A Comparative Study of Different Configuration of Shear Wall Location in Soft Story Building Subjected to Seismic Load.

R.S.Mishra[1], V.Kushwaha[2], S.Kumar[3]

[1 2 3]Assistant Professor, Civil Engineering Department, SSITM Bhilai

---

Abstract — ***During earthquake RC (Reinforced Concrete) structures are subjected to lateral displacement. Most of the RC structures are designed to resist gravity loads only neglecting the effect of lateral forces arising due to earthquake. This study is concentrated to analyze the seismic behavior of structure (Special Moment Resisting Frame, SMRF). The study has been carried out using STAAD.PRO software, IS 1893:2002, IS 13920:1993 and IS 456:2000. The building under analysis consist of 11 floors and has 5 bays along both direction with a span of 4m each, floor to floor height is 3m, ground floor to first floor height is 2.80m. The building has been to be located in seismic zone- II (Bhilai region, Chhattisgarh) of India. While analyzing using STAAD.PRO, soft storey has been observed at 1st and 11th floor. A comparative has been done by placing shear wall at different location in the building subjected to seismic load. These locations consist of shear wall being placed at periphery, at intermediate position and in the core.***

Key Words: Drift, Seismic Force, Shear Wall, Soft Storey, STAAD.Pro, Stiffness.

1. INTRODUCTION

Soft story or stilt storey is a feature which can be seen frequently in India and abroad also, generally used for parking or retail purpose.These are basically ground story which consists of only columns without any pattern wall. Soft storey is one in which lateral stiffness is less than 70% of that in story above or less than 80% of average lateral stiffness of three stories above (IS 1893 Part-I, 2002) [1]. It has been observed that soft storey buildings are easily vulnerable to damage under the effect of seismic forces.

It doesn't meet the minimum bare requirement with respect to drift and stiffness. With respect to floors above the soft storey shows larger flexibility and hence larger displacement under the effect of seismic forces. When subjected to seismic loads the upper stories move almost together as a single block and hence most of horizontal displacement of building occurs in soft story which causes failure of structure due to excessive drift. During the earthquake the dynamic ductility demand gets intense in soft storey and upper storey tends to remain elastic. This is where the importance of shear wall comes into picture.

Shear wall is vertical structure member which can resist moment, shear and axial load arising due to gravity and lateral (earthquake) load. It offers adequate rigidity for lateral load resistance and provides sufficient stiffness to whole structure. Mark Fintel, a noted civil engineer in U.S.A said "We cannot afford to build concrete buildings meant to resist severe earthquake without shear wall". Structure with shear wall offer significant reduction in lateral sway. Apart from structural advantages shear walls are cost efficient also. Misam.A and MangulkarMadhuri.N et al [2] investigated the addition of shear wall to the building in different arrangement in order to reduce soft storey effect on structural seismic response and recommended that location and numbering of shear wall acts as an important factor for the soft storey structures to displace during earthquake. G.V.S.Siva Prasad and S.Adiseshu et al [3] developed a new method and analysis of shear wall framing system and a new model to compare the safety of structure and cost effectiveness structure for a lateral loading system for a tall and high rise structure.

2. STRUCTURAL PROPERTIES OF RC BUILDING

- stories – G+11
- Storey height – 3m
- Beam dimension – 0.25m*0.25m
- Inner column dimension – 0.35m*0.35m
- Outer column dimension – 0.40m*0.40m
- Shear wall thickness – 0.20m
- Grade of concrete – M30
- Grade of steel (IS) – Fe 415
- F_{ck} – 30 N/mm^2
- F_y – 500 N/mm^2
- Slab thickness – 150 mm
- Zone factor – 0.1

- Importance factor – 1
- Response reduction factor – 5
- Rock and soil site factor (SS) – 1
- Damping ratio – 5
- Period in Z direction – 0.50 seconds

