International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 07, July-2015

Analysis and Comparison of Different Lateral Load Resisting Structural Forms

Thejaswini R M
Assistant Professor (Structural Engineering)
Department of Civil Engineering
Govt S K S J T I Bangalore (India) 560001

Rashmi A R
M-Tech Student (Structural Engineering)
Department of Civil Engineering
Govt S K S J T I Bangalore (India) 560001

Abstract: **Nowadays there has been a considerable increase in the number of tall buildings. In one or the other residential and commercial buildings, there is always a trend towards taller and more slender structures. Here, in this present work a particular type of irregular building with different structural forms are considered and seven models are developed in Etabs software with codal provisions. These models are analyzed for response spectrum method and wind load. When seismic analysis is considered some of the major factors come into picture like lateral displacement, storey drift, and stability of columns in particular storey due to lateral forces and when the building is in irregular configuration torsion irregularity will also become an important factor. In this present work all this points are considered and the results obtained are tabulated, graphs are plotted and compared. The results shows that the tube structure and 'L' shape shear wall are more stable and does not have torsion irregularity and also the displacement is less compared to other general structures. Drift can be controlled by providing outrigger at optimum location of the building.**

Keywords: Dynamic Analysis Response Spectrum Method, Displacement, Drift, Stability And Torsion Irregularity.

I. INTRODUCTION

From the ancient pyramids to present modern skyscrapers, the progress, power and wealth has been repeatedly expressed through fabulous and monumental structures. The advancement in modern tall building construction began in 1880's has been largely for commercial and residential purposes. The rapid growth of urban population and the consequent pressure on limited space have substantially influenced city residential development. The land value is increasing, the aspiration to avoid a continuous urban sprawl and the need to retain important agricultural production have all contributed to drive residential building upwards. Tall building comprises many important factors like economics, technology, aesthetic, politics and municipal regulation. Among all these, the primary governing factor is the increase in land value.

We have numerous aspects that have to be considered in deciding the structural form, which will include the material and method of construction, planning of interior, the external architectural regimen, the planned location and to map the service system, to conclude the nature and magnitude of horizontal loading, to arbitrate the height and dimension of building. The essential objective in deciding the structural form of a tall building to hold up gravity, live and dead loading and to withstand external lateral load, moment, shear force and torque with acceptable strength and stiffness.

The key reasons for the demand of tall building are population and migration trends, global competition and proliferation, urban reformation, agglomeration, land prices, climate change and energy, land conservation, infrastructure and transportation, human endeavor and ego, emerging technologies.

II. OBJECTIVE AND MODEL DESCRIPTION

A. The scope of this study is as follows:

- To model the building for different structural forms in ETABS software and to perform linear dynamic analysis.
- To examine the lateral displacement for the models considered and to compare the maximum displacement values of all the models.
- To know the structure response through acceleration produced during response spectrum analysis.
- To observe the storey drift for all the models and to observe the storey in which the maximum drift occurs.
- To determine the stability of columns for sway and non-sway in particular storey according to IS 456: 2000 Annex E.
- To check the torsional irregularity according to IS 1893(Part I): 2002 clause 7.1 table 4 in all the models for first three modes.

B. Preliminary Data for building:

Design loads:

1. Dead load as per IS 875 – Part I (1987).

Table 1: Material Properties

Materials	Density (KN/m^3)
Concrete	24
Steel	78.5
Solid concrete block	18
cinder	7.85
water	10

2. Live load as per IS 875- Part II (1987)

Table 2: Residential Properties

Residential components	Imposed load (KN/m^2)
kitchen	2
rooms	2
Toilet & bathrooms	2
staircase	3
corridor	3
balcony	3
Floor finish (0.05 X 24)	1.2
Partition wall load as per IS 875(part 2)-1987	1.5
Sunken load (Density of cinder 8KN/m^3 X depth considered is 0.15m)	1.2

3. Wind load as per IS 875- Part III (1987)

Zone III = 0.16

City = Pune, V_b = 39 m/s

Table 3: Calculation of Wind Speed

Height of building(m)	K_1	K_2	K_3	V_Z (m/s^2)	$P_Z=0.6\ V_Z^2$ (KN/m^2)
10	1	1.03	1	40.17	0.968
15	1	1.07	1	41.73	1.044
20	1	1.10	1	42.9	1.104
30	1	1.13	1	44.07	1.165
50	1	1.18	1	46.02	1.270

