Seismic analysis of flat slab multi-storey Building with varying Shear wall indices

Manish Dubey[1], Dr. Pankaj Singh[2], Niraj Kumar Soni[3], Goutam Varma[4]

[1,3,4]P.hd Research Scholars, Civil Engineering Department, SRK University, Bhopal, M.P., India
[2] HOD & Associate Professor, Civil Engineering Department, SRK, University, Bhopal, M.P., India

---***---

Abstract - *One of the most commonly used lateral load resisting systems in buildings is shear wall system. Shear walls have very high in-plane stiffness and strength, which can be used simultaneously to resist large horizontal loads and support gravity loads, making them quite beneficial in seismic performance of buildings. Shear walls contribute significant lateral stiffness, strength, and overall ductility and energy dissipation capacity. Therefore, we have introduced shear walls at different location with different wall indices on plan of building like side centre shear wall, corner shear wall, shear wall at near to centre of building plan. In the present study main focus is to determine the effect of shear wall configuration on seismic performance of flat slab buildings. Time history analysis has been done to flat slab buildings with various configurations with same plan. The top storey displacements have been obtained and compared to each other for all models to meet the effect of shear wall configuration on seismic performance of flat slab buildings.*

Key Words: Shear wall, flat slab, Shear wall indices, SAP200, Time history analysis, Storey Displacement.

1. INTRODUCTION

Shear walls are designed to resist gravity load and lateral load. The major factors for inclusion of shear walls are ability to minimize lateral drifts, simplicity of design and excellent performance in past earthquakes. They have very large in-plane stiffness that limit the value of lateral drift of the building under lateral loadings. Shear walls are intended to behave elastically during wind loading and in case of low to moderate seismic loading to prevent non-structural damage in the building. However, it is expected that the walls will be exposed to inelastic deformation during less frequent, severe earthquakes. Therefore, Shear walls must be designed to withstand forces that cause inelastic deformations while maintaining their ability to carry load and dissipate energy. Structural and non-structural damage is expected during severe earthquakes; however, collapse prevention and Life safety is main concern.

Shear walls are very effective at limiting damage according to the post-earthquake evaluations. Observed damage is dependent on the building and wall configuration. All of the early design codes regarding the design of Shear walls were strength-based. However, strict detailing requirements caused code requirements to be overly conservative for a majority of the buildings with Shear wall systems.

A shear wall is defined as a vertical structural member having a length of seven or more times greater than its thickness. Being the major lateral load resistant units in multi storey building structures, shear walls have been studied experimentally and theoretically over the last fifty years.

In the lateral load analysis of building structures having shear walls, proper methods should be used for modelling of shear wall assemblies. Shear wall models in the literature can be divided into two:

1. Models developed for elastic analysis of building structures.

2. Models developed for nonlinear analysis of building structures.

1.1 Classification of Shear wall

Shear walls are classified mostly according to their Aspect Ratios (overall height to length ratio)

- Walls that have aspect ratios of one or less are commonly referred to as short wall.
- Walls with aspect ratios of three or greater are typically named as tall, slender or Cantilever wall.
- Shear walls that have aspect ratios between one and three are commonly referred to as intermediate walls or squat walls.

Applied Technology Council ATC 40 defines: -

- Walls as slender if their aspect ratio is equal to or greater than four.
- Walls as squat if the aspect ratio is equal to or smaller than two.

1.2 Existing wall Indices

Shear wall index is an indicator of the proportioning of walls that are used for seismic resistance of buildings. Wall index for a structure is generally obtained by the ratio of total area of shear walls at a typical storey in the direction of seismic analysis (ΣA_w) to floor plan area at that storey (A_p) or total floor plan area of the building (ΣA_p).

1.3 Objective of the study

Good performance of the flat slab building with shear wall or Shear walls in recent severe earthquakes has drawn attention of researchers. These earthquakes showed that the large in plane stiffness provided by walls reduce lateral drift which in turn limits damage of both structural and non-structural components. This fact reveals drift ratio of flat slab buildings. The relationship between shear wall ratio and lateral drift ratio can be used to suggest sufficient wall ratio at the preliminary design stage of buildings.

- In order to evaluate shear wall indices for reinforced concrete structures, five 3D models, mid-rise (10 & 15 stories) flat slab building with different wall ratio are generated.
- Modal analysis of these flat slab model building is performed by SAP2000 to get the necessary modal information.