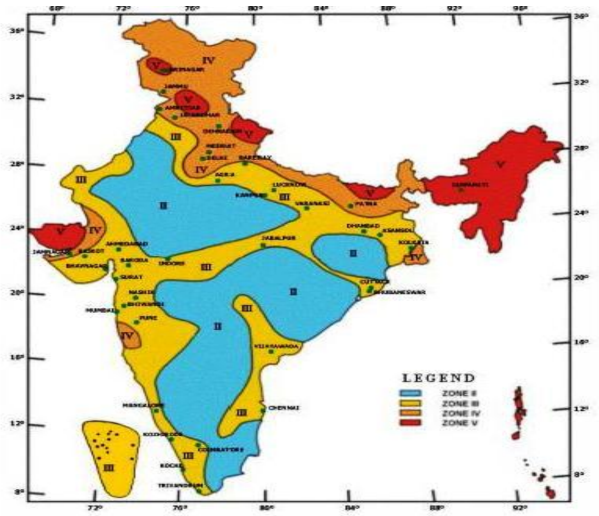


Figure – 1 Seismic zone of India as per geological map

3. ANALYTICAL METHODOLOGY

The analysis of structure is done by using STAAD PRO software. The different configuration position of shear wall in Reinforced Concrete building were analyzed for stiffness and seismic stability with respect to the lateral displacement in X and Z direction, drift at different storey height level, buckling mode factor, node displacement data and concrete and steel usage for economic and safe construction of structure under seismic analysis.

The data used is as per Seismic definition (1983-2002) provided which is static earthquake analysis method and then applying soft storey check for deducting any soft storey in building designed. The specification used by the software is -

1893-Specification = {RF f2, I f3, SS f4, (ST f5), DM f6, (PX f7), (PZ f8), (DT f9)}

Where,

Zone f1 = Seismic zone coefficient. Refer to Table 2 of IS:1893 (Part 1)-2002.

RF f_2 = Response reduction factor. Refer Table 7 of IS: 1893 (Part 1) -2002.

I f_3 = Importance factor depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance. Refer Table 6 of IS: 1893(Part 1)-2002.

SS f_4 = Rock or soil sites factor (=1 for hard soil, 2 for medium soil, 3 for soft soil). Depending on type of soil, average response acceleration coefficient S_a/g is calculated corresponding to 5% damping. Refer Clause 6.4.5 of IS: 1893 (Part 1) -2002.

ST f_5 = Optional value for type of structure (=1 for RC frame building, 2 for Steel frame building, 3 for all other buildings). If this parameter is mentioned the program will calculate natural period as per Clause 7.6 of IS: 1893(Part 1)-2002.

DM f_6= Damping ratio to obtain multiplying factor for calculating Sa/g for different damping. If no damping is specified 5% damping (default value 0.05) will be considered corresponding to which multiplying factor is 1.0. Refer Table 3 of IS: 1893(Part 1)-2002.

PX f_7 = Optional period of structure (in sec) in X direction. If this is defined this value will be used to calculate S_a/g for generation of seismic load along X direction.

PZ f_8 = Optional period of structure (in sec) in Z direction. If this is defined this value will be used to calculate Sa/g for generation of seismic load along Z direction.

DT f_9 = Depth of foundation below ground level. It should be defined in current unit. If the depth of foundation is 30 m or below, the value of Ah is taken as half the value obtained. If the foundation is placed between the ground level and 30 m depth, this value is linearly interpolated between Ah and 0.5Ah.

By default STAAD calculates natural periods of the structure in both X and Z directions respectively which are used in calculation for base shear. If, however, PX and PZ are mentioned the program will consider these values for calculation of average response acceleration coefficient. If instead of PX and PZ values ST is mentioned the program will calculate natural period depending upon the empirical expression given in IS: 1893 (Part 1)-2002.

Soft Storey Checking –

As per the IS: 1893-2002 code Clause 7.1, to perform well during an earthquake a building must have simple and regular configuration, adequate lateral strength, stiffness and ductility. This is because a building with simple regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation, will suffer much less damage than buildings with irregular configurations.