4. Seismic load as per IS 1893 (Part I): 2002

Table 4: Seismic Parameters

Zone factor, Z	Zone III
Response reduction factor, R (Special moment resisting frame with shear wall)	5
Importance factor, I	1
Soil type (medium)	II
Damping	5%

C. Model Description:

In the present work seven models of RCC high rise building **G+14** floors are considered to know the realistic behavior of building during earthquake. These buildings were analyzed in acceptance to the Indian Code of practice for seismic resistant design of buildings. The length and width of the building is **48.641 X 42.1244m** size of each block is taken as **20mX14m**. Height of the storey of building is **3m** and is constant including the ground storey. Building is considered to be located in **zone three**. Modal damping **5%** is considered. The buildings considered are assumed to be fixed at the base and the floors act as a rigid diaphragm. For the modeling and analysis **ETABS 13.1.2** is used.

Table 5: Structure Parameters

Zone	III
Floor to floor height (including ground storey)	3.0m
No. of stories	G+14
Shear wall thickness	230mm
Thickness of slab	150mm, 200mm
Thickness of wall	200mm
Size of columns	300X900mm^2 450X1000mm^2
Size of beams	230X600mm^2 300X300mm^2
Grade of concrete and steel	Beams and slabs - M30 Columns - M45 Rebar - Fe500

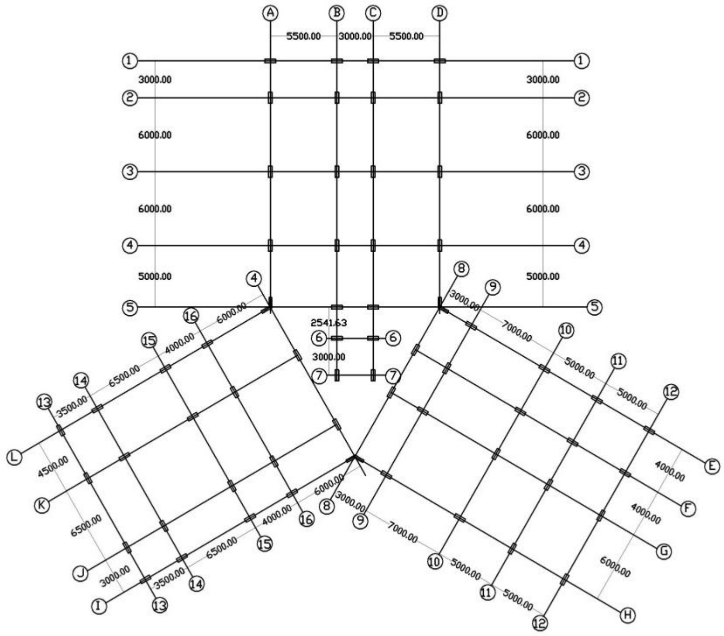

Fig 1: Plan of Considered Model

D. Models considered:

1. Model-1:

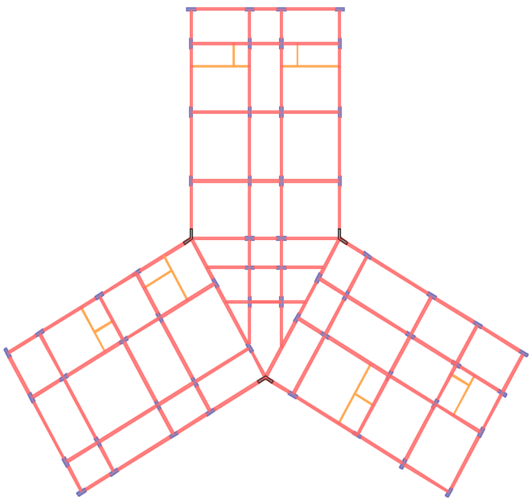

Fig 2: Model-1(Rigid Frame Structure)

Model-2:

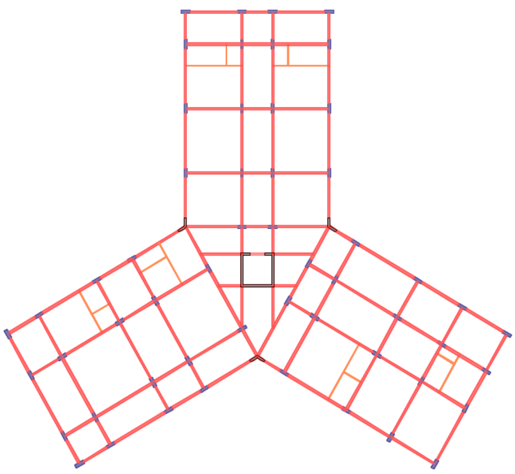

Fig 3: Model-2(Core Wall Structure)

Model-3:

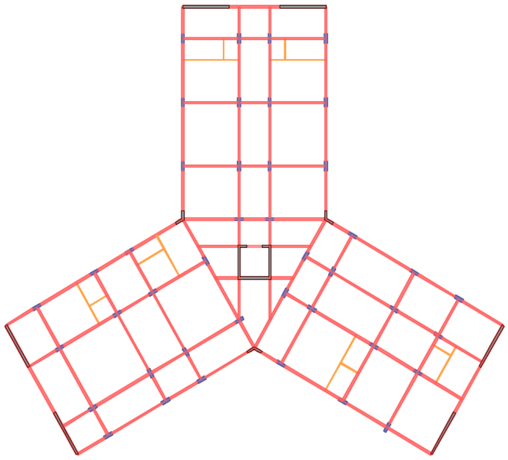

Fig 4: Model-3(Shear Wall along Width of Each Block)

Model-4:

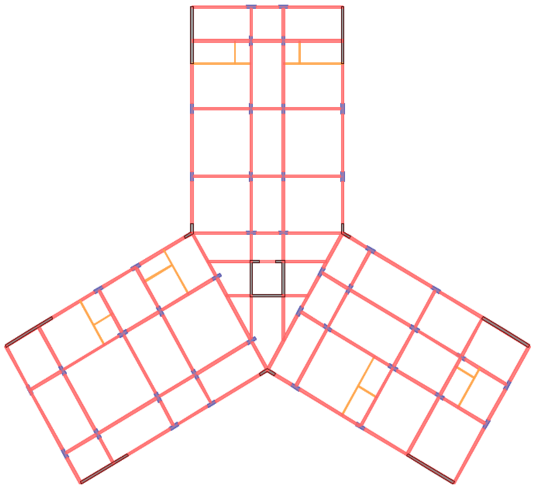

Fig 5: Model-4 (Shear Wall along Length of Each Block)

Model-5:

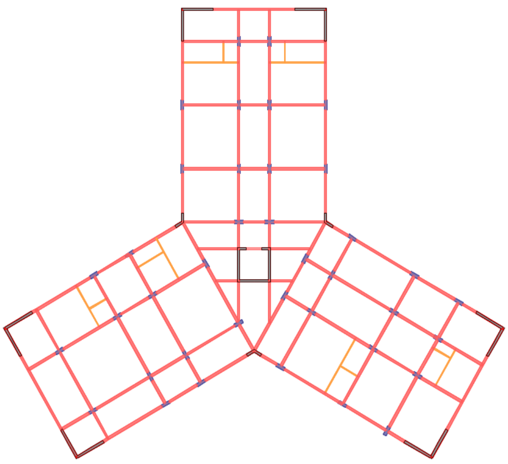

Fig 6: Model-5(Shear Wall at Corners of Each Block)

Model-6:

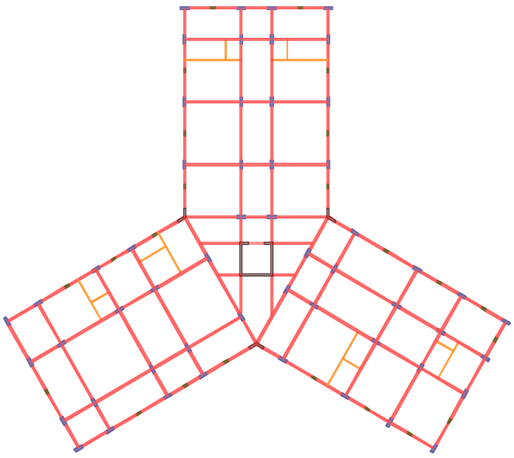

Fig 7: Model-6 (Tube Structure)