Linear Time history analyses of modeled building are performed in SAP2000 to get the Displacement and Inter storey drift

2. METHOD OF ANALYSIS

The structural models of the analyzed flat slab buildings are prepared and analyzed by SAP2000. Shear walls are located in axes similar to the practice. Then, shear wall ratios of the model buildings are changed to obtain different shear wall ratio. Five different models for each number of storey having same floor dimensions but different shear wall ratio is created for use in the analyses. Shear wall ratio is determined by dividing total shear wall area in one direction to the floor plan area of one storey. Wall ratios change from 0.49 to 3.60 percent in the models

2.1 Representation of Building

The letters; "W", "C" and "B" are used for abbreviation of shear walls, columns and beams, respectively. Members in X direction are numbered in increasing order from left to right and members in Y direction are numbered in increasing order from top to bottom in all models. The first number after the letter "B" designates the storey number that beams exist. Models are named according to a standardized procedure. A general format of "Mi_n_Tx" is used. In this format, the letter "M" is the abbreviation of the word "Model", the letter n designates the storey number and the letter "T" shows shear wall thickness. The letter "i" which is next to "M" designates the model number and changes from 1 to 5. The letter "x" next to "T" shows the wall thickness in mm and takes values of 150 and 300.

For example, M3_10_T150 is the third model with ten storey having shear wall thickness of 150 mm.

2.2 Computation of Shear Wall Index

The calculation of shear wall index for M3_15_T300 in X & Y direction using the parameter from plan model 3 is as follows:

Number of shear wall in
X – direction of 3.5m length = 6

Area of shear wall
in X - Direction = (6 X 3.5 X 0.3) = 6.3 m^2

Total plan area = 24.5 X 17.5 = 428.75 m^2

Wall ratio for M3_15_T300 =

(Total area of shear wall / Total floor plan area) X 100

= (6.3 / 428.75) X 100 = 1.47 %

Similarly, for Y direction:

Number of shear wall in
Y - direction of 3.5m length = 6

Area of shear wall in
Y - Direction = (4 X 3.5 X 0.3) = 4.2 m^2

Total plan area = 24.5 X 17.5 = 428.75 m^2

Wall ratio for M3_15_T200 =
(Total area of shear wall / Total floor plan area) X 100
= (4.2 / 428.75) X 100
= 0.98 %

2.3 Building Parameter

Size of column = 0.6 m X 0.6 m
Shear wall thickness = 0.15 m and 0.30 m
Slab thickness = 0.12 m
Concrete f_{ck} = 20 N/mm^2
Steel f_y = 415 N/mm^2
Floor to floor height = 3.0 m
Number of storey = 10 and 15

Table No. 1 Model Description

S.No	Model ID	X direction	Y Direction
1	M1(Model without shear wall)	-----	-----
2	M2_10_T150	0.73	0.73
3	M2_10_T300	1.47	1.47
4	M3_10_T150	0.73	0.49
5	M3_10_T300	1.47	0.98
6	M4_10_T150	0.98	0.49
7	M4_10_T300	1.96	0.98
8	M5_10_T150	1.96	0.98

9	M5_10_T300	3.92	1.96
10	M2_15_T150	0.73	0.73
11	M2_15_T300	1.47	1.47
12	M3_15_T150	0.73	0.49
13	M3_15_T300	1.47	0.98
14	M4_15_T150	0.98	0.49
15	M4_15_T300	1.96	0.98
16	M5_15_T150	1.96	0.98
17	M5_15_T300	3.92	1.96

