Optimum Location of Different Shapes of Shear Walls in Unsymmetrical High Rise Buildings

A Murali Krishna[1]
JNTUA College of Engg. Ananthapuramu,
Ananthapuramu, Andhra Pradesh

Dr. E Arunakanthi[2]
JNTUA College of Engg. Ananthapuramu,
Ananthapuramu, Andhra Pradesh

***Abstract* - Shear walls are structural members used to augment the strength of RCC structures. These concrete or masonry continuous vertical walls will serve both architecturally as partitions and structurally to carry gravity and lateral loading. Their very high in-plane stiffness and strength makes them ideally suited for bracing tall buildings. They act as vertical cantilevers in the form of separate planar wall, and as non planar assemblies of connected walls around stairs, elevators and service shafts. Shear walls are added to the building interior to provide extra strength and stiffness to the building when the exterior walls cannot provide sufficient strength and stiffness. It is very necessary to determine the efficient, effective and ideal location of shear wall. The present work deals with a study on the optimum location of shear walls in an unsymmetrical high rise buildings. In this work a high rise building with different locations of shear walls with different shapes is considered for analysis. The high rise building is analyzed for its torsion, strength and stability using ETABS software. The results of the analysis on the shear force, bending moment and torsion are compared. The results are presented in tabular and graphical form. The results on the drift and displacement are checked with serviceability condition and are compared and presented in tabular form.**

Keywords: Shear walls, shapes of shear walls, lateral loading, Etabs, Equivalent static, RSM method, Time period, mode shapes, storey drift, Axial loads.

1. INTRODUCTION:

Buildings engineered with structural walls are almost always stiffer than framed structures, reducing the possibility of excessive deformation and hence damage. RC multi storied buildings are adequate for resisting both the vertical and horizontal load. When such buildings are designed without shear walls, beams and column sizes are quite heavy. Shear walls may became imperative from the point of view of economical and control large deflection. Lateral forces, that is, the forces applied horizontally to a structure derived from winds or earthquakes cause shear and overturning moments in walls. The shear forces tend to tear the wall just as if you had a piece of paper attached to a frame and changed the frame's shape from a rectangle to a Parallelogram. The changing of shape from a rectangle to parallelogram is referred to as racking. At the end of shear walls, there is a tendency for the wall to be pushed down at the end away from the force. This action provides resistance to overturning moments.

Kasliwal Sagar K.et al [2] considered two multi storey buildings, both are sixteen storeys have been modeled using software package ETABS for earthquake V zone in India. Different position and location of shear walls are considered for studying their effectiveness in resisting lateral forces. This paper also deals with the Dynamic linear Response spectra method and static method on multi-storey shear wall building with variation in number and position of shear wall. Based on the analysis results they found that as per the analysis storey drift in the Model M2 is less than Model M1.For earth quake forces in X and Y direction i.e. EQX and EQY shows that Story Drift along Y is larger than along X for M2. Story drift in model M1 is larger than model M2, Story Drift due to SPECX and SPECY is along Y is larger than along X, also shows story drift in model M1 is larger than model M2 Story. Show that base shear obtained in response spectra in X is larger than Y i.e. (spec X > spec Y.) for both model M1 & M2 and also base shear obtain in Response spectra for M2 is larger than M1. Thus shear walls are one of the most effective building elements in resisting lateral forces during earthquake. One can minimize the damage caused by earthquake and wind by providing shear walls in proper position.

The present work deals with the study of effect of seismic loading on placement of different shapes of shear walls in high rise buildings, say 30 storied at different locations. The residential high rise building is analyzed for earthquake force by considering two types of structural systems i.e. Frame system and Dual system. Effectiveness of shear wall has been studied with the help of seven different shapes of shear walls. Model one is bare frame structural system and other seven models are dual type structural systems. The seven shapes of shear walls are placed at different locations separately and checked for the values of center of gravity and center of rigidity to be nearer. The optimum location for the particular case is found and compared with the other shapes. The analysis is carried out by using standard package ETABS. The comparison of these models for different parameters like displacement, storey drift, column forces, storey shears etc. has been in tabular and graphical forms.

2. NEED AND OBJECTIVE OF THE STUDY:

Earthquakes are occurring frequently now a day. The seismic analysis and design of buildings has traditionally focused on reducing the risk of loss of life in the largest expected earthquake. To reduce the effects caused by these earth quakes and wind loads different lateral loading systems are introduced in the structures. Shear walls are one of the lateral loading systems commonly constructed in high rise buildings below 35 stories. Position of shear walls in unsymmetrical buildings has due considerations. It is very necessary to determine efficient and ideal location of shear walls in unsymmetrical buildings. In the present work the following tasks are carried out,

1 The study behavior of high rise building of 30 storeys, T –shaped RCC structure for various locations of different types of shear walls with seismic & wind loading has been done.
2 Both Equivalent static analysis and Response spectrum analysis are carried out.
3 The variation of lateral loads to diaphragms of the models has been studied.
4 The variation of maximum storey axial force, storey shear, storey moment and Storey torsion of the models has been studied.
5 The variation of storey drifts of the models has been studied
6 The variation of displacement of the models has been studied
7 The variation of maximum column axial force, maximum column shear force, maximum column moment and maximum column torsion of the models has been studied.
8 And the variation of time period has been studied.