Model-7:

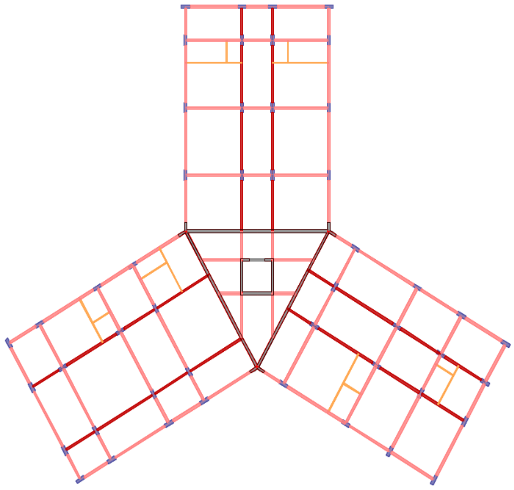

Fig 8: Model-7 (Outrigger Structure)

III RESULTS AND DISCUSSION

A. Storey Displacement:

Here I have tabulated the storey displacement in mm for 6 load combinations considered.

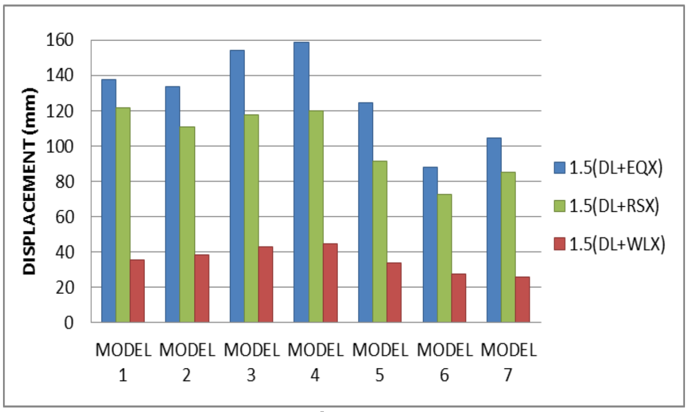

Fig 9: Maximum Displacement in X Direction

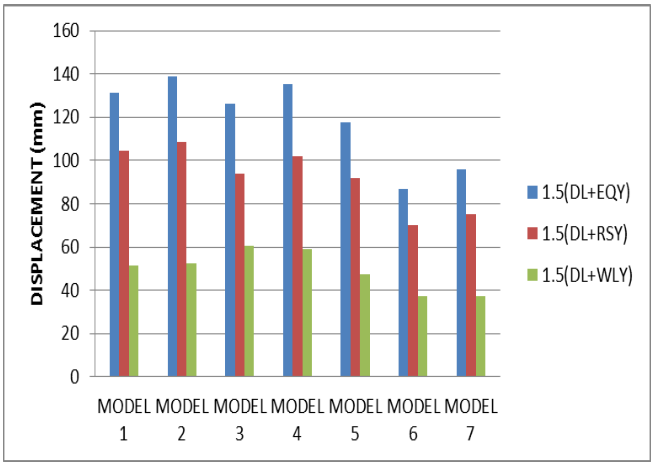

Fig 10: Maximum Displacement in Y Direction

Here the displacement values are more for earthquake load than wind load. Hence earthquake load are more critical and also most of the minimum displacement values at the top are obtained for seismic load combination in **Model-6 i.e tube structure** and for wind load combination for **Model-7 i.e for outrigger structure**. Then we can see that maximum displacement value at the top is obtained for **Model- 4 i.e shear wall in longer span .**

There is maximum displacement in model 4 because the lateral load acting in X direction will act on the minor axis of the shear wall. And this shear wall are less stiffer and are not able to compensate the stiffness of column which are replaced by shear wall. The displacement values are less in tube structure and outrigger structure. In tube structure perimeter columns are closely spaced and hence most of the lateral forces are resisted by them. In outrigger the central core is connected to outer periphery hence this reduces the displacement.