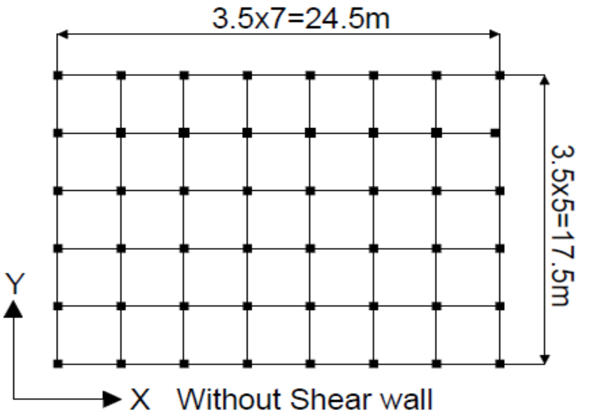


Fig.1 Shear wall configuration-1

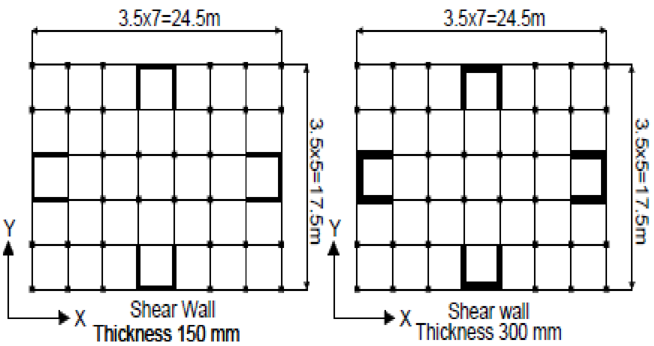


Fig. 2 Shear wall configuration-2

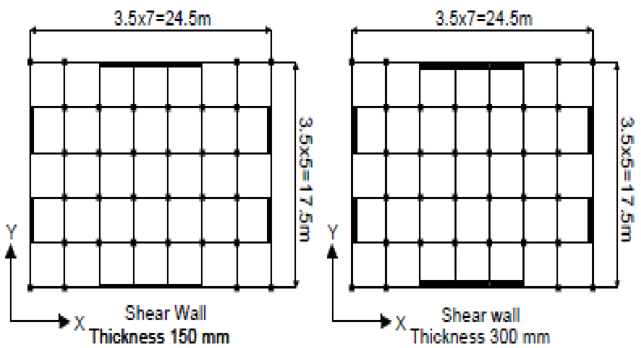


Fig. 3 Shear wall configuration-3

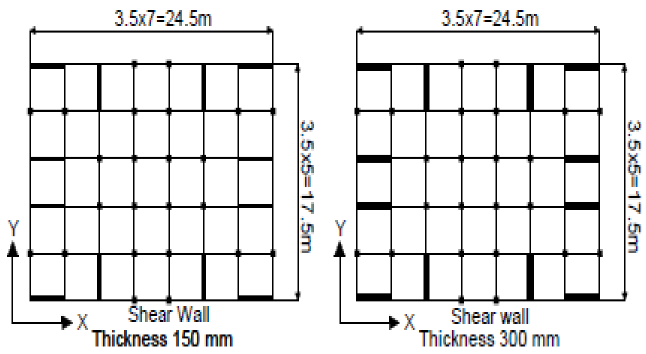


Fig. 4 Shear wall configuration-4

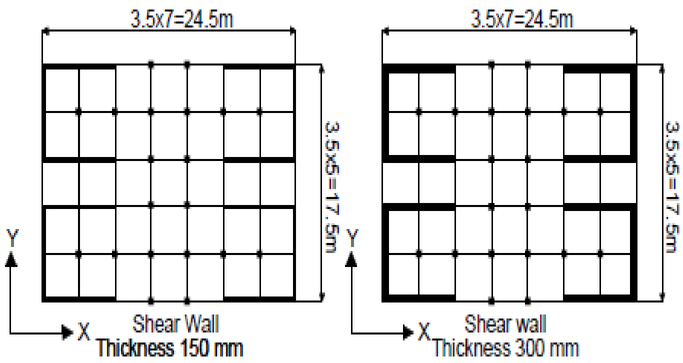
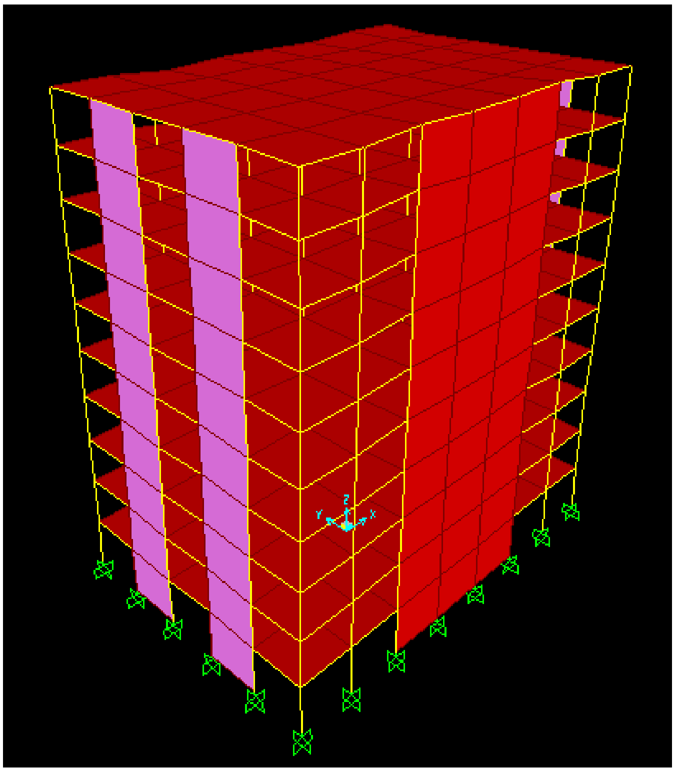


