COMPARATIVE STUDY BETWEEN OUTRIGGER STRUCTURAL SYSTEM VS. SHEAR WALL STRUCTURAL SYSTEM IN TALL BUILDINGS

[1]Abdul Raheem, [2] Chitturi Sravanti,
[1]M.Tech Student, [2]Assistant Professor
Department of Civil EngineeringMahatma Gandhi Institute of Technology, Gandipet, Hyderabad – 500 075

Abstract: High-rise buildings are very vulnerable to earthquake and wind loads regularly. These structures must satisfy three basic requirements which are stability, strength, and serviceability. Hence to make high-rise buildings safe against lateral loads, different types of structural systems are used such as Moment resisting frames with shear walls, outrigger system, Frame tube system, Tube in tube system, etc.

My project is on comparative study between outrigger structural system and shear wall structural system for resisting lateral loads in Tall Buildings. In which I considered two structures of 25 storeys and 30 Storey with outrigger structural system and two structures of 25 storeys and 30 Storey with shear wall structural system. In these systems, I am going to adopt analysis methods such as Response spectrum analysis according to the 4 seismic zones (Zone 2, 3, 4, and 5).In which different parameters are considered such as Storey drift, base shears, storey joint displacement, time period. Which is analyzed in Etabs software.

I. INTRODUCTION

1.0 General

In old days people traveled thousands of kilometers in search of food & safety wherein modern days people still migrate from one place to another place for a better lifestyle and better job opportunities as we know big cities provide a great deal to human life so people are attracted towards the big cities for a better lifestyle and better job opportunities so these are the major issue to increase the population in big cities around ten times and supporting a large amount of population in a limited area which challenges the human society and the environment

By considering the challenge in past years different types of land utilization techniques are developed .one of land utilization technique is the tall structure in the current period it can save a lot of land area in a horizontal direction when compared to the elevation which as no limit in a vertical direction but with the great advantage tall structure it has great Challenges are faced by engineering to make the structure in reality.

1.1 Tall Structure

According to the design consideration there is no particular definition for tall structure and there is no general consideration in terms of maximum height or maximum no of stories to define a tall structure A tall building or high rise building is usually defined as high rise when it's proportion is enough to provide the appearance of tall building .in 19th century construction of tall structure is started because of the possible of new invention such as safe elevator for transport of building material at higher levels and telephone to communicate at higher level Tall building are generally constructed for office use at the beginning of 20th century today in almost all major cities tall structure are constructed for either for residential or commercial use in some cities tall structure are accepted as symbol for inevitable feature of urban development in earlier day building which are built with heavy masonry walls which is be a limited to certain heights by its great amount self-weight but now a days it's possible to construct a tall structure by considering the various design and construction rules . The definition of a tall building is quite subjective. Even different design approaches exist for tall buildings:

A) Selection of the appropriate structural system;

B) Geometric proportioning of the building;

C) Integrity of structural system;

D) Considering the wind and earthquake effects

E) Other special considerations related to tall buildings

Design of tall structure as changed over past years due to increase of computational power and advance software to analyze the tall structure from this procedure model produce a large number of analysis results from which we can overlook the possible errors and resolve them. The engineer should have the lack of knowledge in the structural behavior of the tall structure

1.2 Structural System

Structural system act like mechanism which provides strength and stability to the tall structure during which we majorly provide braces, shear wall, tubes, etc. With different material like concrete, steel. The majorly structural system is adopted to withstand the gravitational loads and lateral loads, therefore, there is a requirement of having a good lateral load resisting system for maintaining the lateral stability of the building based on the height and other arrangements of the building, for which the foremost suitable structural system is chosen one or more structural system can be utilized in one tall building by considering the stability of the lateral load resisting system

1.2.1 Shear Wall Structures

A shear wall is a reinforced concrete wall that can resist the shear forces and provide the stability to the structure .shear forces can also be resisted by steel braced frames but compared to reinforced concrete shear walls it is more expensive. A tall structure majorly fails by shear in two parts in a different direction for instance when a paper tears in a different direction. Shear walls are majorly used for tall structures in areas of high wind and seismic forces. When lateral force tends to act on the structure it produces compression in the one end and tension in the other end of the structure. If the forces are acting in opposite directions then the couple is revised .so a shear wall should be provided in both directions to capable forces in both directions. The position of the shear wall depends upon the forces in a different direction it may be positioned as the perimeter of the building, corners of the structure, and it is more effective when we placed at the center of the structure as core which passes through each floor and it controlled the overturning moment of the structure. Majorly shear walls are provided as the perimeter of the staircase or lift. Material is used for the construction of shear walls such as reinforced concrete and masonry.

The Shear Wall sections are classified as

(a) Box Section
(b) L – Section
(c) U – Section
(d) W – Section
(e) H – Section
(f) T – Section