Using the command PDELTA ANALYSIS instead of PERFORM ANALYSIS. The PDELTA ANALYSIS will accommodate all requirements of the second- order analysis described by IS: 456, except for the effects of the duration of the loads. PDELTA ANALYSIS, as performed by STAAD may be used for the design of concrete members. However it must be noted, to take advantage of this analysis, all the combinations of loading must be provided as primary load cases and not as load combinations.

This is due to the fact that load combinations are just algebraic combinations of forces and moments, whereas a primary load case is revised during the P-delta analysis based on the deflections. Also it should be noted that the proper factored loads (like 1.5 for dead load etc.) should be provided by user. STAAD does not factor the loads automatically.

The total requirement of concrete and steel bars is calculated by the software as per IS-456, the node displacement data provided in the form of table is tabulated summary of maximum node displacement at various locations of shear wall in the structure. By the application of shear wall the lateral stability is checked along with moment generated in the joint (nodes) of the designed structure.

Figure 2 – Failure of multi storey building due to soft storey at parking level.

4. SOFT STOREY AND SHEAR WALL

Shear wall is vertical structure member which can resist moment, shear and axial load arising due to gravity and lateral (earthquake) load. A soft storey is generally a weak story which offers less stiffness or insufficient ductility to the stresses generated due to earthquake. Soft stories are generally encountered on the bottom stories of building and hence failure at soft stories may result in failure of whole structure. In such case providing shear wall is an effective measure to counteract this problem. Shear walls have appreciable stiffness in their own plane but offer very little stiffness in a perpendicular plain.

- **As per IS-1893:2002 (part I) [6]**

A Soft Storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

Due to high rise in population at a frequent rate construction of apartment and high rise buildings is in fashion to alter the land use to accommodate such huge population. To further alter the land use and to make construction economic parking and retail space is provided at the ground floor of these structures and this is where soft storey is encountered. Figure - 2 shows the failure of whole structure due to soft storey at parking level. Although no structural damage has been observed in upper stories, but the structure looses it's capacity to resist gravity loads partially or fully making the structure unusable as a whole.

Location of Shear Wall –

A shear wall is similar to column taking axial load but of smaller thickness with respect to standard column as such slab is to beam,

Shear wall has been also adopted as a member to bear lateral forces due to various loading patterns specially to counter lateral stress generated by seismic earthquake forces.

It has been studied and advised that building structure provided with shear wall like member could easily bear stress and enhance stiffness of the structure against the drift of vertical structural alignment i.e. displacement of column to beam or slab member forming a storey. The structural location of shear wall should be such that it allows maximum load to pass through it in lateral direction for reducing shear failure to other structural members such as column in normal direction, which may fail in shear to lateral load induced by seismic waves.

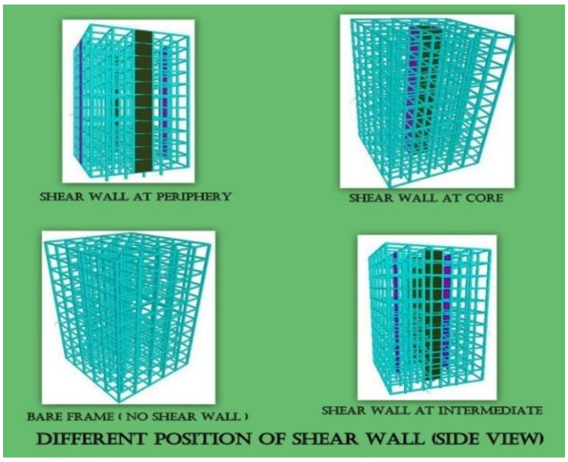


Figure – 3 Different position of Shear Wall, Side view.