B. Period and Acceleration:

Table 6: Period and Acceleration

Model	Period (sec)	Acceleration(mm/s^2)
Model-1	2.349	403.92
Model-2	2.304	380.18
Model-3	2.226	373.2
Model-4	2.451	329.93
Model-5	2.045	383.34
Model-6	1.813	396.27
Model-7	2.061	374.07

The **period** in first mode is **maximum** and the corresponding **acceleration is mimimum** for Model-4. Hence the displacement has increased. For Model-6 the period is very less compared to other models. Hence structure has minimum displacement and have increased accleration.

C. Storey Drift:

Storey drift is the displacement of one level relative to other level above or below

$$\frac{\text{difference between displacement of two storey}}{\text{height of that storey}}$$

In accordance with IS 1893(Part I) cl 7.11.1 the storey drift in any storey due to minimum specified design lateral force, having partial load factor of 1, should not be more than 0.004 times the storey height. Here the storey drift ratio has been tabulated for six load combination and graph have been plotted to the corresponding value below.

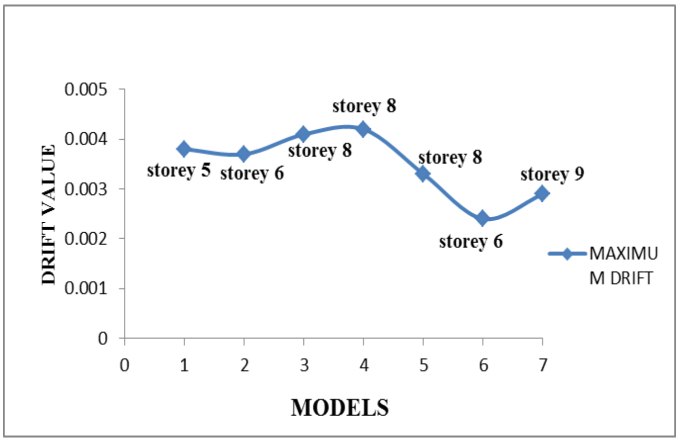

Fig 11: Maximum drift values of all models

From above tabulations and graphs we can see that the maximum drift value of Model-1 is 0.0038 in storey 5, in model 2 it is 0.0037 in storey 6, in model 3 it is 0.0041 in storey 8, in model 4 it is 0.0042 in storey 8, in model 5 it is 0.0033 in storey 8, in model 6 it is 0.0024 in storey 6 and in model 7 it is 0.0029 in storey 9. The drift value is maximum in **Model-4** i.e. shear wall in long span direction and minimum in **Model-6** (tube structure).

D. Stability Indices:

For a building it is necessary to check the stability indicies which is given in Annex E of IS 456:2000 for all the storeys to differentiate the columns in a given storey as sway and non-sway columns. The stability indicies Q_{si} may be computed as,

STOREY	PLINTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Axial Load Pu in KN	208472.9	206063	191363	177391	163420	149448	135477	121505	107533.7	93556.19	79584.7	65613.22	51641.73	37670.25	23698.76	9727.28
Lateral load H_u (RSX) in KN	7338.42	7327.64	7102.45	6754.32	6382.37	6038.46	5714.27	5402.2	5108.97	4819.05	4494.25	4107.98	3636.01	3008.96	2125.71	938.01
Δu (mm) in X direction	0	6	6.3	6.8	6.7	6.7	6.4	6.1	5.7	5.3	4.8	4.4	3.8	3.2	2.7	2
Lateral load H_u (RSY) in KN	6829.35	6819.1	6614.32	6294.19	5947.62	5624.45	5320.44	5029.78	4758.32	4491.48	4192.96	3836.24	3398.56	2816.53	1995.21	885.04
Δu (mm) in Y direction	0	5	5.3	5.7	5.7	5.6	5.4	5	4.8	4.5	4.1	3.7	3.2	2.8	2.2	1.7
Q_{si} (X)	0	0.056	0.056	0.059	0.057	0.055	0.05	0.045	0.039	0.034	0.028	0.023	0.018	0.013	0.01	0.007
Q_{si}(Y)	0	0.05	0.051	0.053	0.052	0.049	0.045	0.04	0.036	0.031	0.023	0.021	0.016	0.012	0.008	0.006
X Classification	NO-SWAY	SWAY	SWAY	SWAY	SWAY	SWAY	SWAY	SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY
Y Classification	NO-SWAY	SWAY	SWAY	SWAY	SWAY	SWAY	SWAY	SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY	NO-SWAY