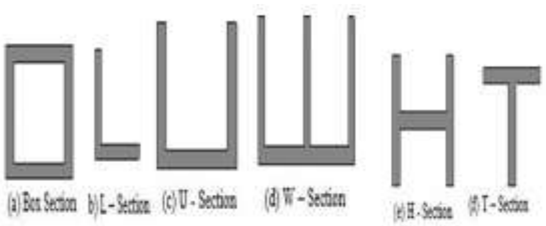


Fig 1: Shear Wall Section and Their Types

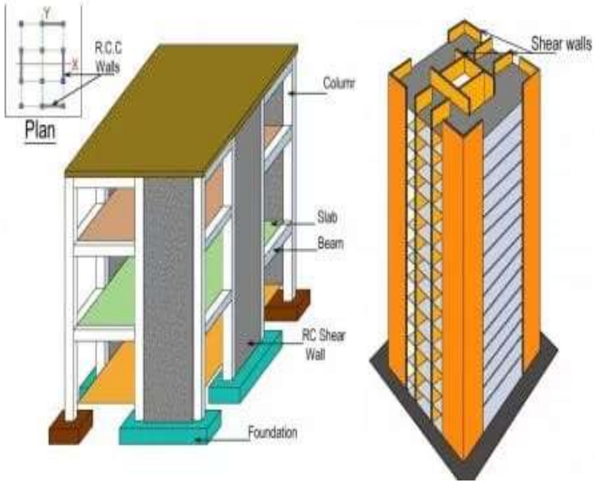


Fig 2: Structure with Shear Wall

1.2.2 Outrigger Structural System

The outrigger structural system consists of a central core, outrigger, and mega column. Which provides structural stability to the structure. The central core majorly consists of the reinforced concrete shear wall, braced frames. Outrigger structural system acts like a sailing ship to resist the wind forces .as shown in fig 01. Shear wall is like the mast of the ship, outrigger-like spreaders and exterior columns act like stays. When the effect lateral forces act on the central core then it acts like a pure cantilever then to reduce the forces from the central core. Forces are transferred through the outrigger to the mega column and the foundation when the structure is loaded laterally then vertical plane rotation is resisted by the outrigger through compression in leeward columns and tension in windward columns so it will provide the lateral stiffness and lateral deflection to the structure Types of outrigger structural system

A) steel outrigger

B) concrete outrigger

C) hybrid outrigger

D) damped outrigger

Fig3: Outrigger Ship

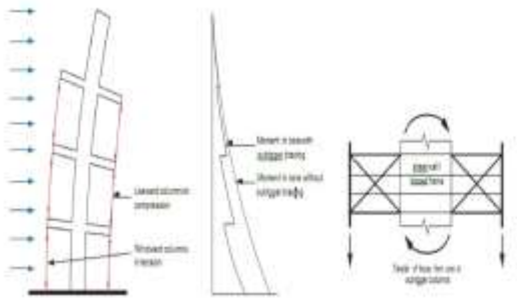


Fig4: Outrigger Behaviors

1.3 Methodology

This study focuses on understanding the seismic behavior of two different structural systems they are the outrigger structural system and the other one is shear wall structural system. In this project there are four tall structures 1) outrigger structural system with 25 floors 2) shear wall structural system with 25 floors 3) outrigger structural system with 30 floors 4) shear wall structural system with 30 floors. All the four seismic zones are considered for all four structures to analyze the models using equivalent static methods, response spectrum methods in etabs software. A total of 16 models are analyzed in this project

1.4 Objectives

The objective of this project is

- To understand the seismic behaviour of the different structural system
- To compare the models with a displacement of stories and storey drift ratio
- To compare the models with base shear and modes shapes
- To understand the seismic behaviour through irregularity in height
- To understand the seismic behaviour of the structures through different zones

II. LITERATURE REVIEW

pankajSharma,gurpreetsingh(2018), "dynamic analysis of outrigger systems in high rise building against lateral loading", This paper deals with resisting the lateral loads in high rise structures and an outrigger structural system is used which is carried for the 60 storey building with an overall height of 180m.plan dimensions are 38 x38 m with five bays in both directions, m30 grade concrete is used and the size of the column was taken as 0.8 x 0.8 m and the size of the beam 0.5 x 0.8 m, slab thickness was kept as 0.2 m. Analysis is carried out in all shapes of outrigger are used such as x, v, inverted v, shear wall and steel outrigger but it gives the better the results in concrete shear wall outrigger .considered design loads are such as dead load on floor slab is 1 kN/m2 and masonry load was also considered, live load is 3 kN/m2, wind load is calculated with wind speed 50 m/s as per is 875 part 3 and earthquake load was calculated for seismic zone v as per is 1893 part 01 and all the analysis was done in etabs software .and the results are max storey displacement is shear wall outriggers the displacement decreases by 87.34 mm and max storey drift 26.14% shear wall outrigger with shear band

Jaimin dodiya, mayankdevani, akashdobariya, mehulbhuva, kamalsinhpadhiar (2018), "analysis of multistory building with the shear wall using Etabs software", The principal objective of this project is to analyze the g +20floors structure to determine the displacement, base shear, which is carried out by using etabs software. In the project different types of analysis such as equivalent static method, response spectrum method. Geometrical description of the structure is classified as the height of the structure is 60m height with each floor of 3m height, column size is 900x600 mm and beam size is 400 x 600 mm, m25 grade of concrete is adopted, fe-415 steel, seismic zone iii is considered with soil type ii, importance factor 1, response reduction factor 5. In this structure 3 models are adopted in which shear wall are provided in a different position 1) "I" shaped shear wall in building 2) shear wall at corners in the building 3) shear wall in opposite direction in the building. Different loads are considered such as dead load 3.75kn/m2, live load 2kN/m2, floor finish 1.5kN m2 an analysis is carried out in etabs software by using different types of load combinations. Analysis results such as max displacement in corner shear wall building are 101.29 mm in 20 story, displacement in opposite direction shear wall building is 17.706 mm in 20 story, displacement in "i" section building is 30.936 mm in 20 storey building. Providing the shear wall in opposite direction give the better and more effective than all other 3 structure

III. MODELLING AND ANALYSIS

3.0 General

My project is on comparative study between outrigger system and shear wall system for resisting lateral loads in tall buildings. In which I considered two structures of 25 storeys and 30 Storey with outrigger structural system and two structures of 25 storeys and 30 Storey with shear wall structural system with dimension 20 x 32 M. In these systems I am going to adopt different types of analysis methods according to the 4 seismic zones in which different parameters are considered.