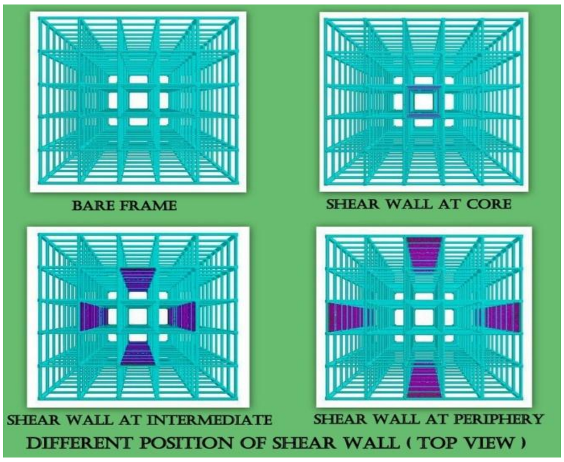


Figure – 4 Different position of Shear Wall, Top view.

5. RESULT AND DISCUSSION

a) Table for various mode of structures used.

Table -1 Bare frame displacement data as per software calculations.

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	rY rad	rZ rad
Max X	419	1 LOAD CAS	0.118	10.798	201.686	201.975	0.004	-0.000	-0.000
Min X	424	1 LOAD CAS	-0.118	10.798	201.686	201.975	0.004	0.000	0.000
Max Y	130	1 LOAD CAS	0.017	28.661	72.914	78.345	0.006	-0.001	0.000
Min Y	160	1 LOAD CAS	-0.017	-28.650	72.915	78.341	0.006	-0.001	-0.000
Max Z	444	1 LOAD CAS	-0.037	-25.634	201.998	203.618	0.004	-0.000	0.000
Min Z	37	1 LOAD CAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max rX	122	1 LOAD CAS	-0.008	-24.625	46.468	52.589	0.007	-0.000	-0.000
Min rX	37	1 LOAD CAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max rY	31	1 LOAD CAS	0.096	-28.642	24.199	37.496	0.005	0.002	0.000
Min rY	36	1 LOAD CAS	-0.096	-28.642	24.199	37.496	0.005	-0.002	-0.000
Max rZ	12	1 LOAD CAS	0.080	10.770	24.230	26.516	0.004	-0.001	0.001
Min rZ	7	1 LOAD CAS	-0.080	10.770	24.230	26.516	0.004	0.001	-0.001
Max Rst	418	1 LOAD CAS	-0.047	28.585	201.713	203.728	0.004	0.000	0.000

Table –2 Periphery frame displacement data as per software calculations.

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	rY rad	rZ rad
Max X	442	1 LOAD CAS	0.150	-13.295	187.786	188.256	0.004	0.000	-0.001
Min X	424	1 LOAD CAS	-0.150	13.294	187.785	188.256	0.004	0.000	0.001
Max Y	89	1 LOAD CAS	-0.035	28.333	57.698	64.279	0.005	0.001	-0.000
Min Y	124	1 LOAD CAS	-0.035	-28.333	57.698	64.279	0.005	-0.001	-0.000
Max Z	415	1 LOAD CAS	0.007	23.243	188.465	189.892	0.004	-0.000	-0.000
Min Z	37	1 LOAD CAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max rX	91	1 LOAD CAS	-0.003	23.275	44.170	49.927	0.007	0.000	-0.000
Min rX	37	1 LOAD CAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max rY	31	1 LOAD CAS	0.107	-28.332	28.610	40.265	0.005	0.002	0.000
Min rY	6	1 LOAD CAS	0.106	28.332	28.610	40.265	0.005	-0.002	0.000
Max rZ	12	1 LOAD CAS	0.092	13.271	28.627	31.554	0.004	-0.002	0.001
Min rZ	30	1 LOAD CAS	-0.092	-13.271	28.627	31.554	0.004	-0.002	-0.001
Max Rst	413	1 LOAD CAS	0.051	28.321	187.783	189.907	0.005	-0.000	-0.000

Table -3 Core frame displacement data as per software calculations.

