Journal of Engineering Sciences

Vol 13, Issue 03, MARCH /2022

ISSN NO:0377-9254

DESIGN AND DYNAMIC RESPONSE OF (BASE+ G+9) BUILDING WITH SHEAR WALL

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Abstract: Many reinforced concrete buildings in urban regions lying in active seismic zones, may suffer moderate to severe damages during ground motions. Shear walls are extensively used for buildings to resist lateral loads induced by earthquake. Constructions made of shear walls majorly resist the seismic force, wind forces and even can be built on soils of weak bases by adopting various ground improvement techniques. Not only the quickness in construction process but the strength parameters and effectiveness to bare horizontal loads are very high. Shear walls generally used in high earth quake prone areas, as they are highly efficient in taking the loads. The present study aims to investigate the effectiveness of reinforced concrete shear wall in the buildings subjected to seismic loads. The shear wall is an alternate structural form for resisting the earthquake forces. In this study, (Base+ G+9) building seismic analysis is carried out with and without shear wall by using response spectrum method as per IS: 1893-2002 (Part I). The analysis is carried out using ETABS finite element analysis software. It is concluded that, presence of shear wall in the structure decreases percentage of reinforcement in the columns and increases the lateral stiffness of the building, thus performing effectively in resisting lateral forces induced by an earthquake.
Keywords: (Base+ G+9), E-tabs, Earthquake forces, Shear walls

1.0 INTRODUCTION

The walls, in a building, which resist lateral loads originating from wind or earthquakes, are known as shear walls. A large portion of the lateral load on a building, if not the whole amount, as well as the horizontal shear force resulting from the load, are often assigned to such structural elements made of RCC. These shear walls, may be added solely to resist horizontal force, or concrete walls enclosing stairways, elevated shafts, and utility cores may serve as shear walls. Shear walls not only have very large in-plane stiffness and therefore resist lateral load and control deflection very efficiently, but may also help to ensure development of all available plastic hinge locations throughout the structure prior to failure. The other way to resist such loads may be to have the rigid frame augmented by the combination of masonry walls. The use of shear walls or their equivalent becomes imperative in certain high-rise buildings, if inter-storey deflections caused by lateral loadings are to be controlled. Well-designed shear walls not only provide adequate safety, but also give a great measure of protection against costly non-structural damage during moderate seismic disturbances. The term shear wall is actually a misnomer as far as high-rise buildings are concerned, since a slender shear wall when subjected to lateral force has predominantly moment deflections and only very insignificant shear distortions. High-rise structures have become taller and slenderer, and with this trend the analysis of shear walls may emerge as a critical design element. More often than not, shear walls are pierced by numerous openings. Such shear walls are called coupled shear walls. The walls on both sides of the openings are interconnected by short, open deep, beams forming part of the wall, or floor slab, or both of these. The structural engineer is fortunate if these walls are arranged in a systematic pattern. The scope of the book limits the discussion to shear walls without any openings.

Shear Walls

Shear walls are vertical elements of the horizontal force resisting system. Shear walls are constructed to counter the effects of lateral load acting on a structure. In residential construction, shear walls are straight external walls that typically form a box which provides all of the lateral support for the building. When shear walls are designed and constructed properly, and they will have the strength and stiffness to resist the horizontal forces. In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes. Examples are the reinforced-concrete wall or vertical truss. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants; create powerful twisting (torsion) forces. These forces can literally tear (shear) a building apart. Reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape of the frame and prevents rotation at the joints. Shear walls are especially important in high-rise buildings subjected to lateral wind and seismic forces.

Purpose of Constructing Shear Walls

Shear walls are not only designed to resist gravity / vertical loads (due to its self-weight and other living / moving loads), but they are also designed for lateral loads of earthquakes / wind. The walls are structurally integrated with roofs / floors (diaphragms) and other lateral walls running across at right angles, thereby giving the three dimensional stability for the building structures.Shear wall structural systems are more stable. Because, their supporting area (total cross sectional area of all shear walls) with reference to total plans area of building, is comparatively more, unlike in the case of RCC framed structures. Walls have to resist the uplift forces caused by the pull of the wind. Walls have to resist the shear forces that try to push the walls over. Walls have to resist the lateral force of the wind that tries to push the walls in and pull them away from the building.