3.1 Geometrical Confirmation of Structure

Structural properties considered for modelling and analysis

Table 1: Structural Properties of the Structure

Description	Outrigger system	Shear wall system
Plan area	20 x 32 M	20 x 32 M
No of bays along x direction	5	5
No of bays along y direction	7	7
Column cross section	600 x600 mm	600 x 600 mm
Mega column	900 mm	0
No of storey	25, 30	25,30
Height of each storey	3 M	3M
Shear wall thickness	152.4 mm (6inch)	152.4 mm (6inch)
Position of shear wall	Center with outrigger	Center and edges
Slab thickness	152.4 mm(6")	152.4 mm(6")

Height limit for structural systems: the maximum building height (in m) shall not exceed the values given in table 1 (is16700-2017) for buildings with different structural systems.

Table 2: Height Limit for Structural System

sno	seismic zone	Height of G+25 floors structure	Height of G+30 floors structure	structural system (structural wall+ moment frame)	The maximum building height (in M) shall not exceed the structural system
1	v	78	93	100	safe
2	iv	78	93	100	safe
3	iii	78	93	160	safe
4	ii	78	93	180	safe

Slenderness Ratio: The maximum value of the slenderness ratio which is the ratio of height to min base width B shall not exceed values given in Table 2. (IS16700:2017)

Table 3: Slenderness Ratio of Structures

sno	seismic zone	Height of G+25 floors structure	Height of G+30 floors structure	minimum base width	Ratio(H/B) G+25 floors structure	Ratio(H/B) G+30 floors structure	structural system (structural wall+ moment frame)	The maximum building height (in m) shall not exceed the structural system
1	v	78	93	20	3.9	4.65	8	safe
2	iv	78	93	20	3.9	4.65	8	safe
3	iii	78	93	20	3.9	4.65	8	safe
4	ii	78	93	20	3.9	4.65	9	safe

Plan Aspect Ratio: The maximum plan aspect ratio (Length / width) of the overall Building shall not exceed 5.0

Table 4: Plan Aspect Ratio of Structures

structure	Length	Breadth	ratio(L/B)	maximum plan aspect ratio (L/b) of the overall building shall not exceed 5.0
G+25 floors structure	20	32	0.625	safe
G+30 floors structure	20	32	0.625	safe

Table 5: Seismic Load Parameters

Seismic load				
	Zone ii	Zone iii	Zone iv	Zone v
Area	Bangalore	Ahmadabad	Amritsar	Gauhati
Zone factor	0.1	0.16	0.24	0.36
Site type	Medium soil II	Medium soil II	Medium soil II	Medium soil II
Importance Factor	1.5	1.5	1.5	1.5
Response reduction factor	OMRF DUAL SYSTEM "3"	OMRF DUAL SYSTEM "3"	OMRF DUAL SYSTEM "3"	OMRF DUAL SYSTEM "3"

Plan view of four structure (outrigger system, shear wall system)