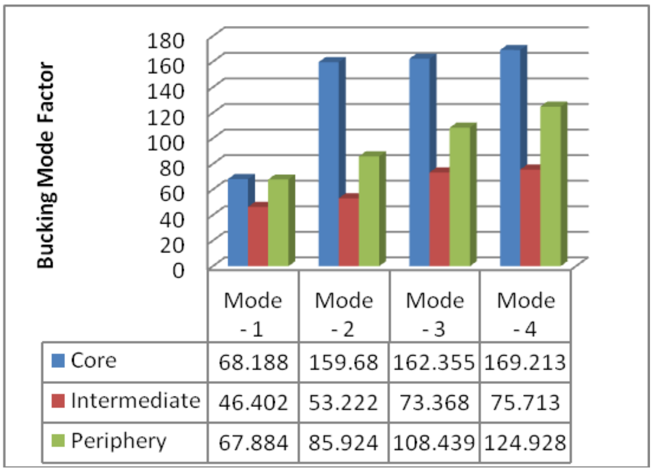
	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	rY rad	rZ rad
Max X	22	1 LOAD CAS	0.162	-1.244	5.330	5.475	0.001	0.000	0.000
Min X	16	1 LOAD CAS	-0.165	1.244	5.330	5.475	0.001	0.000	-0.000
Max Y	197	1 LOAD CAS	-0.018	8.191	30.618	31.694	0.002	0.000	-0.000
Min Y	232	1 LOAD CAS	-0.022	-8.191	30.622	31.698	0.002	-0.000	-0.000
Max Z	448	1 LOAD CAS	-0.012	-8.181	60.562	61.112	0.001	-0.001	-0.000
Min Z	37	1 LOAD CAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max rX	268	1 LOAD CAS	-0.025	-8.191	36.223	37.137	0.002	-0.000	-0.000
Min rX	37	1 LOAD CAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max rY	378	1 LOAD CAS	-0.029	6.943	51.492	51.958	0.001	0.001	-0.000
Min rY	411	1 LOAD CAS	-0.034	-6.943	51.495	51.961	0.001	-0.001	-0.000
Max rZ	15	1 LOAD CAS	0.161	1.244	5.329	5.475	0.001	-0.000	0.000
Min rZ	21	1 LOAD CAS	-0.164	-1.244	5.329	5.474	0.001	-0.000	-0.000
Max Rst	448	1 LOAD CAS	-0.012	-8.181	60.562	61.112	0.001	-0.001	-0.000

Table – 4 Intermediate frame displacement data as per software calculations.

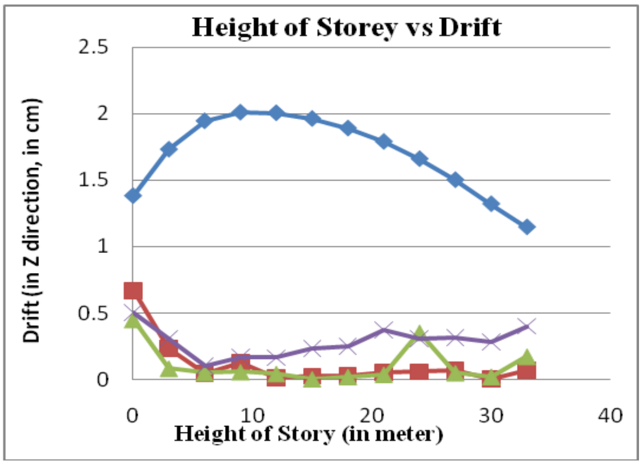
	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	rY rad	rZ rad
Max X	442	1 LOAD CAS	0.038	-3.668	60.399	60.510	0.001	-0.000	-0.000
Min X	424	1 LOAD CAS	-0.038	3.668	60.399	60.510	0.001	-0.000	0.000
Max Y	346	1 LOAD CAS	0.004	8.782	50.813	51.567	0.002	-0.000	0.000
Min Y	376	1 LOAD CAS	-0.004	-8.782	50.813	51.566	0.002	-0.000	-0.000
Max Z	416	1 LOAD CAS	-0.006	7.405	62.200	62.639	0.002	0.000	0.000
Min Z	37	1 LOAD CAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max rX	301	1 LOAD CAS	-0.000	-7.411	40.718	41.387	0.002	-0.001	0.000
Min rX	37	1 LOAD CAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max rY	374	1 LOAD CAS	0.001	-7.408	52.461	52.981	0.002	0.001	-0.000
Min rY	343	1 LOAD CAS	0.000	7.408	52.460	52.981	0.002	-0.001	-0.000
Max rZ	25	1 LOAD CAS	0.012	-3.658	7.368	8.226	0.001	0.000	0.000
Min rZ	7	1 LOAD CAS	-0.012	3.658	7.368	8.226	0.001	0.000	-0.000
Max Rst	416	1 LOAD CAS	-0.006	7.405	62.200	62.639	0.002	0.000	0.000

