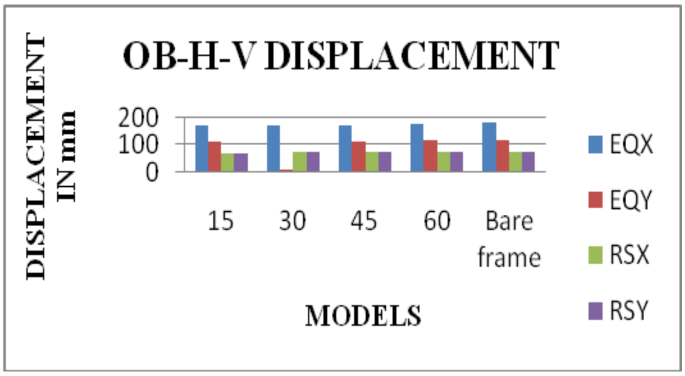
Graph 3.1: Single O-H-V Displacement in mm



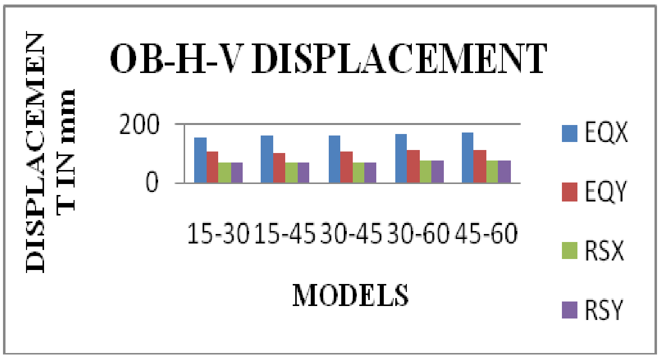
Graph 3.2: Double O-H-V Displacement in mm



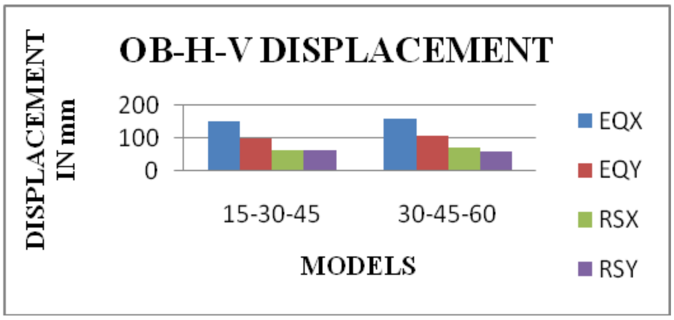
Graph 3.3: Multi O-H-V Displacement in mm



Graph 3.4: Single OB-H-V Displacement in mm



Graph 3.5: Double OB-H-V Displacement in mm



Graph 3.6: Multi OB-H-V Displacement in mm

DISCUSSION - DISPLACEMENT

- maximum displacement of the structure is reduced by the introduction of outrigger
- Providing the outrigger and outrigger with belt truss to the structure the stiffness of the structure will increases resulting the reduction of displacement compare to the bare frame.
- Providing a outrigger and outrigger with belt truss system at 15th storey will decrease the displacement of the structure and hence it is effective in resisting the lateral force compare to the other stories as observed in above graph
- In double and multi outrigger and outrigger with belt truss system at 15-30, 15-30-45 storey the displacement will be minimum compare to the single outrigger and outrigger with belt truss system, it is observed in the graph
- For single, double, multi storeys the provision of outrigger with belt truss system at 15, 15-30, 15-30-45 storeys will decrease the displacement of the structure.
- It was found that a gap of 15 storeys in introducing outrigger and outrigger with belt truss system worked out effective in reducing the displacement.

3.2 Base Shear results

Table 3.6: Single O-H-V Base shear in kN

Base shear in kN				
O-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15	16835	11162	9832	9832
30	16845	11223	9745	9745
45	16835	11194	9789	9789
60	16789	11192	9747	9742
Bare frame	16813	11209	9748	9748

Table 3.7: Double O-H-V Base shear in kN

Base shear in kN				
O-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15-30	16857	11238	9851	9851
15-45	16816	11241	9884	9884
30-45	16855	11236	9816	9816
30-60	16856	11207	9752	9752
45-60	16856	11207	9820	9820

Table 3.8: Multi O-H-IV Base shear in kN

Base shear in kN				
O-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15-30-45	16786	11221	9320	9920
30-45-60	16831	11221	9847	9847

Table 3.9: Single OB-H-V Base shear in kN

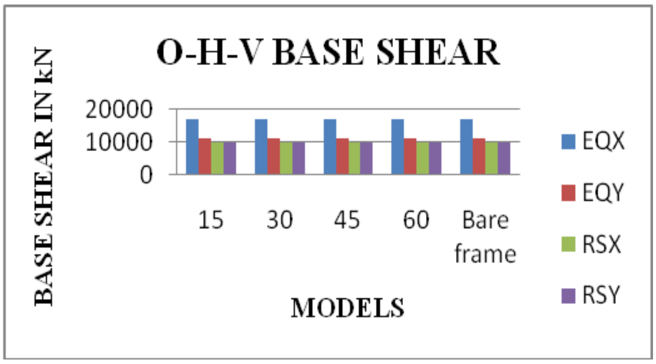
Base shear in kN				
OB-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15	16840	11148	9880	9880
30	16859	11209	9767	9767
45	16860	11239	9814	9814
60	16900	11239	9867	9761
Bare frame	16920	11178	9711	9711