3. BUILDING CONFIGURATION:

Total height of the building	107.4 m
No. of stories	30
Height of each storey	3.6 m
Height of ground storey	3.0 m
Grade of concrete	M40
Grade of steel	Fe500
Depth of slab	150 mm
Size of beams	400 X 600 mm
Size of columns	1200 X 1200 mm
	1000 X 1000 mm
	800 X 800 mm
Shear wall thickness	230 mm

LOADING:

Live load	4 kN/m²
Floor finish	1.5 kN/m²
Wall weight	13.8 kN/m
	6.9 kN/m on roof
Seismic loading:	IS 1893
Zone factor	0.24 (zone IV)
Soil type	II
Importance factor	1.5
Response reduction, R	5
Ecc. Ratio	0.05
Wind loading:	IS 875
Wind speed	39 m/s
Risk coefficient K1	1
Terrain category type K2	4
Topography K3	1.05

The following Load combinations are considered:

A. Serviceability combinations:

1. (DL+ LL)
2. (DL ± EQXTP)
3. (DL ± EQYTP)
4. (DL ± EQXTN)
5. (DL ± EQYTN)
6. (DL + LL ± EQXTP)
7. (DL + LL ± EQYTP)
8. (DL + LL ± EQXTN)
9. (DL + LL ± EQYTN)
10. (DL ± WLX)
11. (DL ± WLY)
12. (DL + LL ± WLX)
13. (DL + LL ± WLY)

B. Design Combinations:

14. 1.5(DL+ LL)
15. 1.5(DL ± EQXTP)
16. 1.5(DL ± EQYTP)
17. 1.5(DL ± EQXTN)
18. 1.5(DL ± EQYTN)
19. 1.2(DL + LL ± EQXTP)
20. 1.2(DL + LL ± EQYTP)
21. 1.2(DL + LL ± EQXTN)
22. 1.2(DL + LL ± EQYTN)
23. 1.5(DL ± WLX)
24. 1.5(DL ± WLY)
25. 1.2(DL + LL ± WLX)
26. 1.2(DL + LL ± WLY)

Shapes of shear walls:

The shape and location of shear wall have significant effect on their structural behavior under lateral loads. Lateral loads are distributed through the structure acting as a horizontal diaphragm, to the shear walls, parallel to the force of action. A core eccentrically located with respect to the building shapes has to carry torsion as well as bending and direct shear These shear wall resist horizontal forces because their high rigidity as deep beams, reacting to shear and flexure against overturning. However torsion may also develop in building symmetrical featuring of shear wall arrangements when wind acts on the facades of direct surface textures or when wind does not act through the centre of building's mass.

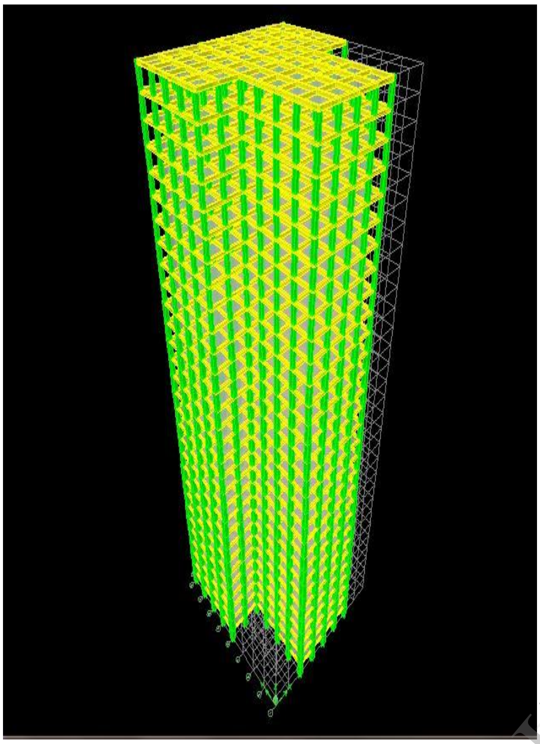
The Shear Wall sections are classified as six types.