b) Graphical analysis based on software evaluated result data

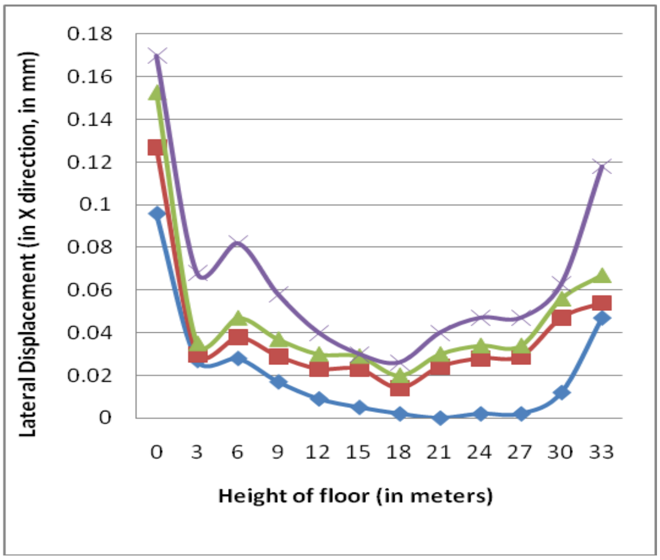
Graph –1



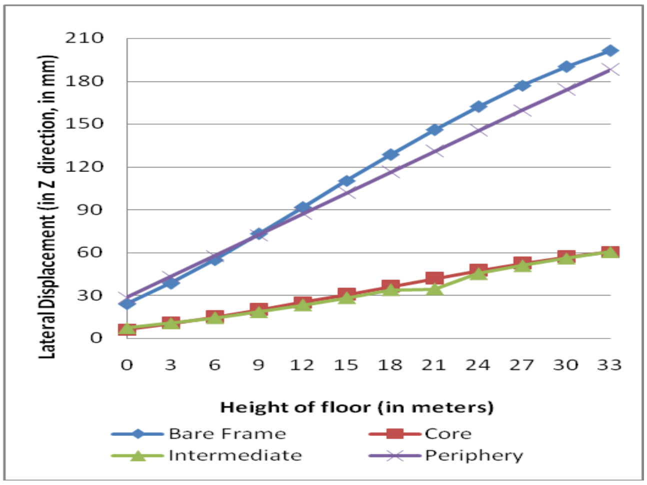
Graph –2



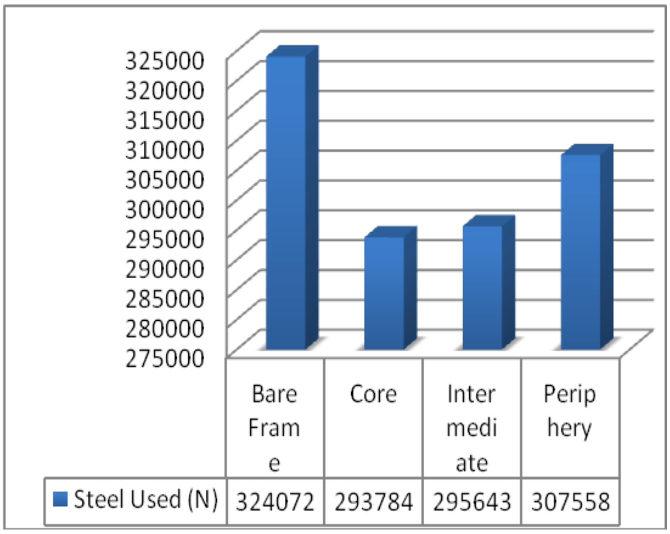
Graph – 3



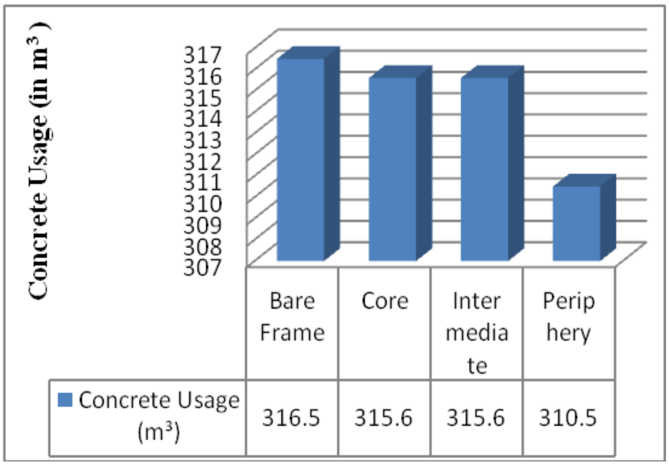
Graph - 4



Graph - 5



Graph – 6



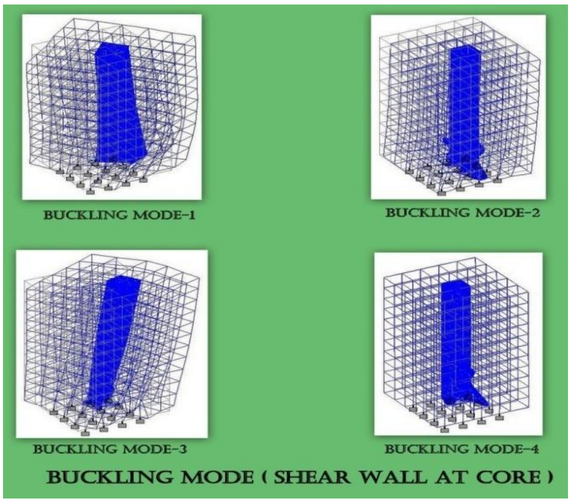


Figure – 4

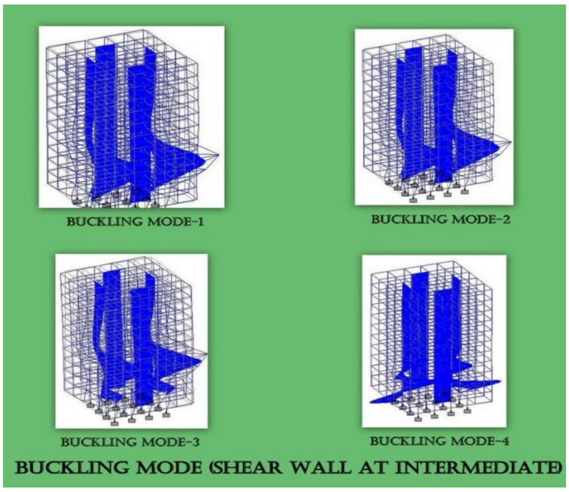


Figure - 5

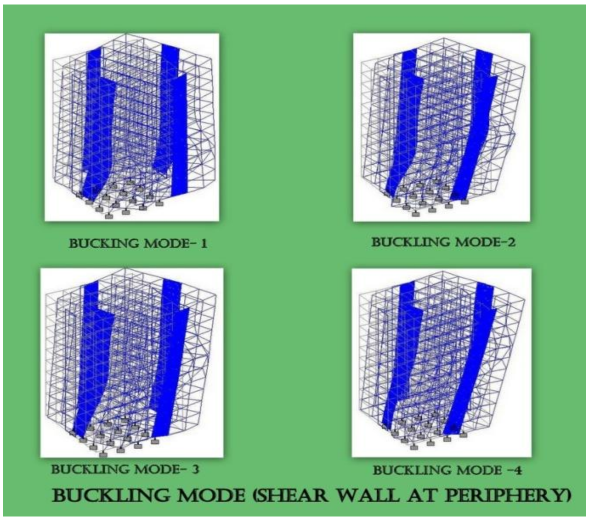


Figure – 6

6. CONCLUSION.

On analysis based on designed structure with various positional configuration of shear wall with respect to seismic load acting as calculated from STAAD.Pro software shows that, Intermediate position of shear wall is best suited with respect to core and periphery positions of the structure.
The lateral displacement in X- direction and Z- direction is restricted more by the intermediately configured shear wall making building structure safe to shear failure.
The Proportionate material requirement for the restriction of applied load safely; in the construction of building also shows the Intermediate configuration will be more economical than other with exception of steel in core and concrete in periphery position; but this could not retard structural buckling considerably.

The shear wall make the structure safe by enhancing stiffness, ductility and reducing lateral and vertical drift of the storey at joints, which is due to direct reduction of displacement of member along the propagation of seismic force.