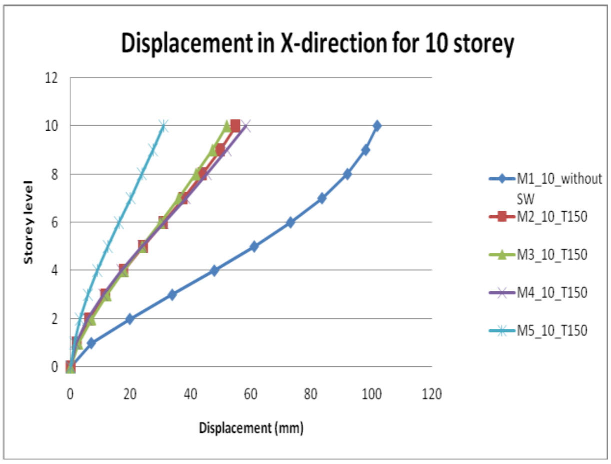
Fig. 5 Shear wall configuration-5



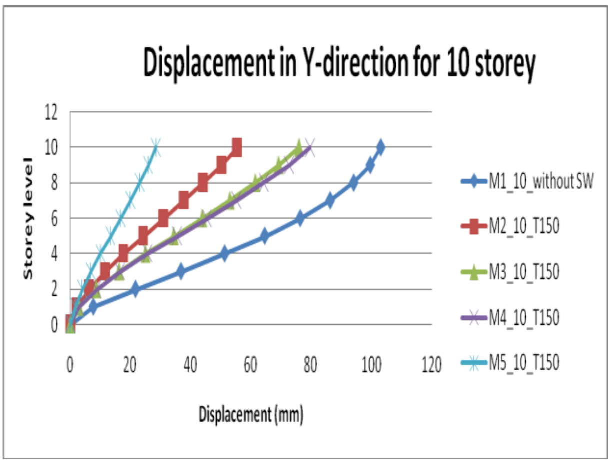
Model Id {M3_10_150}

Fig. 6 3D Structural model with 10 storey

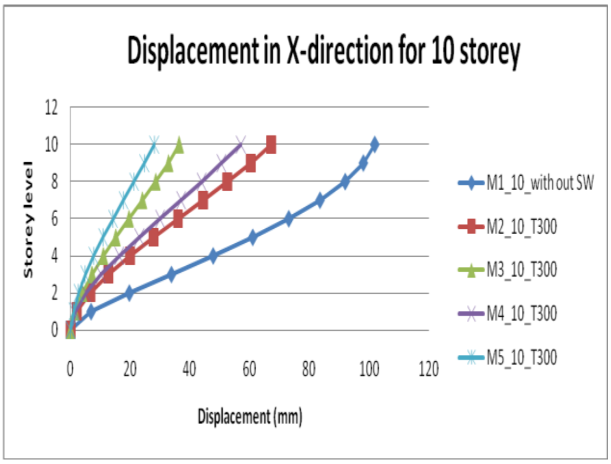
3. Result



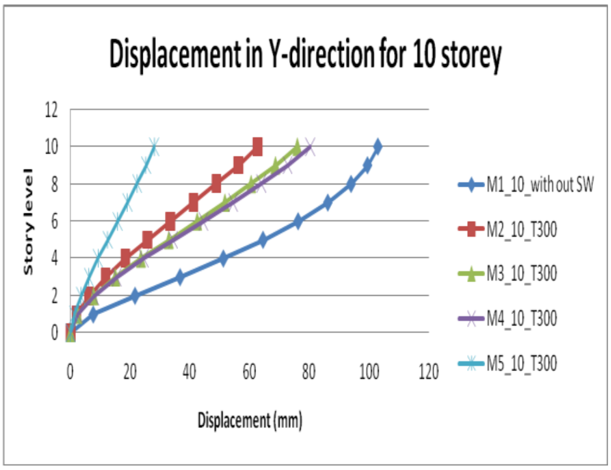
Graph 1 Storey Displacement in X-direction for Shear wall thickness of 150 mm