Advantages of Steel Plate Shear Wall to Resist Lateral Loads

- The system, designed and detailed properly is very ductile and has relatively large energy dissipation capability. As a result, steel shear walls can be very efficient and economical lateral load resisting systems.
- The steel shear wall system has relatively high initial stiffness, thus very effective in limiting the drift.
- Compared to reinforced concrete shear walls, the steel shear wall is much lighter which can result in less weight to be carried by the columns and foundations as well as less seismic load due to reduced mass of the structure.
- By using shop-welded, field-bolted steel shear walls, one can speed-up the erection process and reduce the cost of construction, field inspection and quality control resulting in making these systems even more efficient.

Behaviour of frame with shear wall

Generally, the frame deflects in a shear mode analogous to that of a fixed ended beam subjected to support settlement. When these two combined, their compatibility requirement causes the deflection of the wall and the frame to be identical. In order to deform identically both wall and frame some internal forces will develop, which will equalize the deflected shape of total structure.

Thus, the frame pulls the wall back in the upper stories and the wall pushes the frame back in the lower stories. These internal interactive forces are shown in Fig. The internal forces greatly reduce the deflection of the combined systems. This creates stiffness considerably higher than the sum of-the individual components with each resisting a portion of the exterior load. The frame-shear wall system also reduces the shear deflections of the columns.

2.0 LITERATURE REVIEW

Mr. K. Lova Raju (**et.al**) conducted non-linear analysis of frames to identify effective position of shear wall in multi storey building. An earthquake load was applied to a eight storey structure of four models with shear wall at different location in all seismic zones using ETABS. Push over curves were developed and has been found the structure with shear wall at appropriate location is more important while considering displacement and base shear.

Syed. M. Katami et.al presented the results of time history analysis which addressed the effect of openings in shear walls near- fault ground motions. A model of ten storey building with three different types of lateral load resisting system: Complete shear walls, shear walls with square opening in the centre and shear wall with opening at right end side were considered.

Dr. B. Kameshwari et.al analysed the influence of drift and inter storey drift of the structure on various configuration of shear wall panels on high rise structures. The bare frame was compared with various configurations like i) Conventional shear wall ii) Alternate arrangement of shear wall iii) Diagonal arrangement of shear wall iv) Zig Zag arrangement of shear wall v) Influence of lift core shear wall. From the study it was found that Zig Zag shear wall enhanced the strength and stiffness of structure compared to other types. In earthquake prone areas diagonal shear wall was found to be effective for structures.

Nanjma Nainan et.al conducted analytical study on dynamic response of seismic resistant building frames. The effects of change in height of shear wall on storey displacement in the dynamic response of building frames were obtained. From the study it was concluded that it is sufficient to raise the shear wall up to mid height of building frames instead of rising up to entire height of the building.

Shahzad Jamil Sardar et.al modeled a 25 storey building zone V and analysed by changing the location of shear wall to determine various parameters like storey drift, storey shear and displacement using ETABS. Both static and dynamic analysis was done to determine and compare the base shear. Compared to other models, when shear wall placed at centre and four shear wall placed at outer edge parallel to X and Y direction model showed lesser displacement and inter storey drift with maximum base shear in addition strength and stiffness of the structure has been increased.

Eshan Salimi Firoozabad et.al determined the shear wall configuration on seismic performance of building. The top storey displacements for different configurations were obtained using SAP 2000. From the study it was observed that the top storey drift can be reduced by changing the location of shear wall and it was suggested that the quantity of shear wall could not influence the seismic behavior of buildings.

3.0 METHODS OF ANALYSIS

Earthquake analysis of a structure can be performed either static analysis or dynamic analysis. The main parameters of the seismic analysis of structures are load carrying capacity, ductility, stiffness, damping and mass. IS 1893-2002 code is used to carry out seismic analysis of multi-storyed building. In this study the buildings are modeled and analyzed using response spectrum analysis.