In Bare frame structure soft storey is found to be acting at base and at 9th storey whereas there was drift in structure (The storey drift exceeds 0.004 times the storey height for 1893 load case - 1 applied) after configuration of shear wall to structure both soft storey and drift exit due to resistive layer of shear wall body attached to structure assembled as additional column to retard the displacement and counter shear failure.

6. REFERENCES

[1] IS: 1893**(part 1)** : 2002, " Criteria for earthquake resistant design of structures, part 1, general provisions and buildings ", Fifth revision, Bureau of Indian Standerds, Manak Bhavan, Bahadur Shah Zafar Marg, New Delhi 110002.

[2] "Review on Shear wall for soft storey high rise building, Misam Abidi and Mangulkar Madhuri N. ,International Journal of Civil and Advance Technology, ISSN 2249-8958,Volume-1,Issue-6, August 2012

[3] "A comparative study of omrf & smrf structural system for tall & high rise buildings subjected to seismic load", Volume: 02 Issue: 09 | Sep-2013 by G.V.S.Siva Prasad and S.Adiseshu.

[4] "Effect of change in shear wall location on storey drift of multi-storey residential building subjected to lateral load", Ashish S. Agrawal and S. D. Charkha, International journal of Engineering Research and Applications, Volume 2, Issue 3,may-june 2012, pp.1786-1793.