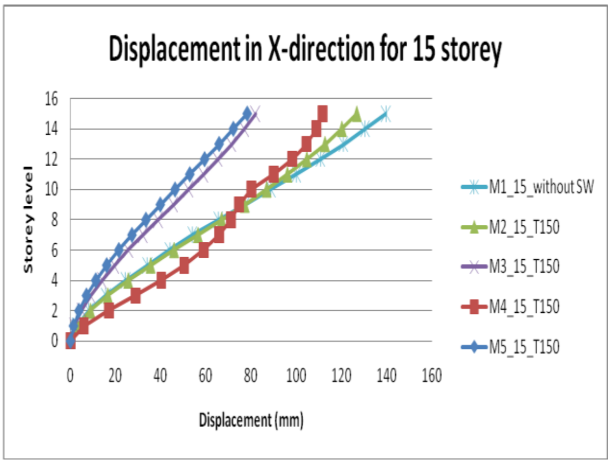
Graph 2. Storey Displacement in Y-direction for Shear wall thickness of 150 mm



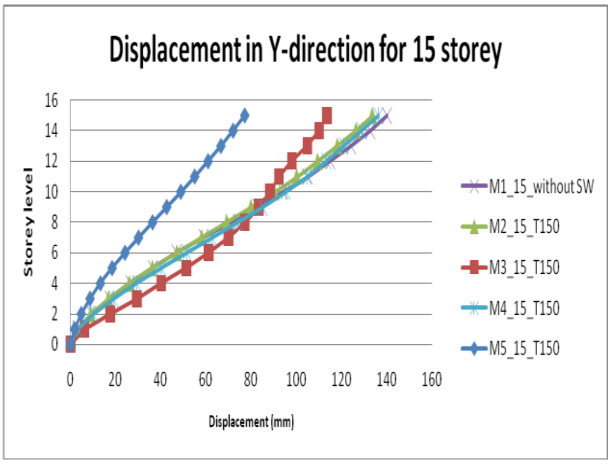
Graph 3 Storey Displacement in X-direction for Shear wall thickness of 300 mm



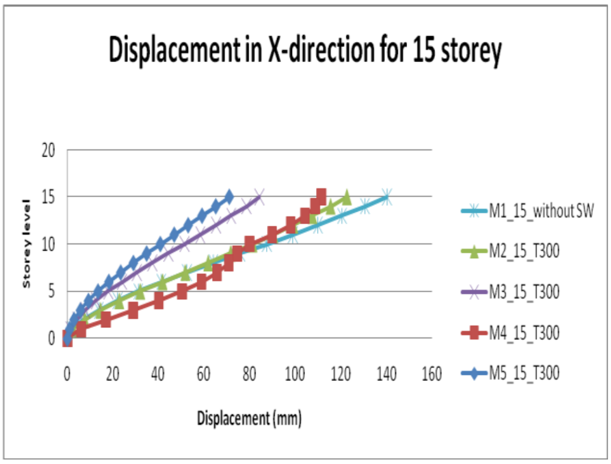
Graph 4 Storey Displacement in Y-direction for Shear wall thickness of 300 mm



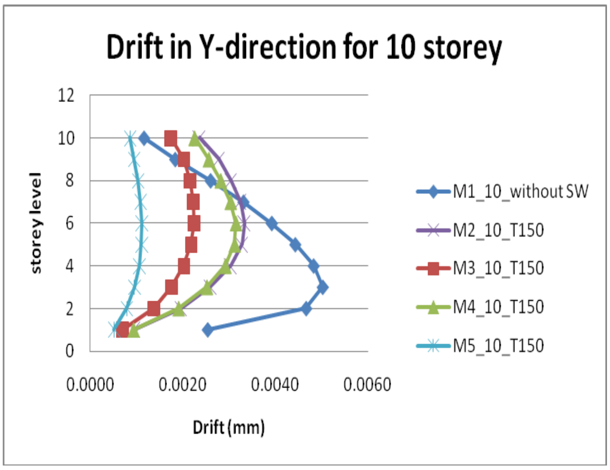
Graph 5 Storey Displacement in Y-direction for Shear wall thickness of 150 mm



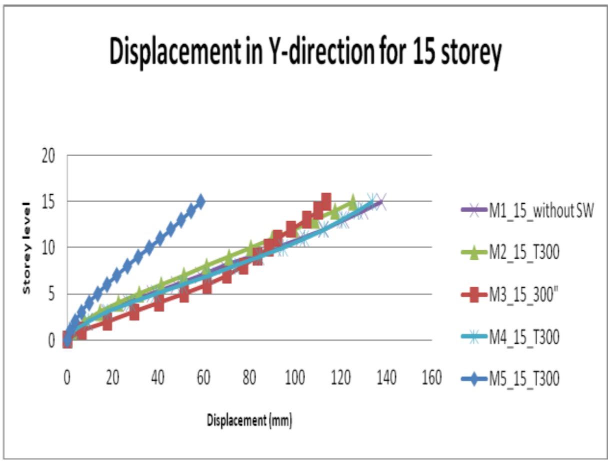
Graph 6 Storey Displacement in Y-direction for Shear wall thickness of 150 mm