Table 7: Stability Check for Model-1

$$Q_{si} = \frac{\Sigma P_u \Delta_u}{H_u h_s}$$

Q_{si} = stability indicies of i^{th} storey
P_u = total axial load on all columns in the i^{th} storey
Δ_u = elastically computed first order lateral deflection
H_u = total lateral force acting within the storey
h_s = height of storey (3000mm)

Here the calculation for model-1 is tabulated. Similarly for other models the discussions are made.

- From the tabulated values we can see that in Model-1 the columns have sway both in X and Y direction from storey 1 to storey 7.
- In Model-2 also the columns have sway both in X and Y direction from storey 1 to storey 7.
- When we come to Model-3 the sway in column reduces. When force is applied in X direction sway in column take place from storey 3 to storey 7 and when force is applied in Y direction the sway occurs in columns of storey 4 to storey 7.
- In Model-4 the sway occurs in storey 4 to storey 8 in X direction but there is no sway in Y direction.
- **Model-5 and Model-6 have no sway** columns in all storeys in both directions.
- In Model-7 column sway exist in storey 2 and 3 in X direction, but in Y direction the sway is only in storey 3.
- The magnitude of gravity load and factors which increase lateral displacement effect lateral stability of structure. As the moment increases it forms plastic hinge, it causes sway which leads to instability of structure.

E. Torsional Irregularity:

According to IS 1893 (Part I): 2002 table 4 torsional irregularity is to be considered whenever floor diaphragms are rigid in their own plan with reference to vertical structural elements that resist the lateral forces. This Torsional irregularity is to be considered to exist when the maximum storey drift, calculated with design eccentricity, at one corner of the structures transverse to an axis is greater than 1.2 times the average of the storey drifts at the two ends of the structure.
Then these modes are combined by square root of sum of square method, here the sum of square refer to ratio of maximum storey drift to average drift. Then this value must be less than 1.2 times the square root of number of modes considered. This determines whether the structure contains torsional irregularity or not.

MODEL	MODE	AVERAGE STOREY DRIFT (mm)	MAXIMUM STOREY DRIFT (mm)	$\Delta max/\Delta avg < 1.2$	STRUCTURAL IRREGULARITY
MODEL 1	Mode 1	0.0075	0.00226	0.3	Does not exist
	Mode 2	0.011	0.0012	0.11	
	Mode 3	0.0124	0.0015	0.13	
MODEL 2	Mode 1	0.0028	0.00062	0.22	Does not exist
	Mode 2	0.0187	0.00163	0.09	
	Mode 3	0.00605	0.0008	0.13	
MODEL 3	Mode 1	0.0238	0.00205	0.09	Does not exist
	Mode 2	0.00002	$6X10^{-6}$	0.3	
	Mode 3	0.0015	0.00021	0.14	
MODEL 4	Mode 1	0.0028	0.00039	0.14	Does not exist
	Mode 2	0.0186	0.0012	0.06	
	Mode 3	0.0005	0.000057	0.11	
MODEL 5	Mode 1	0.012	0.001	0.08	Does not exist
	Mode 2	0.0078	0.00074	0.09	
	Mode 3	0.00046	0.000068	0.15	
MODEL 6	Mode 1	0.01	0.0015	0.15	Does not exist
	Mode 2	0.0027	0.00035	0.13	
	Mode 3	0.002	0.0003	0.15	
MODEL 7	Mode 1	0.00036	$6.3X10^{-5}$	0.18	Does not exist
	Mode 2	0.016	0.001436	0.09	
	Mode 3	0.0012	0.00012	0.1	

Table 8: Check for Torsion Irregularity

- Due to shape and symmetry of structure the building has not crossed limiting value of structure irregularity.
- From the discussion of stability, it can be seen that building is almost stable which leads to reduced torsional irregularity in building.

IV CONCLUSION

Design of high rise structures is always a challenging task for engineers with all the uncertainties, inevitable & number of risks involved in it. Here in this project after the analysis I have come to conclusions which are listed below.