Response spectrum analysis

The response spectrum method (RSM) was introduced in 1932 in the doctoral dissertation of Maurice Anthony Biot at Caltech. It is an approach to finding earthquake response of structures using waves or vibrational mode shapes. The mathematical principles of oscillations in n-degree-of-freedom systems were taken largely from the theories of acoustics developed by Rayleigh. Biot stated "A building has a certain number of normal modes of vibrations, and to each of them corresponding to a certain frequency." Biot utilized the Fourier amplitude spectrum to find the maximum amplitude of motion of a system: the sum of amplitudes for each separate mode of oscillation.

Linear time history analysis

The linear time history method involves a time-step-by-step evaluation of the building response, using discretized record or synthetic earthquake records as base motion input. Pair of ground motion records for simultaneous analysis along each horizontal axis of the building should be consistent. Consistent pairs are the orthogonal motions expected at a given site based on the same earthquake. The damping matrix associated with the mathematical model shall reflect the damping in the building a deformation levels near the yield.

Non-linear time history analysis

Some buildings may be too complex to rely on the nonlinear static procedure. Those cases may require time history analysis of the nonlinear behavior of the structure during analysis for a particular example of earthquake. The kinds of the buildings that may require this specialized analysis are highly irregular or complicated.

Manual design of shear walls

The walls, in a building, which resist lateral loads originating from wind or earthquakes, are known as shear walls. A large portion of the lateral load on a building, if not the whole amount, as well as the horizontal shear force resulting from the load, are often assigned to such structural elements made of RCC. These shear walls, may be may be added solely to resist horizontal force, or concrete walls enclosing stairways, elevated shafts, and utility cores may serve as shear walls. Shear walls not only have very large in-plane stiffness and therefore resist lateral load and control deflection very efficiently, but may also help to ensure development of all available plastic hinge locations throughout the structure prior to failure. The other way to resist such loads may be to have the rigid frame

Calculation of rigidity of a Shear Wall:

Torsional rigidity of a shear wall is defined as the torque required to produce a unit rotation. If a torque T acting on a shear wall produces a rotation of _ radians, then the torsional rigidity of the wall is,

J= T/Q

The torsional rigidity of any given shape of a shear wall consists of the summation of its torsional rigidities calculated on the basis of uniform and non-uniform torsional theories, the uniform-torsion theory component for open sections only, being given by,

$$J_u = \frac{E\,t^3\,\Sigma O}{6.6h}$$

Where '0' equals the perimeter of the section of shear wall of height h and thickness 't'. It, however, works out to be negligibly small in the case of open sections such as channels, angles, tees, etc. Being a function of the cube of thickness of shear wall, which is assumed to be very small in comparison to its other dimensions. However, for box sections, it is not a small quantity, as it is proportional to its thickness. The non-uniform torsion theory applied to flanged walls of open cross-sections and gives approximate torsion rigidity based on the rigidities of separated flanges opposite to each other, neglecting the web. Referring to for an I-section, rotation Q in radians due to a unit displacement of either flange on account of force Rf is given by

Q =2/a

This is produced by a torque

T= Rf x a

Where __= rigidity of the flange, i.e. a wall element of length b and thickness t.

The torsional rigidity is, by definition, given on th basis of non-uniform torsion theory as,

$$J_n = \frac{T}{\theta} = R_f x \frac{a^2}{2}$$

For box sections, the torsion due to non-uniform theory can be neglected. The torsional rigidity of a shear wall is then given by,

J= Ju+ Jn

This gives the values of torsional rigidities of various shapes of shear walls.

Design of Shear Walls:

Shear walls construction is an economical method of bracing buildings to limit damage. For good performance of well-designed shear walls, the shear wall structures should be designed for greater strength against lateral loads than ductile reinforced concrete frames with similar characteristics; shear walls are inherently less ductile and perhaps the dominant mode of failure is shear. With low design stress limits in shear walls, deflection due to shear walls is small.