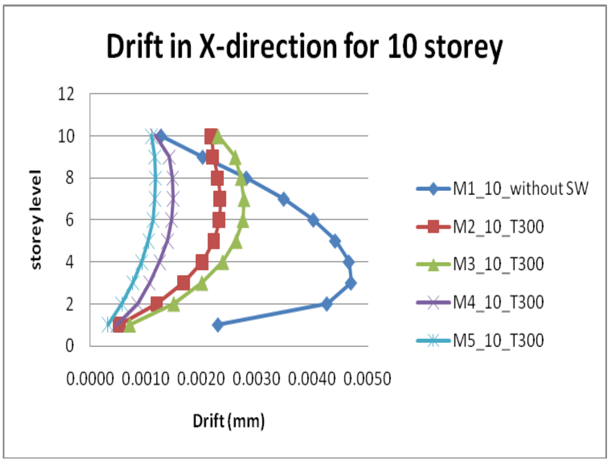
Graph 7 Storey Displacement in X-direction for Shear wall thickness of 300 mm



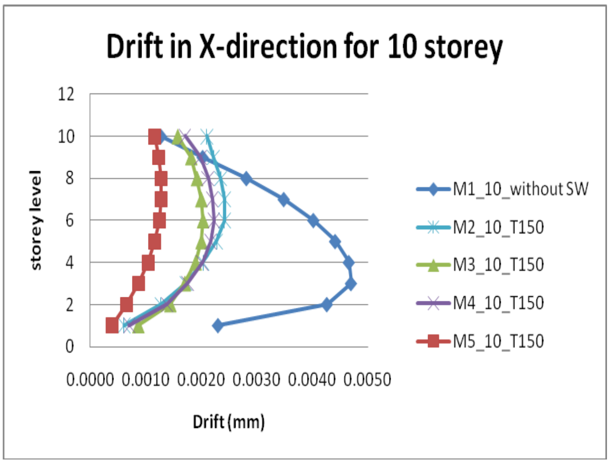
Graph10 Storey Drift in X-direction for Shear wall thickness of 150 mm



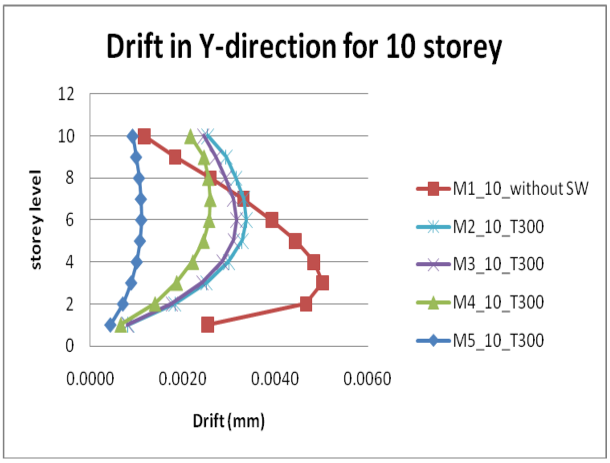
Graph 8 Storey Displacement in Y-direction for Shear wall thickness of 300 mm



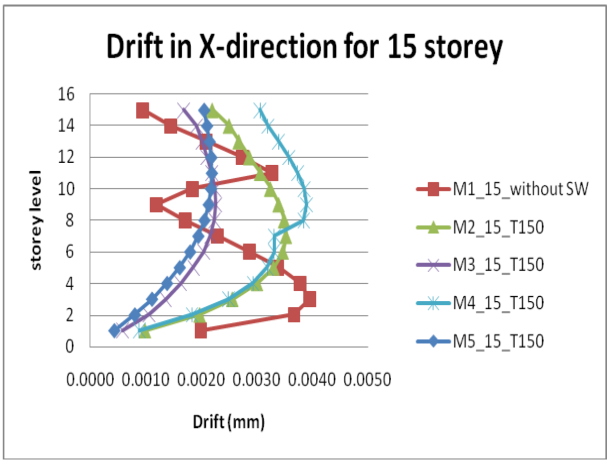
Graph 11 Storey Displacement in X-direction for Shear wall thickness of 300mm