- It is observed that as the density of column increases along periphery it leads to increase in stiffness and acceleration, resulting in decrease of displacement.
- Outrigger behaves as high drift controller when provided at storey which has maximum drift.
- The stability of the structure can be increased and the sway in columns can be avoided by providing tubular structure and 'L' shaped shear walls at corners.
- Torsional irregularity can be avoided in buildings by providing proper shape and symmetry in structure.
- The mass participation factor is more in lower stories which results in increase in amplitude of the mode due to which storey drift in maximum at lower storey.
- Out of all 7 models, Model-6 (tubular structure) is considered as best lateral load resisting system due to lowest displacement, most stable and no torsional irregularity in the building.

REFERENCES

[1]. Richard A. Ellis, David P. Billington, "Construction History of the Composite Framed Tube Structural System". Proceedings of the First International Congress on Construction History, Madrid, 20th -24th January 2003.

[2]. Navab Assadi Zeidabadi, Kamal Mirtalae and Barzin Mobasher, "Optimized use of the Outrigger System to Stiffen the Coupled Shear Walls in Tall Buildings". The structural design of tall and special buildings, 13, 9-27 (2004).

[3]. Alpha Seth, "Effect of Perimeter Frames in Seismic Performance of Tall Concrete Buildings with Shear Wall Core and Flat Slab System". The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[4]. Anshuman. S, Dipendu Bhunia, Bhavin Ramjiyani, "Solution of Shear Wall Location in Multi-Storey Building". International Journal of Civil and Structural Engineering, Volume 2, No 2. 2011.

[5]. M. M. Islam & A. Siddique, "Sustainability development in drift control of tall buildings: study of structural parameters". 4th Annual Paper Meet and 1st Civil Engineering Congress, December 22-24, 2011, Dhaka, Bangladesh.

[6]. N. F. El-Leithy, M. M. Hussein and W. A. Attia, "Comparative Study of Structural Systems for Tall Building". Journal of American Science, 2011; 7(4).

[7]. Wakchaure M. R, Ped S. P, "Earthquake Analysis of High Rise Building with and without In filled Walls International Journal of Engineering and Innovation Technology (IJEIT), Volume 2, Issue 2, August 2012.

[8]. Kiran Kamath, N. Divya, Asha U Rao, "A Study on Static and Dynamic Behavior of Outrigger Structural System for Tall Buildings". Bonfring International Journal of Industrial Engineering and Management Science, Vol. 2, No. 4, December 2012.

[9]. Asif Hameed, Imran Azmeer, Asad-ullah Qazi, Burhan Sharif and Noor Muhammad Khan, "Drift and Cost Comparison of Different Structural Systems for Tall Buildings". Pak. J. Engg. & Appl. Sci Vol. 12, Jan. 2013 (p. 27-38)

[10]. Mohd Irfan Moinuddin, Mohd Afroz Khan, "A Study for the Optimum Location of Outrigger for High-Rise Concrete". International Journal of Advanced Trends in Computer Science and Engineering. Vol. 2, No. 1, pages: 628-633 (2013)

[11]. Alfa Rasikan, M G Rajendran, "Wind Behavior of Building with and Without Shear Wall". International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 2, March-April 2013, pp. 480-485

[12]. P. P. Chandurkar, Dr. P. S. Pajgade, "Seismic Analysis of RCC Building With and Without Shear Wall". International Journal of Modern Engineering Research (IJMER) Vol. 3, Issue. 3, May-June 2013 pp. 1805-1810.

Codes and Books

[16]. S. K. Duggal, Earthquake –Resistant Design of Structures, second edition, 2013.

[17]. Pankaj Agarwal & Manish Shrikhande, Earthquake Resistant Design of Structures, tenth edition, August 2012.

[18]. IS 456: 2000 "Plain and Reinforced Concrete – Code of Practice"

[19]. IS 1893 (Part I): 2002 "Criteria for Earthquake Resistant Design of Structures"

[20]. IS 875 (Part 1, part 2, part 3) - 1987 "Code of Practice for Design Loads for Buildings and Structures" for Dead Load, Imposed Load, and Wind Load respectively .