S. No.	Description of Structure	Values	S. No.	Description of Structure
1	Material	Concrete (M25) and Reinforcement (FE415)	7	Floor Height
2	No. of Storeys	G+9 (10 storey's)	8	Seismic zone
3	Size of Beam	600 x 300 mm	9	Dead Load
4	Size of Column	300 x 600 mm	10	Live Load

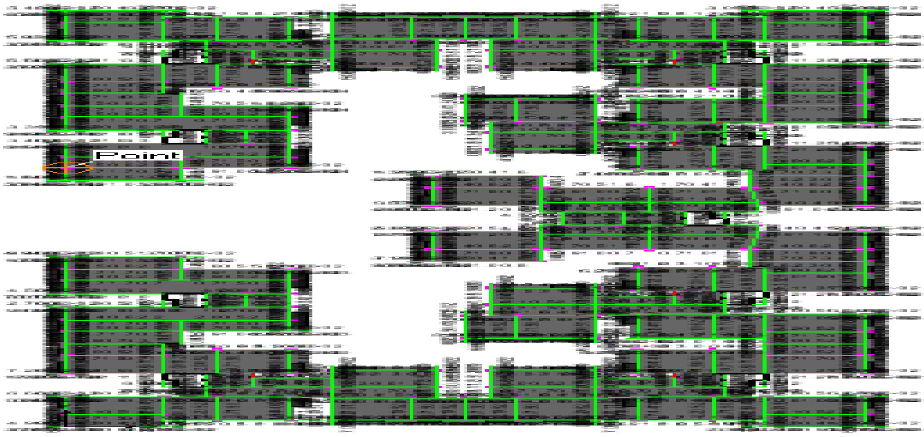


Figure: Overall design of Base+G+9 building plan

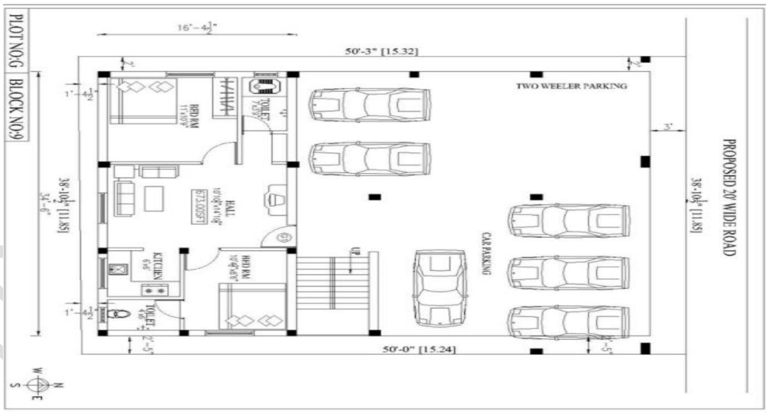
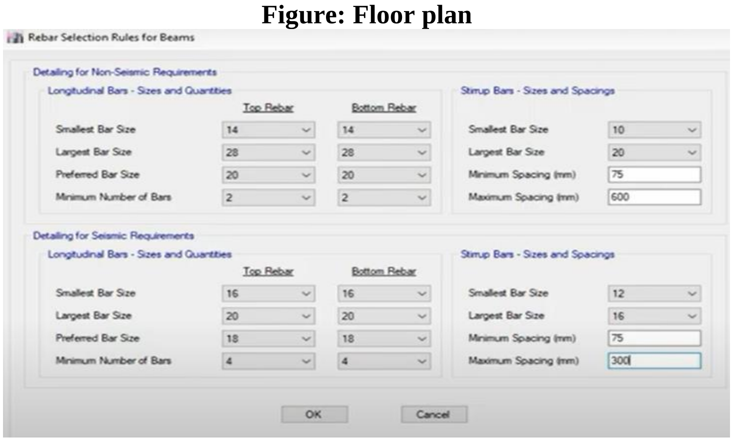