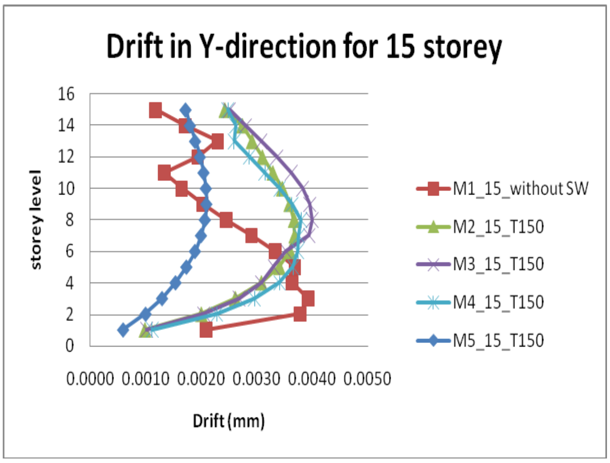
Graph 9 Storey Displacement in Y-direction for Shear wall thickness of 150 mm



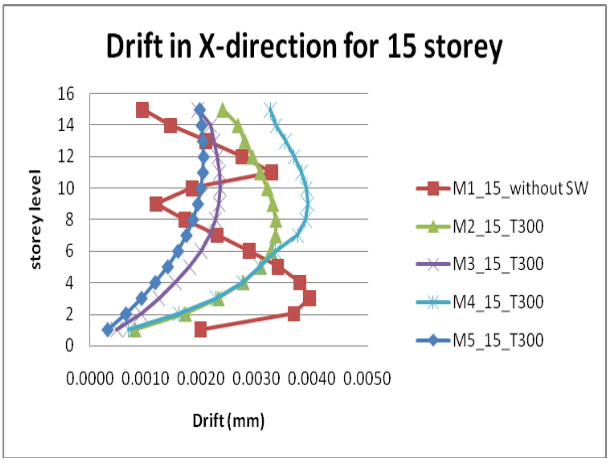
Graph 12 Storey Displacement in Y-direction for Shear wall thickness of 300mm



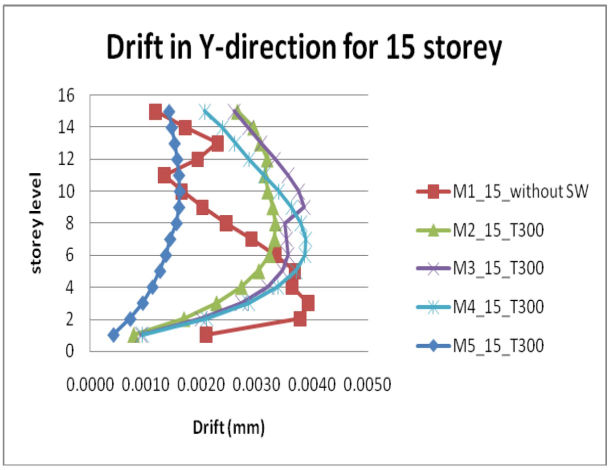
Graph 13 Storey Drift in X-direction for Shear wall thickness of 150 mm



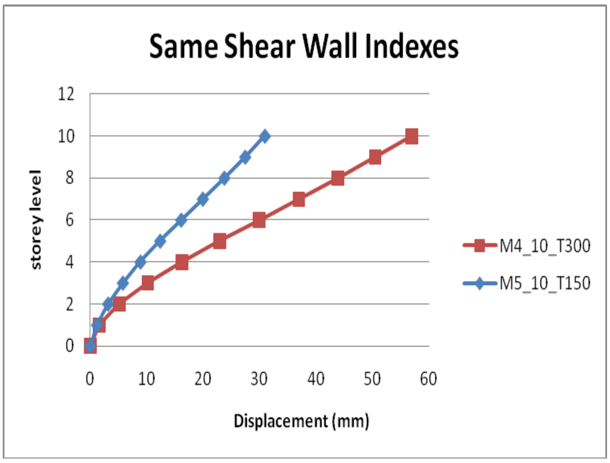
Graph.14 Storey Drift in Y-direction for Shear wall thickness of 150 mm



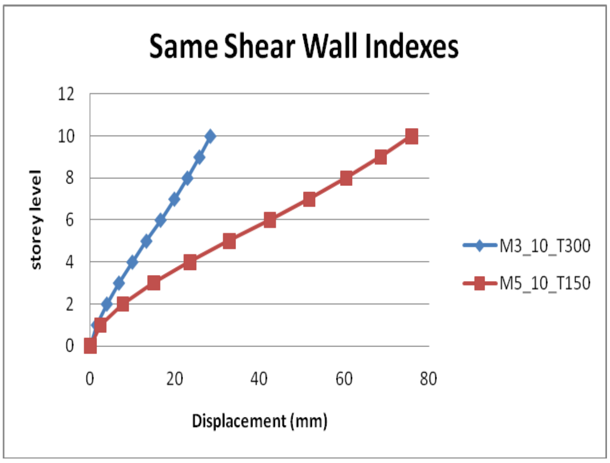
Graph15 Storey Drift in X-direction for Shear wall thickness of 300 mm