(a) Box Section (b) L – Section

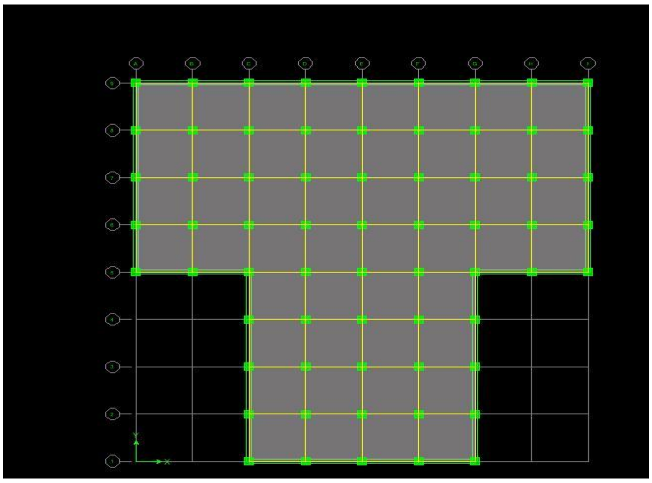
(c) U - Section (d) W – Section

(e) H - Section (f) T – Section

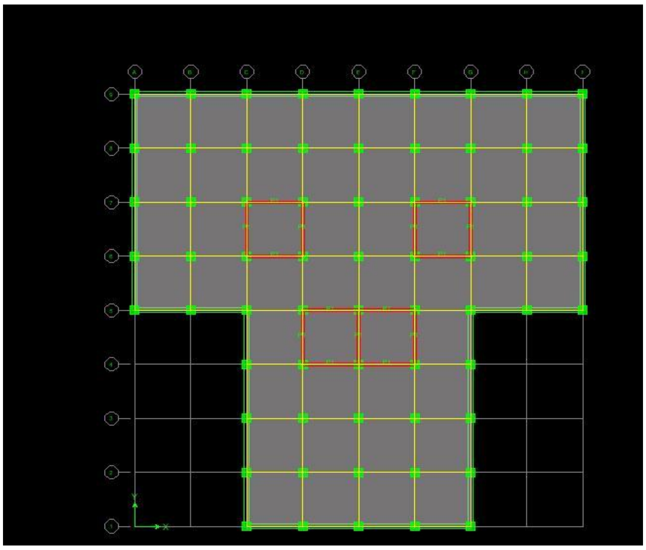
Elevation of the building:



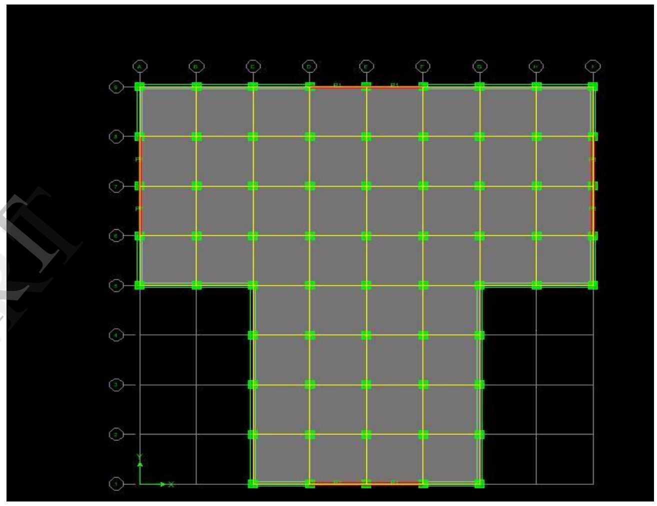
Plan of all the models:



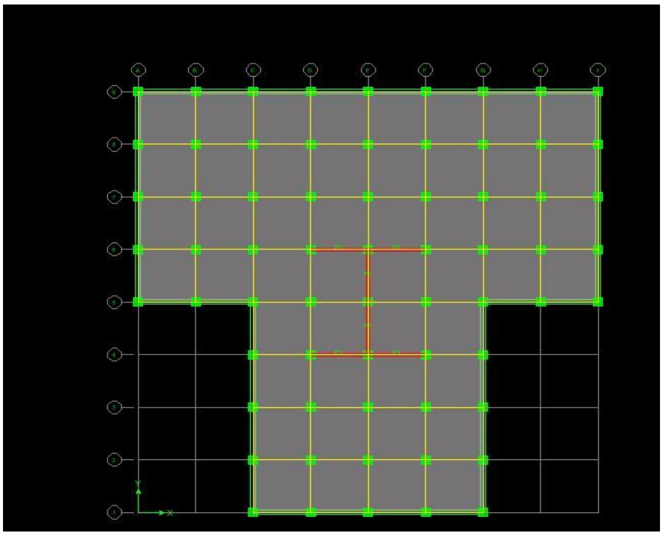
Plan of MODEL 1 at 30th storey level



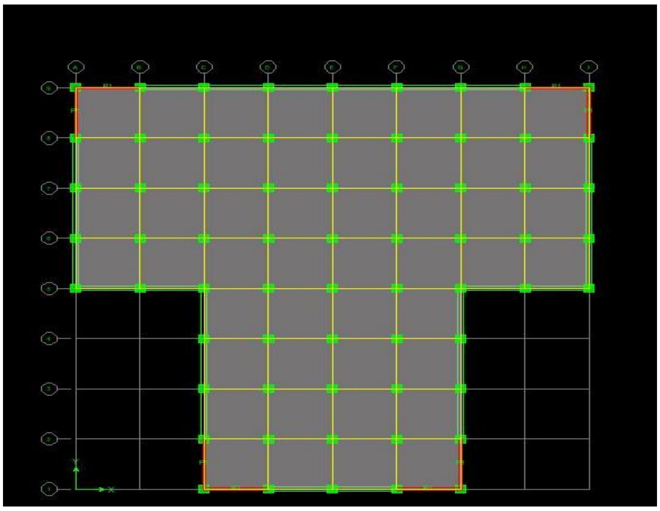
Plan of MODEL 2 at 30th storey level



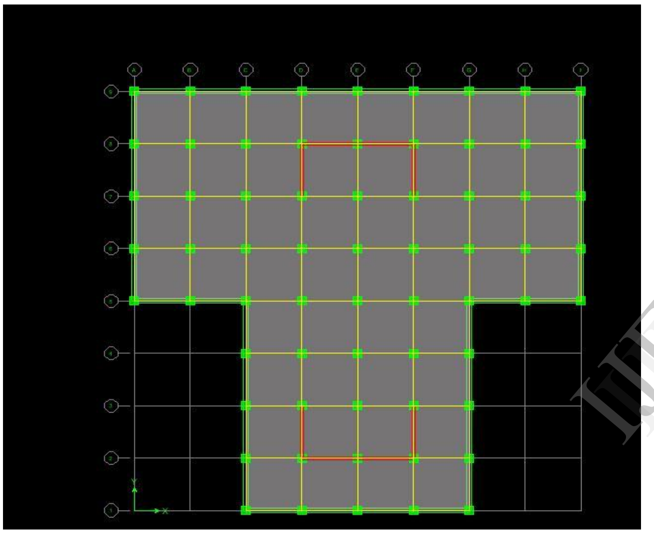
Plan of MODEL 3 at 30th storey level



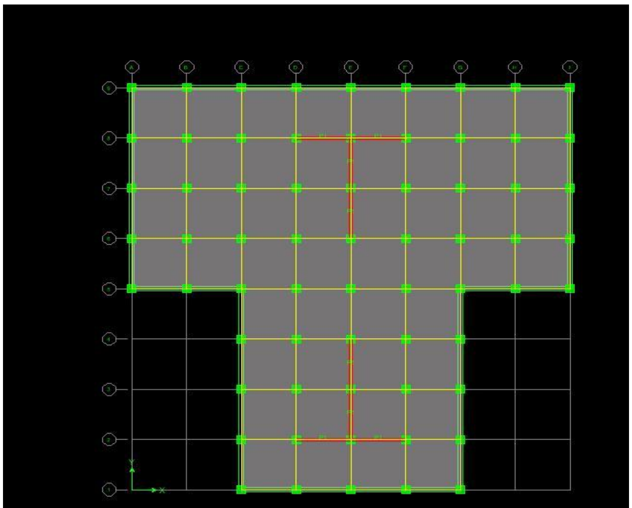
Plan of MODEL 4 at 30th storey level



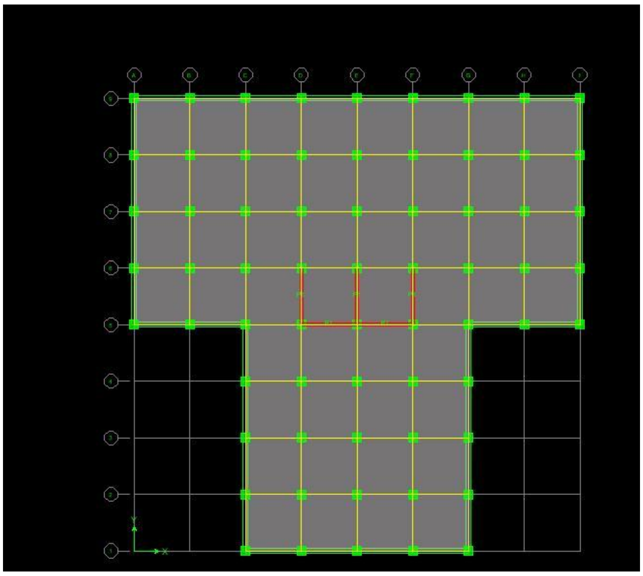
Plan of MODEL 5 at 30th storey level



Plan of MODEL 6 at 30th storey level



Plan of MODEL 7 at 30th storey level



Plan of MODEL 8 at 30th storey level

4. ANALYSIS OF RESULTS:

a) Equivalent static analysis:

This method is also known as seismic coefficient method. It simplest one and it requires less computational effort and it is based on the formula given in the code of practice, IS 1893:2002. In all the methods of analyzing a multi storey buildings recommended in the code of practice, the structure is treated as discrete system having concentrated masses at floor levels which include the weight of the columns and walls in any storey should be equally distributed to the floors above and below the storey. In addition, the appropriate amount of imposed load at this floor is also lumped with it. The total design lateral force or design seismic base shear (V_B) along any principal direction shall be determined by the following expression:

$V_B = A_h \text{ X } W$

Where,

A_h = Design horizontal acceleration spectrum value using the fundamental natural period 'T' in the considered direction of vibration.

W = Seismic weight of the building

The design horizontal seismic coefficient A_h shall be determined by the following expression:

$$A_h = \frac{Z\ I\ S_A}{2\ R\ g}$$

Where,

Z = Zone factor as per table 2 of IS: 1893

I = Importance factor as per table 6 of IS: 1893

R = Response reduction factor as per IS: 1893

The design base shear computed above shall be Distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i\, h_i^2}{\sum_{j=1}^{n} W_j\, h_j^2}$$

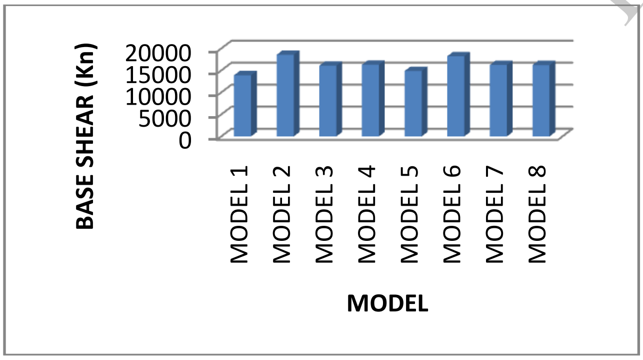
The results for different structures analyzed using Equivalent static method are as follows:

A. Center of mass and rigidity for all structures:

STRUCTURE	CENTER OF MASS		CENTER OF RIGIDITY	
	XCM	YCM	XCR	YCR
1	20	23.234	20	22.659
2	20	23.308	20	23.62
3	20	23.185	20	22.784
4	20	23.161	20	23.306
5	20	23.161	20	22.93
6	20	23.161	20	23.241
7	20	23.224	20	22.033

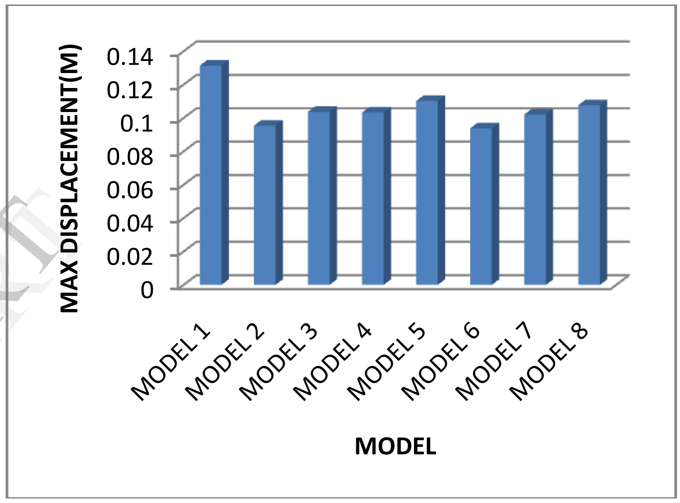
B. Base shear for different structures with combination (DL+LL+EQXTP):

STRUCTURE	BASE SHEAR (KN)
MODEL 1	13910.64
MODEL 2	18571.59
MODEL 3	16090.73
MODEL 4	16305.45
MODEL 5	14883.15
MODEL 6	18236.96
MODEL 7	16264.39
MODEL 8	16226.06