Figure: Floor plan



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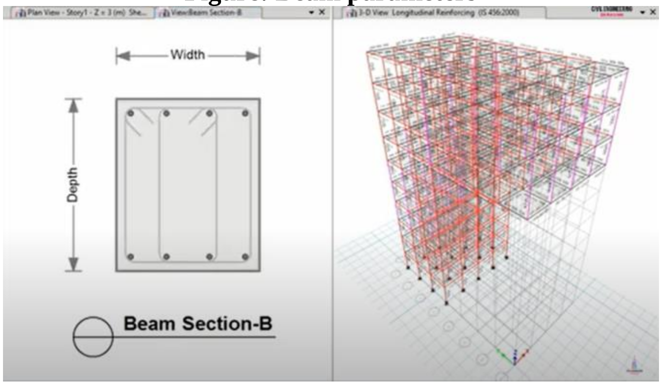
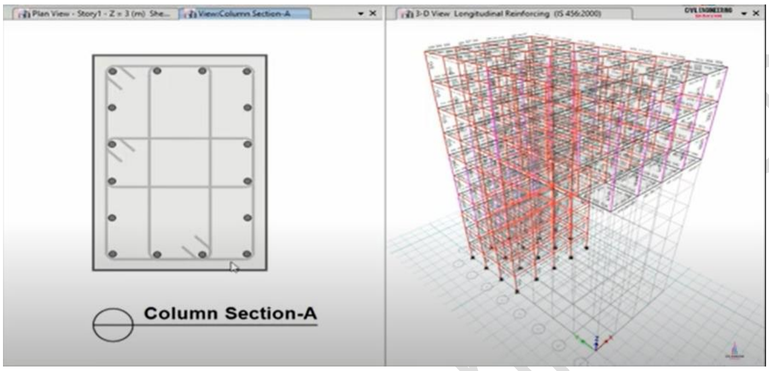
ISSN NO:0377-9254

Figure: Beam parameters



Beam sectional view



Column sectional view

4.0 ETABS Models of Buildings:

A (BASE+ G+9) building is analyzed in ETABS with and without shear wall. The models of buildings are as shown in figures.

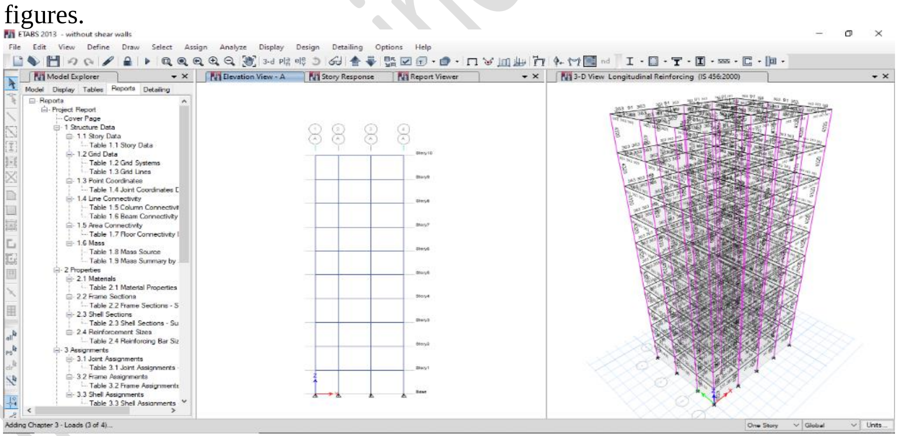


Figure: A building model without shear wall

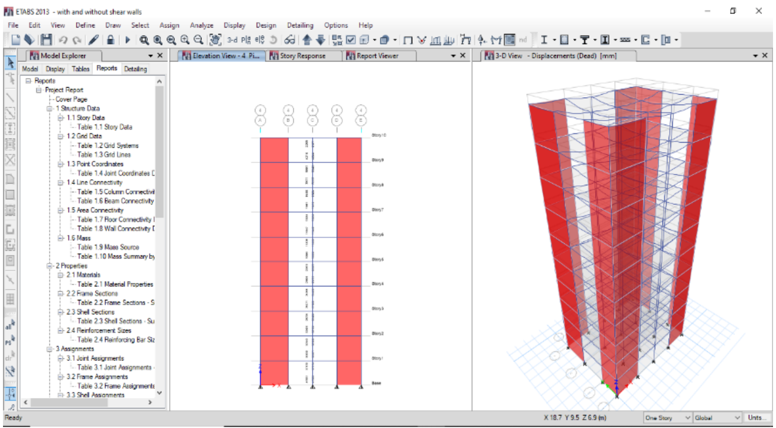


Figure: A building model with shear walls

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Table: Storey displacements of (BASE+ G+9) without shear wall