[5] "Configuration of multi-storey building subjected to lateral forces", M Ashraf, Z. A. Siddiqui, M. A. Javed, Asian journal of civil engineering ,vol. 9,no.5, pp. 525-535, 2008.

[6] Solution of shear wall in multi-storey building", Anshuman, Dipendu Bhunia, Bhavin Ramjiyani, International journal of civil and structural engineering, Volume 2, no.2, 2011.

[7] IS: 875 **(**Part 2**) –** 1987 **(**Reaffirmed 2008), "Code of practice for design loads for buildings and structures. Part 2- Imposed load".

[8] Shrikhande Manish, Agrawal Pankaj (2010). "Earthquake Resistant Design of Structures." PHI Learning Private Limited New Delhi.

[9] Jaswant N. Arlekar, Sudhir K. Jain and C.V.R. Murty. Seismic response of RC frames buildings with soft first story's. Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, 1997, New Delhi.

[10] Wakchaure MR, Ped SP. Earthquake Analysis of High Rise Building with and Without Infilled Walls. International Journal of Engineering and Innovative Technology. 2012; volume 2; 89-94.

[11] M. Asharaf, Z. A. Siddiqi, M. A. Javed, "Configuration of Multi-storey building subjected to lateral forces". Asian Journal of Civil Engineering (Building & Housing), Vol. 9, No. 5 Pages 525-537.

[12] H.-S. Kim, D.-G. Lee"Analysis of shear wall with openings using super elements" Engineering Structures 25 (2003) 981–991 [13]. M. Shariq, H. Abbas, H. Irtaza, M. Qamaruddin "Influence of openings on seismic performance of masonry building walls" Building and Environment 43 (2008) 1232–1240