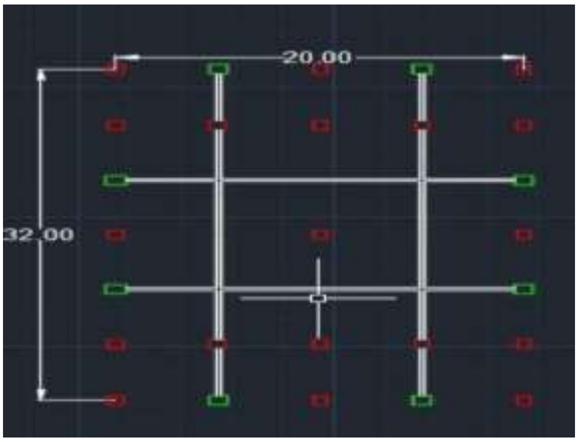


Fig 5: Floor Plan of Outrigger System

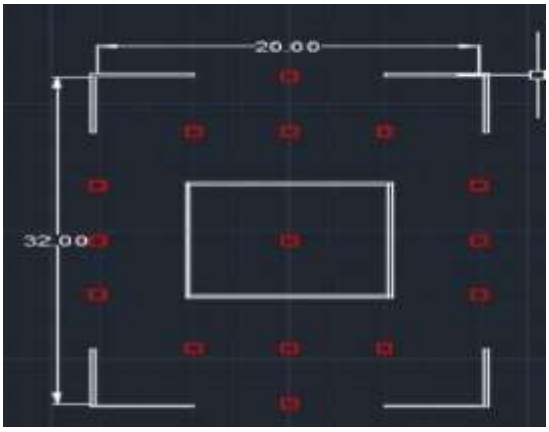


Fig 6: floor plan shear wall system

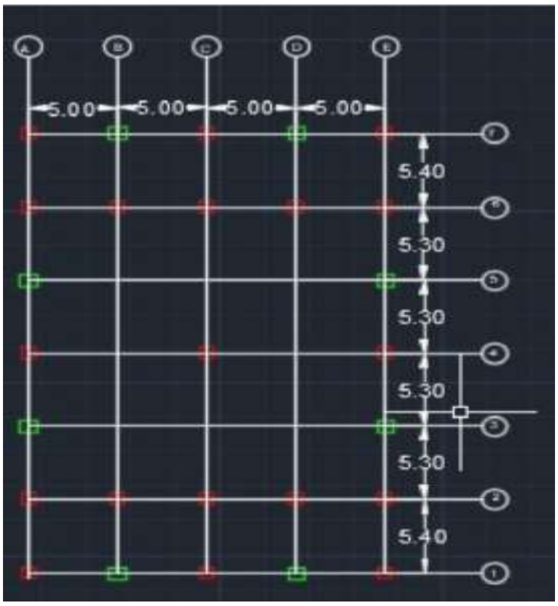


Fig 7: Outrigger system grid plan

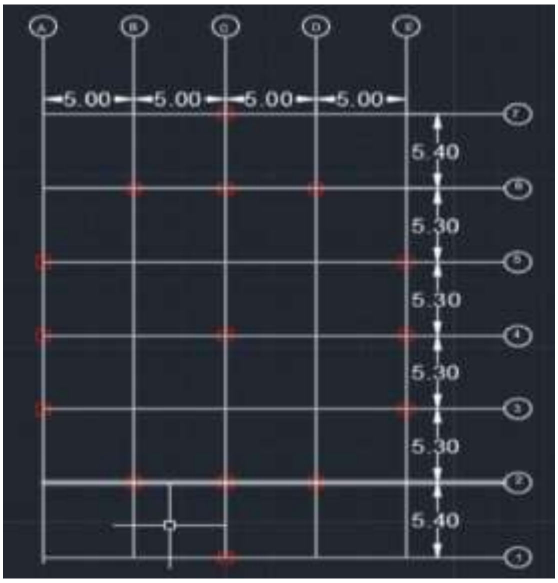


Fig 8: shear wall system grid plan

Modelling using etabs:

A) outrigger system	B) shear wall system
In outrigger system shear walls provided a core in center and place the outrigger in each 10 floors with thickness of 152.4 mm(6")shown in figure	In shear wall system the shear wall is provided as a core in center and I section. In the edges with thickness of 152.4 mm(6") as shown in figure

Column positioning for structural system

A)outrigger system**:-**column are placed according to grid plan with bay in x direction is 5 m each and y direction 5.3M , 5.4m and column size with 600 x600 mm and mega column size is 900 x 900mm

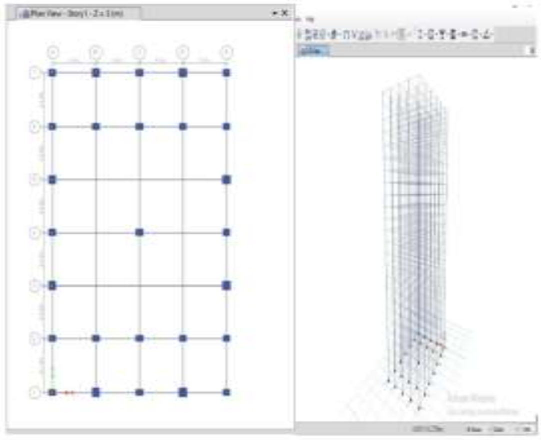


Fig 9: column position of outrigger structural system

Shear wall system:- column are placed according to grid plan with bay in x direction is 5 m each and y direction 5.3M , 5.4m and column size with 600 x 600 mm

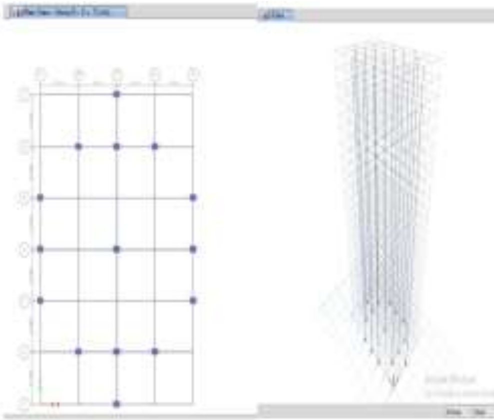


Fig10: Column Position of Shear Wall Structural System

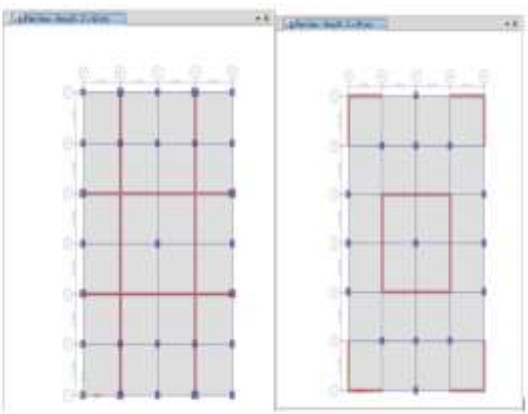


Fig 11: Plan View of Outrigger System & Plan View of Shear Wall System

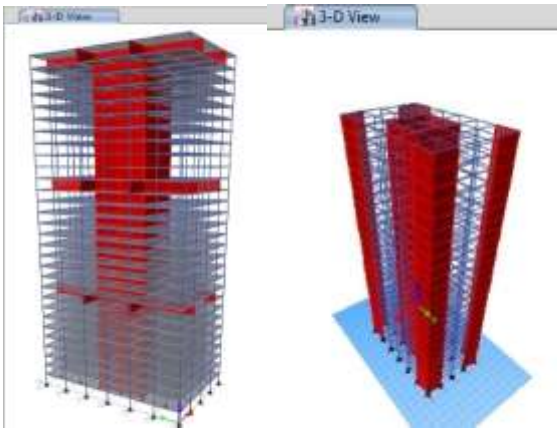


Fig 12: 3D View of Outrigger structural System &3D View of Shear Wall structural system