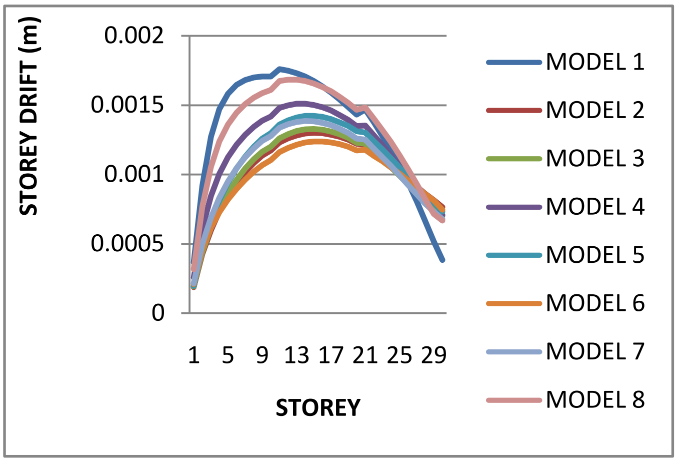
C. Maximum displacement for all structures with combination (DL+LL=EQXTP) in X-direction:

STRUCTURE	MAXIMUM DISPLACEMENT
MODEL 1	0.1314
MODEL 2	0.0954
MODEL 3	0.1037
MODEL 4	0.1033
MODEL 5	0.1102
MODEL 6	0.0938
MODEL 7	0.1021
MODEL 8	0.1077

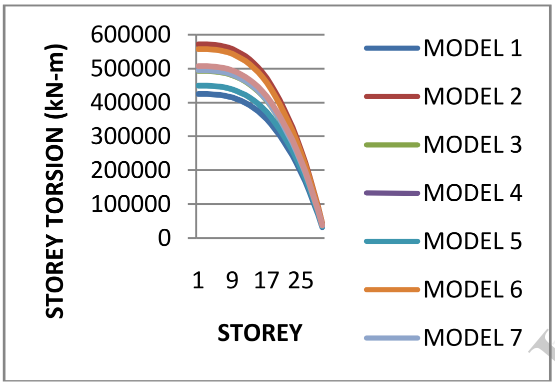


International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 9, September- 2014

D. Variation of storey drifts for all structures with combination (DL+LL+EAXTP) in X-direction:



E. Variation of storey torsion for all structures with combination 1.2(DL+LL+EAXTP):



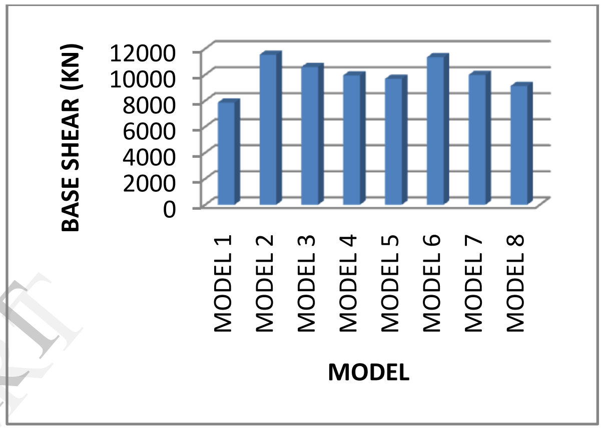
b) Response spectrum method:

In order to perform the seismic analysis and design of a structure, the actual time history record of the particular place is required. It is not possible to have such records at each and every location. Further, the seismic analysis can't be carried based on the peak value of the ground acceleration. To overcome the above difficulties, the earthquake response spectrum is the most popular tool in the seismic analysis of the structure. The method involves only the calculation of only the maximum values of the displacement and member forces in each mode of vibration using smooth design spectrum. This spectrum is the average of several earthquake motions.

The results for different structures analyzed using Response spectrum method are as follows:

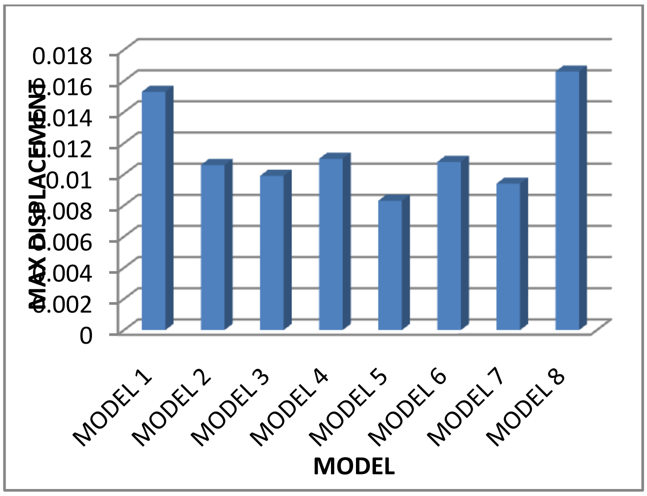
A. Base shear for different structures with combination (DL+LL+SPECX):

STRUCTURE	BASE SHEAR (KN)
MODEL 1	7854.94
MODEL 2	11537.05
MODEL 3	10594.48
MODEL 4	9946.9
MODEL 5	9678.83
MODEL 6	11338.35
MODEL 7	9984.07
MODEL 8	9123.91