Story	Elevation m	Location	For EQ X		For EQ Y	
			X-Dir (mm)	Y-Dir (mm)	X-Dir (mm)	Y-Dir (mm)
Story9	27	Top	9.7	0.2	0.1	10.6
Story8	24	Top	9.1	0.2	0.1	9.9
Story7	21	Top	8.4	0.2	0.1	9.1
Story6	18	Top	7.5	0.1	0.1	8.1
Story5	15	Top	6.5	0.1	0.1	7
Story4	12	Top	5.4	0.1	4.752E-02	5.9
Story3	9	Top	4.2	0.1	3.774E-02	4.7
Story2	6	Top	3	0.1	2.724E-02	3.4
Story1	3	Top	1.7	3.417E-02	1.663E-02	2
Base	0	Top	0	0	0	0

Table: Storey Shears of (BASE+ G+9) without shear wall

Story	Elevation m	Location	For EQ X		For EQ Y	
			X-Dir (kN)	Y-Dir (kN)	X-Dir (kN)	Y-Dir (kN)
Story9	27	Top	-295.8612	0	0	-269.8938
		Bottom	-295.8612	0	0	-269.8938
Story8	24	Top	-418.5201	0	0	-381.7871
		Bottom	-418.5201	0	0	-381.7871
Story7	21	Top	-512.4308	0	0	-467.4554
		Bottom	-512.4308	0	0	-467.4554
Story6	18	Top	-581.4264	0	0	-530.3954
		Bottom	-581.4264	0	0	-530.3954
Story5	15	Top	-629.3401	0	0	-574.1037
		Bottom	-629.3401	0	0	-574.1037
Story4	12	Top	-660.0048	0	0	-602.077
		Bottom	-660.0048	0	0	-602.077
Story3	9	Top	-677.2537	0	0	-617.812
		Bottom	-677.2537	0	0	-617.812
Story2	6	Top	-684.9199	0	0	-624.8054
		Bottom	-684.9199	0	0	-624.8054
Story1	3	Top	-686.8364	0	0	-626.5537
		Bottom	-686.8364	0	0	-626.5537
Base	0	Top	0	0	0	0
		Bottom	0	0	0	0