3D views of all 4 models

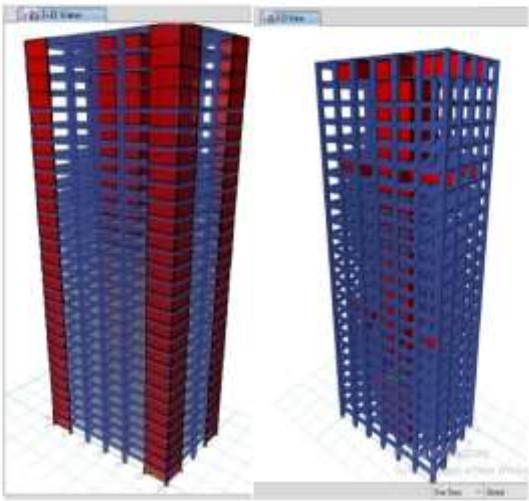


Fig 13 : Shear Wall System 25 Floors & Outrigger System 25 Floors

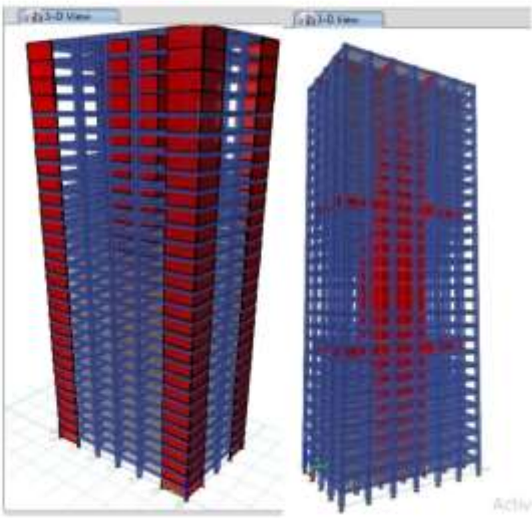


Fig 14 : Shear Wall System 30 Floors & Outrigger System 30 Floors

IV. RESULTS AND DISCUSSIONS

4.0 General

The study is conducted on four structures such as outrigger structures with 25 stories, outrigger structures 30 stories, shear wall structures with 25 stories, shear wall structures with 30 stories. All four models are analyzed in four different zones. Total 16 models as shown . All the 16 models are analyzed in etabs software by using equivalent static analysis and response spectrum analysis.

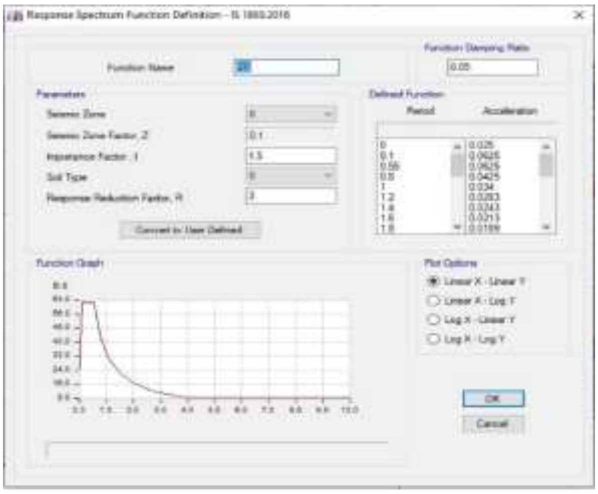


Fig 15 : Response Spectrum Function

In this study parameters such as displacement, storey drift, mode shapes, base shear of every model are tabulated and studied. The seismic effect is considered in both X and Y directions in all four zones and all the parameters are formatted in tables and graphs to compare easily between the models. By seeing the comparison between the graphs and tables, the structural performance of the structure is obtained

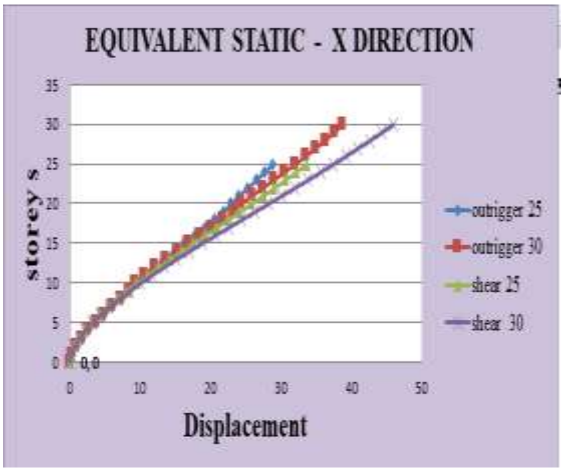
Max displacement through equivalent static analysis in X –direction in mm

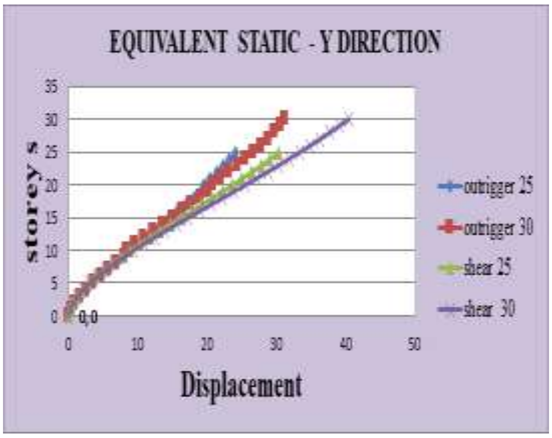
in X direction	zone 2	zone 3	zone 4	zone 5
outrigger 25	28.849	46.159	69.238	103.858
shear 25	33.634	53.815	80.722	121.114
outrigger 30	38.721	61.953	92.929	139.394
shear 30	45.962	73.539	110.309	165.464