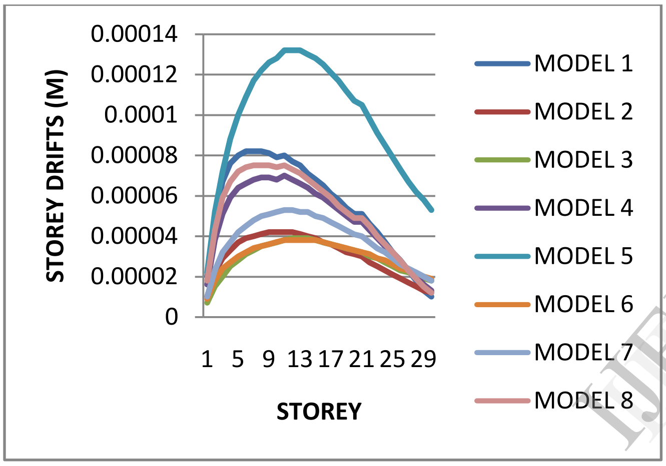


B. Maximum displacement for all structures with combination (DL+LL-WINDX) in X-direction:

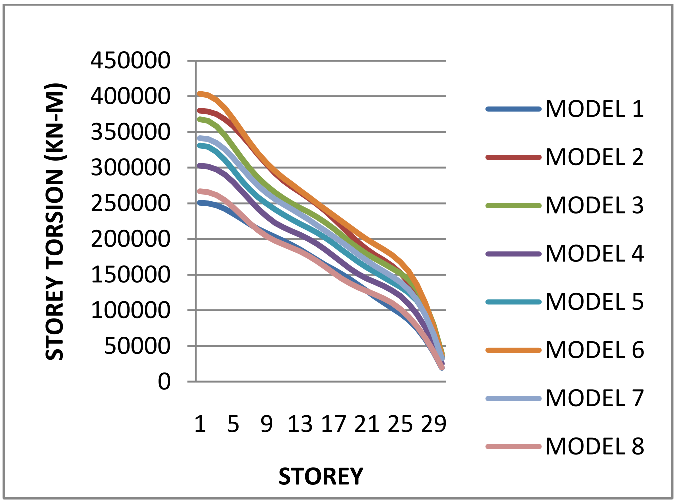
STRUCTURE	MAXIMUM DISPLACEMENT (M)
MODEL 1	0.0153
MODEL 2	0.0106
MODEL 3	0.0099
MODEL 4	0.011
MODEL 5	0.0083
MODEL 6	0.0108
MODEL 7	0.0094
MODEL 8	0.0166



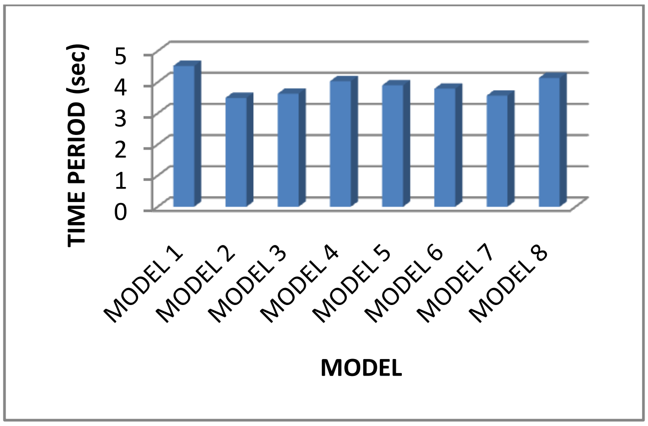
C. Variation of storey drifts for all structures with combination (DL+LL+SPECX) in X-direction:



D. Variation of storey torsion for all structures with combination 1.2(DL+LL+SPECX):



E. Variation of Time period for all structures:



5. DISCUSSIONS:

1. The base shear is increased by addition of shear walls due to increase in seismic weight. The percentage of Base shear increased by addition of Shear walls in MODEL 2 to MODEL 8 when compared with MODEL 1 in equivalent static method.

33.51% for MODEL 2.
15.67% for MODEL 3.
17.21% for MODEL 4.
6.7% for MODEL 5.
31.1% for MODEL 6.
16.9% for MODEL 7.
16.64% for MODEL 8.

The MODEL 5 has least increase of Base shear when compared to all other structures with shear wall. In Response spectrum method, the percentage of base shear increased by addition of Shear walls in MODEL 2 to MODEL 8 when compared with MODEL 1 is:

46.87% for MODEL 2.
34.87% for MODEL 3.
26.63% for MODEL 4.
23.21% for MODEL 5.
44.34% for MODEL 6.
27.10% for MODEL 7.
16.15% for MODEL 8.

In RSM method of analysis it is found that MODEL 8 has least Base shear.