Table 3.10: Double OB-H-V Base shear in kN

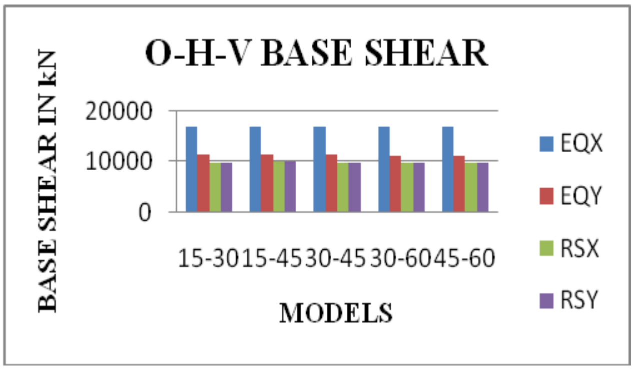
Base shear in kN				
OB-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15-30	16906	11240	9909	9909
15-45	16911	11213	9985	9973
30-45	16812	11269	9859	9859
30-60	16814	11240	9815	9815
45-60	16906	11270	9658	9858

Table 3.11: Multi OB-H-V Base shear in kN

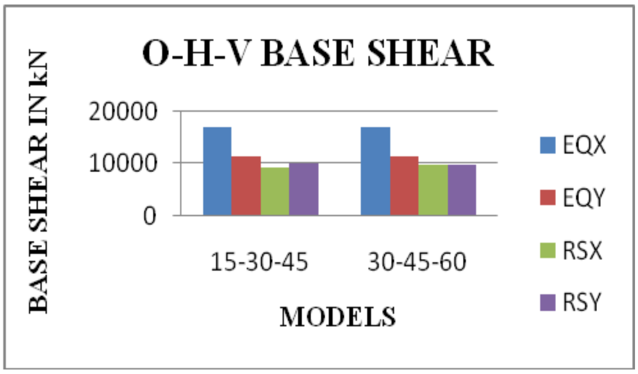
Base shear in kN				
OB-H-V				
Outrigger placed at storey level	EQX	EQY	RSX	RSY
15-30-45	16952	11270	9997	9997
30-45-60	16966	11301	9904	9904



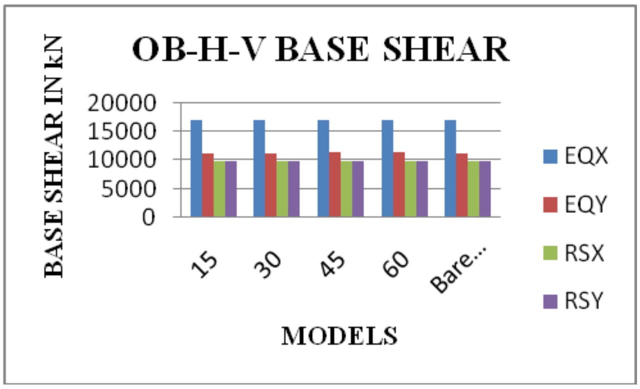
Graph 3.7: Single O-H-V Base shear in kN



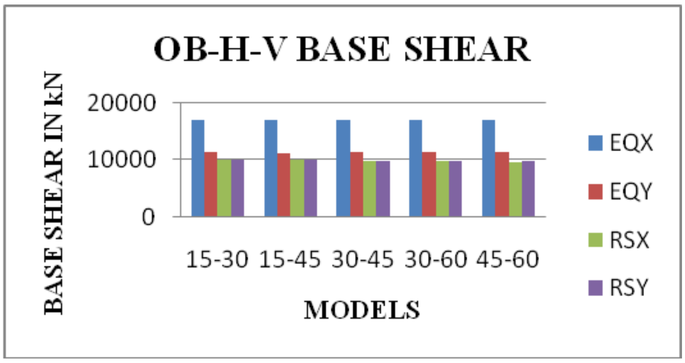
Graph 3.8: Double O-H-V Base shear in kN



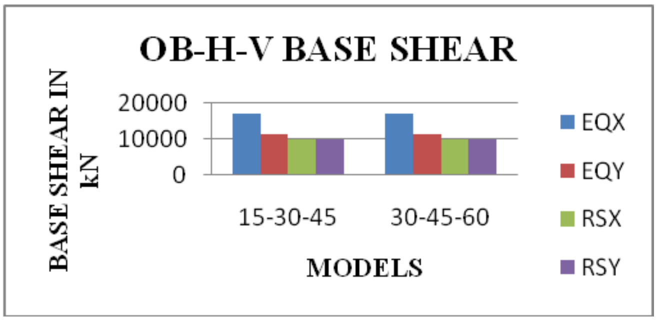
Graph 3.9: Multi O-H-V Base shear in kN



Graph 4.0: Single OB-H-V Base shear in kN



Graph 4.1: Double OB-H-V Base shear in kN



Graph 3.9: Multi O-H-V Base shear in kN

Discussion – Base shear

- By analyzing the above graph it is observed that by introduction of outrigger system there will be an increase in base shear.
- The base shear is increased when outrigger is provided it occurs due to increase in stiffness and mass.
- The base shear will be less for the outrigger system compare to the outrigger with belt truss system

4. CONCLUSIONS

As per the study made the following conclusion have been arrived at

- The introduction of outrigger and outrigger with belt truss there is a significant contribution to the stiffness of the structure.
- For single, double, multi storeys the provision of and outrigger with belt truss system at 15, 15-30, 15-30-45 storeys will increase the lateral stiffness of the structure and resulting the reduction of natural time period.
- The base shear is increased when outrigger is provided and base shear will be less for the outrigger system when compared to the outrigger with belt truss system.
- Providing a outrigger and outrigger with belt truss system at 15, 15-30, 15-30-45 storey will decrease the displacement of the structure and hence it is effective in resisting the lateral force compare to the other stories.

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