Graph.16 Storey Drift in Y-direction for Shear wall thickness of 300 mm



Graph 17 Different models with same shear wall Indices in X-direction



Graph.18 Different models with same shear wall Indices in Y-direction

4. Conclusion

Following conclusions were derived as a result of the study performed throughout work: As per discussion of results we conclude that there is marginal reduction in Displacement, by introducing shear wall. But the Displacement is reduced by introducing shear wall at corner along both directions.

1. For earthquake as per IS 1893-1-2002CL:7.11.1 page no 27, Maximum drift limitation of 0.004 as per IS code is satisfied for all the Shear Wall Models of the building using Elcentro earth quake.
2. Changing the position of shear wall will affect the attraction of forces, so that wall must be in proper position.
3. If the dimensions of shear wall are large then major amount of horizontal forces are taken by shear wall.
4. Providing shear walls at adequate locations substantially reduces the displacements due to earthquake.

REFERENCES

1. Christidis Konstantinos, Vougioukas Emmanouil and Trezos .G Konstantinos (2013) "Seismic assessment of RC shear walls non complaint with current code provision" Magazine of Concrete Research, Vol. 65, No. 17, 1059 – 1072
2. Rajesh Jayarambhai Prajapati &Vinubhai. R. Patel "EFFECT OF DIFFERENT POSITION OF SHEAR WALL ON DEFLECTION IN HIGH RISE BUILDING" International Journal of Advances in Engineering & Technology, Sept. 2013.
3. 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
4. P. S. Kumbhare, A. C. Saoji " Effectiveness of Changing Reinforced Concrete Shear Wall Location on Multi-storeyed Building" Vol. 2, Issue 5, September- October 2012, pp.1072-1076
5. Baetu Sergiu And Ciongradi Ioan-Petru (2011) "Nonlinear finite element analysis of reinforced concrete walls" Gheorghe Asachi" Technical University of IASI , Tomul LVII (LXI), Fasc. 1, 2011.
6. Baros .K .D and Anagnostopoulos .A .S (2008) "An overview of pushover procedures for the analysis of buildings susceptible to torsional behavior" The 14th World Conference on Earthquake Engineering, October 12-17,2008 Beijing, China.
7. Beyer .K, Dazio .A and Priestley .N .J .M (2008) " Quasi-static cyclic tests of two u-shaped reinforced concrete walls " Journal of Earthquake Engineering, 12:1023–1053, 2008.
8. Computers and Structures Inc. (CSI), 2007, CSI Analysis Reference Manual for SAP2000, ETABS, and SAFE, Berkeley, California, USA, January 2007.
9. Gary R. Searer, Sigmund A. Freeman (2004) "Design Drift requirement for Long – period Structures" 13th world conference on earthquake engineering, Vancouver, B.C., Canada, August 1 – 6, Paper number 3292.
10. Gary R. Searer, Sigmund A. Freeman (2004) "Seismic Drift and the Design of Claddings" Proceedings of the ASCE Structures Congress and Exposition, 2004.
11. Hosseini Mahmood, Sadeghi Hossein And Habiby Seidali (2011) "Comparing the Nonlinear Behaviors of Steel and Concrete Link Beams in Coupled Shear Walls System by Finite Element Analysis" Published by Elsevier Ltd., 14 (2011) 2864–2871.
12. IS 456: 2000, "Plain and reinforced concrete code of practice." Bureau of Indian Standards. Fourth revision
13. IS 1893: 2002, "Criteria for Earthquake resistant design of structure." Bureau of Indian Standards. Fifth revision
14. Kelly Trevor (2006) "A blind prediction test of nonlinear analysis procedures for reinforced concrete shear walls" Technical Director, Holmes Consulting Group, Auckland. Lepage Andres and Sanchez .E Reynaldo (2012) "Practical Nonlinear Analysis for Limit Design of Reinforced Masonry Walls" The Open Civil Engineering Journal, 2012, 6, 107-118.
15. Massone .M Leonardo, Orakcal Kutay And Wallace John (2004) "Flexural and shear responses in slender RC shear walls" 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 106