2. The displacements are decreased by addition of shear walls. The percentage decrease of Displacement for MODEL 2 to MODEL 8 when compared with MODEL 1, without shear walls are as follows:

27.4% for MODEL 2.
21.08% for MODEL 3.
21.38% for MODEL 4.
16.13% for MODEL 5.
28.61% for MODEL 6.
22.3% for MODEL 7.
18.03% for MODEL 8.

The percentage decrease of displacement is highest for MODEL 6 in ESA method of analysis.

In Response spectrum method, the percentage decrease of displacement by addition of Shear walls in MODEL 2 to MODEL 8 when compared with MODEL 1 is:

32.5% for MODEL 2.
23.95% for MODEL 3.
26.92% for MODEL 4.
18.7% for MODEL 5.
32.16% for MODEL 6.
25.7% for MODEL 7.
30.6% for MODEL 8.

MODEL 2 shows the highest percentage decrease of displacement in RSM method.

3. The storey torsion increases with addition of shear walls. In ESA method of analysis MODEL 5 has least variation of storey torsion when compared to the rest of models with shear walls. In RSM method MODEL 8 shows least increase in storey torsion.

4. The storey drift in the middle stories are decreased by addition of shear walls when analyzed by both the methods. The percentage decrease in storey drifts in ESA method of analysis is as follows:

26.83% for MODEL 2.
24.50% for MODEL 3.
14.16% for MODEL 4.
19.22% for MODEL 5.
29.62% for MODEL 6.
21.32% for MODEL 7.
4.32% for MODEL 8.

MODEL 2 has highest decrease of percentage of storey drifts and MODEL 8 has least percentage.

In Response spectrum analysis,

41.61% for MODEL 2.
40.51% for MODEL 3.
21.99% for MODEL 4.
31.66% for MODEL 5.
44.43% for MODEL 6.
36.41% for MODEL 7.
19.8% for MODEL 8.

MODEL 6 shows highest percentage decrease of storey drifts in x-direction according to RSM analysis.

5. Time period also decreases when shear wall is added to the structure. The percentage decrease of time period is as follows:

22.7% for MODEL 2.
19.70% for MODEL 3.
10.88% for MODEL 4.
13.78% for MODEL 5.
16.18% for MODEL 6.
21.13% for MODEL 7.
8.56% for MODEL 8.

6. CONCLUSIONS:

1. All the structures are symmetrical about y-axis and unsymmetrical about x-axis. The center of mass and center of rigidity are influenced by the positioning of different shapes of shear walls. The structures with shear wall shows that the CM and CR getting closer compared to the structure without shear walls. MODEL 7 has the least difference between center of mass and center of rigidity.

2. The shape of shear wall and its position have a significantly influenced on the time period. MODEL 2 showed significant difference with respect to time period compared to the model without shear walls.

3. The shape of shear wall and its position has decreased the diaphragm displacement compared to the structure without shear wall. MODEL 2 shows good results with respect to displacement compared to other models according to ESA method. According to RSM method MODEL 5 shows good results with respect to displacement.

4. Positioning and the shape of shear walls do not show much difference on Base shear. But the base shear increases with addition of shear wall since the seismic weight increases. MODEL 5 shows least increase in the base shear.

5. The provision of shear wall and shape of shear wall has significant effect on storey drift in middle storeys. MODEL 6 shows good performance according to both ESA and RSA method of analysis.

6. For the columns located away from the shear wall has the high bending moment and less shear force when compared with the columns connected to the shear walls.

7. The moment resisting frame with shear walls are very good in lateral force such as earthquake and wind force. The shear walls provide lateral load distribution by transferring the wind and earthquake loads to the foundation. And also impact on the lateral stiffness of system and also carry gravity loads.

7. REFERENCES:

[1]. IS: 456-code of practice for plain and reinforced concrete
[2]. IS: 875(part 1-5)- code of practice for structural safety of building loading standards
[3]. IS 1893(Part-1):2002, Criteria for earthquake resistant design of structures.
[4]. IS 13920:1993,Ductile detailing of reinforced concrete structure subjected to seismic forces-code of practice.
[5]. SP: 16-design aids for reinforced concrete
[6] Earthquake resistant design by pankaj agarwal.
[7] Rosinblueth and Holtz “Analysis of shear walls in tall buildings” (1960)
[8] Clough.R, King I.P and Wilson E.I-“Structural analysis of multi storied buildings” (1964)
[9] Khan, F.R. and Sbrounis, J.A,(7) „Introduction of shear wall with frames in concrete Sabrcounis structure under lateral loads‟ (1964).
[10].www.iitk.ac.in/.../SeismicBehaviour_Design&DetailingofShearWalls-...
[11]. www.wisegeek.com/what-is-a-shear-wall.htm