Max displacement through equivalent static analysis in Y- direction in mm

in Y direction	zone 2	zone 3	zone 4	zone 5
outrigger 25	24.169	38.67	58.005	87.008
shear 25	30.444	48.71	73.065	109.626
outrigger 30	31.231	49.97	74.955	112.432

shear 30	40.495	64.793	97.189	145.783





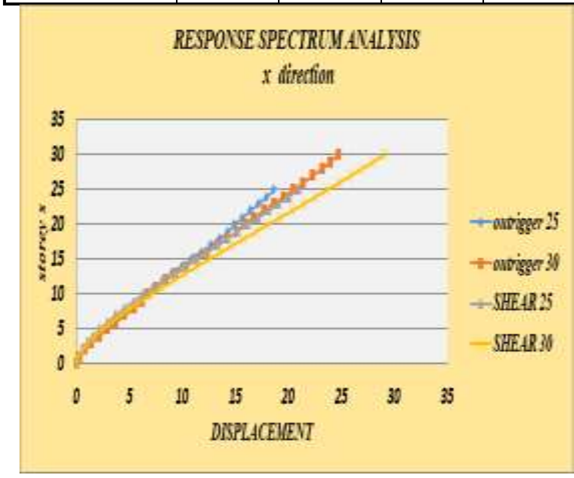
From the maximum deflections, it can be observed that the deflections in the shear wall system are 1.17% (max 165 mm) more than the outrigger system in the x-direction and 1.2 %(max 145mm) more than the outrigger system in the y-direction.

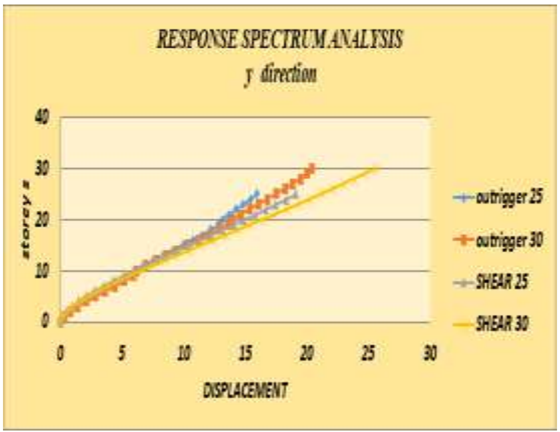
Max displacement through RESPONSE SPECTURM ANALYSIS in X-direction in mm

in X direction	zone 2	zone 3	zone 4	zone 5
outrigger 25	18.654	29.847	44.77	67.155
SHEAR 25	20.978	33.565	50.348	75.543
outrigger 30	24.728	39.564	59.346	89.019
SHEAR 30	29.069	46.51	69.765	104.648

Max displacement through RESPONSE SPECTURM ANALYSIS in Y-direction in mm

in Y direction	zone 2	zone 3	zone 4	zone 5
outrigger 25	15.938	25.501	38.251	57.377
SHEAR 25	19.12	30.591	45.887	68.848
outrigger 30	20.4	32.641	48.961	73.442
SHEAR 30	25.614	40.982	61.473	92.21





From the maximum deflections, it can be observed that the deflections in the shear wall system are 1.15% (max 104 mm) more than the outrigger system in the x-direction and 1.2 %(max 92 mm) more than the outrigger system in the y-direction.

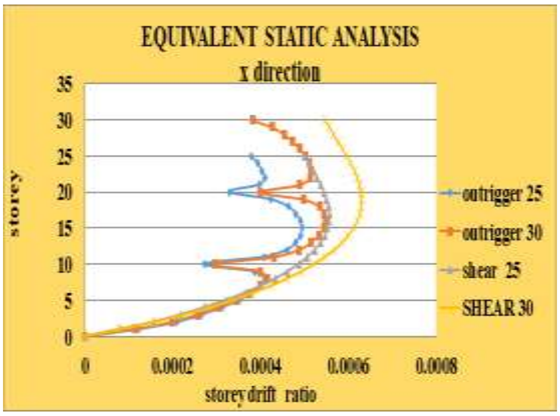
Storey Drift Ratio through Equivalent Static Analysis in X- direction

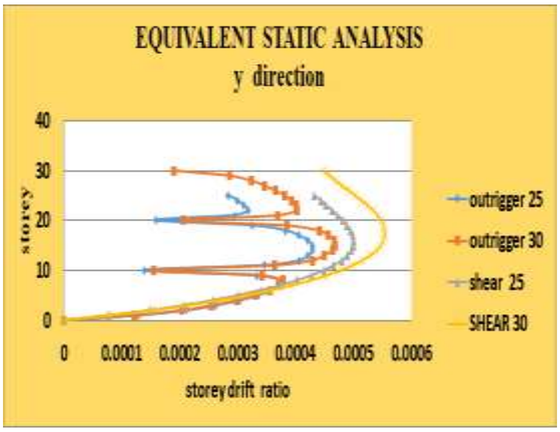
in x direction	zone 2	zone 3	zone 4	zone 5
outrigger 25	0.00050	0.00079	0.00119	0.00178
shear 25	0.00056	0.00089	0.00134	0.00201
outrigger 30	0.00055	0.00088	0.00131	0.00197
SHEAR 30	0.00063	0.00101	0.00152	0.00227

Storey Drift Ratio through Equivalent Static Analysis in Y- direction

in Y direction	zone 2	zone 3	zone 4	zone 5
outrigger 25	0.00043	0.00069	0.00103	0.00155
shear 25	0.00050	0.00080	0.00120	0.00180

outrigger 30	0.00047	0.00075	0.00113	0.00169
SHEAR 30	0.00055	0.00089	0.00133	0.00200





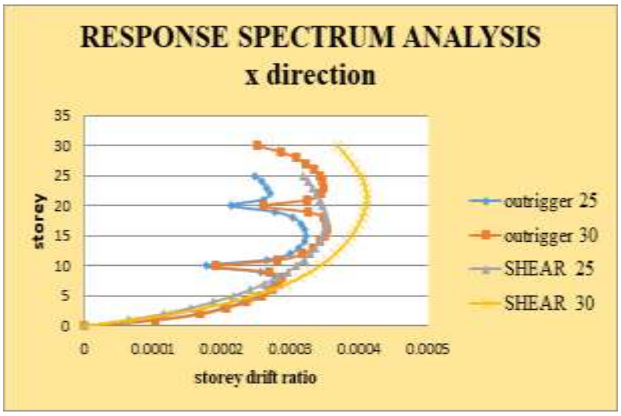
From the storey drift ratio, it can be observed that the storey drift ratio in the shear wall system are 1.13 %(max 0.002) more than the outrigger system in the x-direction and 1.17 %(max 0.002) more than the outrigger system in the y-direction

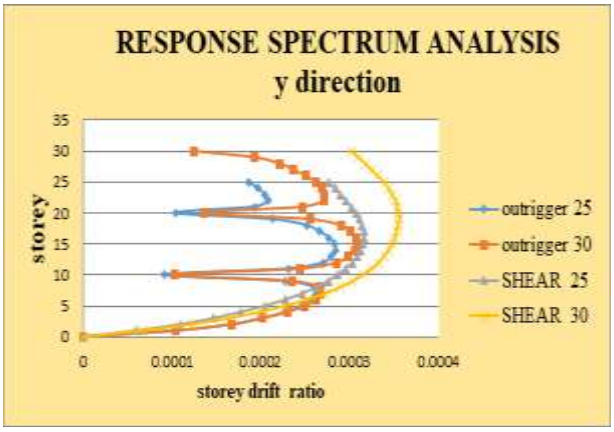
Storey Drift ratio through Response Spectrum Analysis in X- direction

in X direction	zone02	zone03	zone04	zone05
outrigger 25	0.00032	0.00052	0.00077	0.0011
SHEAR 25	0.00035	0.00056	0.00084	0.0012
outrigger 30	0.00035	0.00057	0.00085	0.0012
SHEAR 30	0.00041	0.00066	0.00099	0.0014

Storey Drift ratio through Response Spectrum Analysis in Y- direction

in Y direction	zone02	zone03	zone04	zone05
outrigger 25	0.00028	0.00045	0.00068	0.0010
SHEAR 25	0.00031	0.00051	0.00076	0.0011
outrigger 30	0.00030	0.00049	0.00074	0.0011
SHEAR 30	0.00035	0.00057	0.00085	0.0012

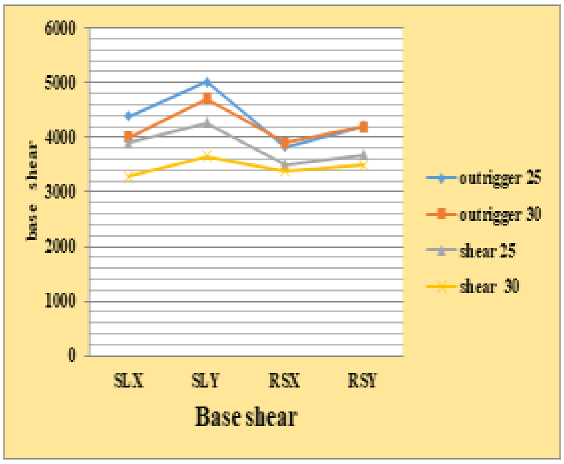




From the storey drift ratio, it can be observed that the storey drift ratio in the shear wall system are 1.12% (max 0.0014)more than the outrigger system in the x-direction and 1.13 % (max 0.0012)more than the outrigger system in the y-direction

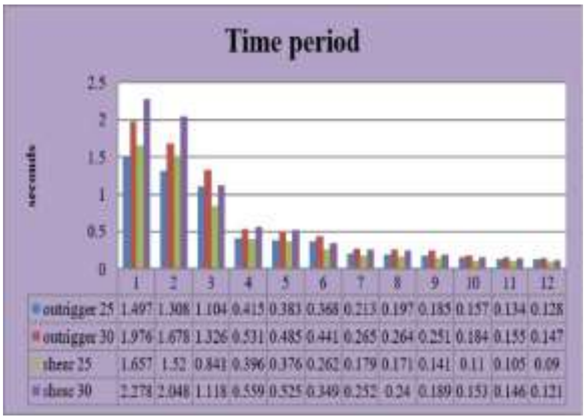
Base Shear through Equivalent Static Analysis, Response Spectrum Analysis for In Four Structures

		SLX	SLY	RSX	RSY
outrigger 25 floors	zone 2	4383.81	5018.42	3825	4205
	zone 3	7014	8029	6121	6729
	zone 4	10521	12044	9182	10094
	zone 5	15872	18066	13773	15141
outrigger 30 floors	zone 2	3997	4707	3900	4190
	zone 3	6395	7531	6240	6750
	zone 4	9593	11297	9361	10057
	zone 5	14391	16946	14042	15086
shear 25 floors	zone 2	3907	4262	3509	3676
	zone 3	6252	6819	5615	5882
	zone 4	9378	10229	8423	8824
	zone 5	14065	15340	12636	13236
shear 30 floors	zone 2	3280	3648	3383	3496
	zone 3	5248	5837	5414	5594
	zone 4	7872	8756	8121	8391
	zone 5	11808	13134	12182	12586



From graph it can be stated that the base shear in the outrigger system is more when compared to shear wall system which indicates that outrigger system is stiffer than the shear wall system hence there is reduction in displacement. And which reduces the lateral loads at different storey levels

Time period in four structure in seconds



Total 12 numbers of modes are used in the analysis of earthquake shaking. It should be such that the total modal masses of these modes are at least 90% of the total seismic mass within the total number of modes considered

Modes shapes

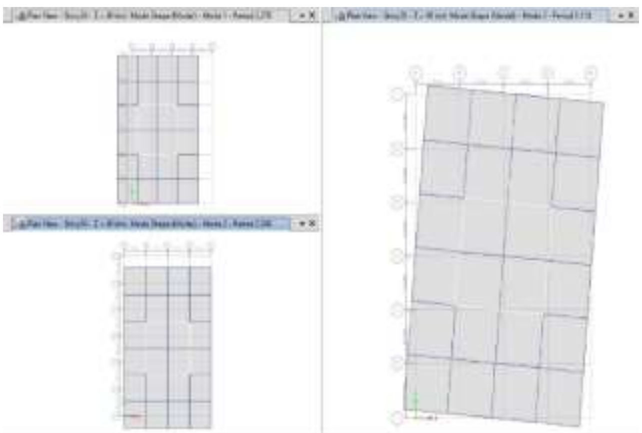


Fig 16 : modes shapes

- It can see in the below figures that the first two modes of the 4 structures should be translational, that a higher amount of mass participated in Ux and Uy direction. Rz should be less than Ux and Uy

IV. CONCLUSIONS

Based on the analysis done the following are the conclusions:

1. The outrigger structural system showed less deflections compared to the shear wall structural system in both x and y directions in both equivalent static analysis and response spectrum analysis.
2. The percentage decrease in deflection in outrigger structural system than shear wall structural system in both x and y directions are almost same in both equivalent static method and response spectrum method.
3. The outrigger structural system showed a less storey drift ratio compared to the shear wall structural system in both x and y directions in both equivalent static analysis and response spectrum analysis.
4. The percentage decrease in storey drift ratio in outrigger structural system than shear wall structural system in both x and y directions are almost same in both equivalent static method and response spectrum method.
5. It can be observed that storey drift is sudden reduced at storey levels where outriggers are provided because of increased stiffness.
6. It has been concluded that base shear in the outrigger system is 1.17% more when compared to the shear wall system which indicates that the outrigger system is stiffer than the shear wall system hence there is a reduction in displacement and reduces the lateral loads at different storey levels.
7. From the 12 modes considered, the time period of the outrigger structural system is less than the shear wall structural system which means the outrigger structural system is stiffer than the shear wall structural system.

REFERENCES

1. Alok rathore and Dr. Savita maru , "Dynamic analysis of outrigger structural system in a tall building"., International Journal of Modern Trends in Engineering and Research Volume 04, Issue 12, [December– 2017]
2. Pankaj sharma,gurpreet singh , "dynamic analysis of outrigger systems in high rise building against lateral loading". International Journal of Civil

Engineering and Technology,Volume 9, Issue 8, August 2018,

3. C. Bhargavkrishna, v. Rangarao , "comparative study of the usage of outrigger and belt truss system for high-rise concrete buildings". International Journal of Recent Technology and Engineering Volume-7, Issue-6, April 2019
4. Shivacharan, chandrakala, Narayana, karthik n, "analysis of outrigger system for tall vertical irregularities structures subjected to lateral loads" International Journal of Research in Engineering and Technology, Volume: 04, Issue: 05, May-2015.
5. Tarunmagendra,abhyudaytitiksh and a.a. Qureshi , "optimum positioning of shear walls in multi-storey – buildings" International Journal of Trend in Research and Development, Volume 3, Issue: 03, May-Jun 2016
6. Santosh singh thakural and manishsaklecha , "the addition of shear walls to enhance the structural stability of medium-rise structures". International Journal of Recent Development in Civil & Environmental Engineering ,Vol. 1, Issue 1 - 2016
7. Jaimindodiya,mayankdevani,akashdobariya,mehulbhuva, kamalsinhpadhiar, "analysis of multistory building with the shear wall using Etabs software". International Research Journal of Engineering and Technology ,Volume: 05 Issue: 02 Feb-2018
8. K crown mojes, b. Ajitha, "the analysis and design of g+40 storey regular structure with different shear walls for loose soils". International Journal of advance Research in science and Engineering Volume: 06 Issue: 05 | may-2017
9. IS 1893 (part I): 2016 – "Criteria for Earthquake Resistant Design of Structures"
10. IS 456:2000 – "Indian Standard plain and reinforced concrete – code of practice"
11. IS 875:1987 PART I "Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, Dead loads – unit weights of building materials and stored materials".
12. IS 875:1987 PART II "Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, Imposed Loads"