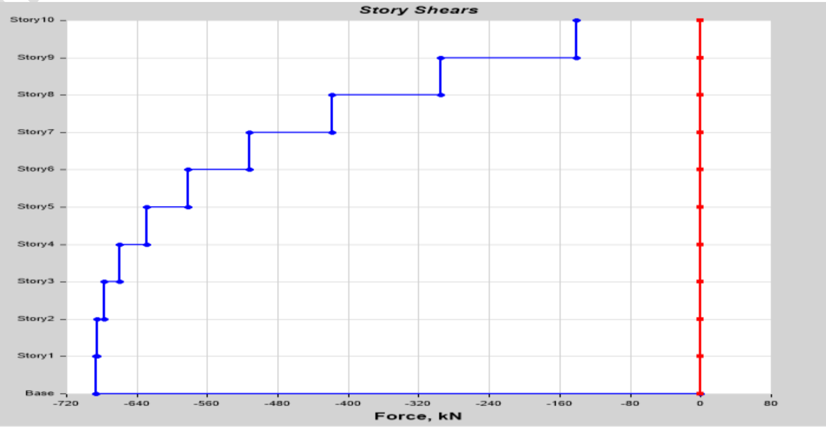

Figure: Maximum storey shears of (BASE+ G+9) without shear wall for EQ X

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ISSN NO:0377-9254

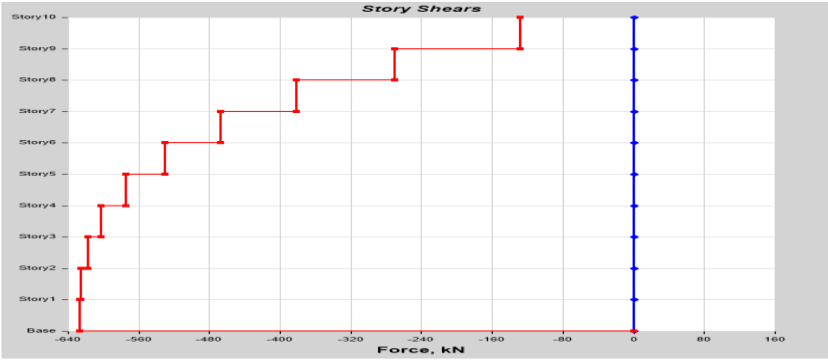

Figure 5.16: Maximum storey shears of (BASE+ G+9) without shear wall for EQ Y

Table 5.8: Storey Shears of (BASE+ G+9) with shear wall

Story	Elevation m	Location	For EQ X		For EQ Y	
			X-Dir (kN)	Y-Dir (kN)	X-Dir (kN)	Y-Dir (kN)
Story9	27	Top	-508.2619	0	0	-508.2619
		Bottom	-508.2619	0	0	-508.2619
Story8	24	Top	-727.9587	0	0	-727.9587
		Bottom	-727.9587	0	0	-727.9587
Story7	21	Top	-896.1641	0	0	-896.1641
		Bottom	-896.1641	0	0	-896.1641
Story6	18	Top	-1019.7436	0	0	-1019.7436
		Bottom	-1019.7436	0	0	-1019.7436
Story5	15	Top	-1105.5626	0	0	-1105.5626
		Bottom	-1105.5626	0	0	-1105.5626
Story4	12	Top	-1160.4868	0	0	-1160.4868
		Bottom	-1160.4868	0	0	-1160.4868
Story3	9	Top	-1191.3817	0	0	-1191.3817
		Bottom	-1191.3817	0	0	-1191.3817
Story2	6	Top	-1205.1128	0	0	-1205.1128
		Bottom	-1205.1128	0	0	-1205.1128
Story1	3	Top	-1208.5455	0	0	-1208.5455
		Bottom	-1208.5455	0	0	-1208.5455
Base	0	Top	0	0	0	0
		Bottom	0	0	0	0

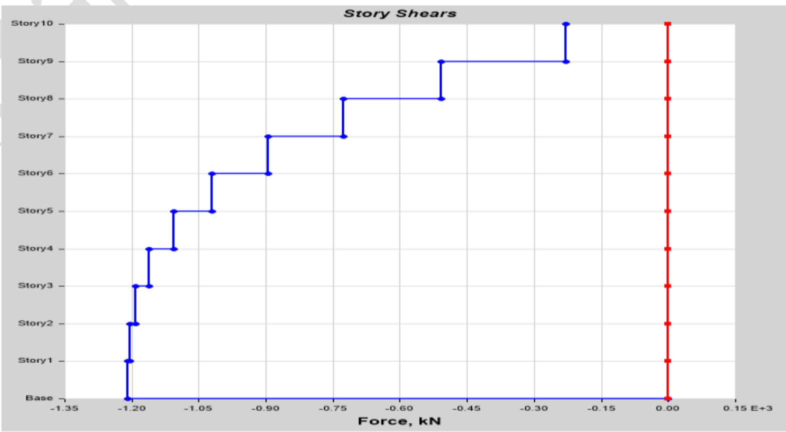

Figure 5.17: Maximum storey shears of (BASE+ G+9) with shear wall for EQ X

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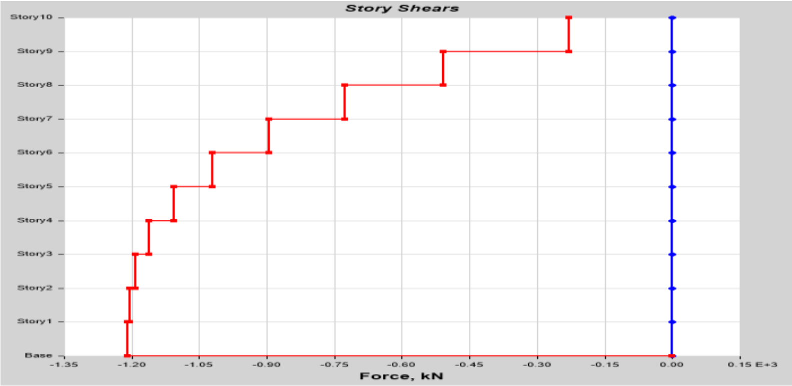

Figure Maximum storey shears of (BASE+ G+9) with shear wall for EQ Y

Table 5.9: Storey stiffness of (BASE+ G+9) without shear wall

Story	Elevation m	Location	For EQ X		For EQ Y	
			X-Dir KN/m	Y-Dir KN/m	X-Dir KN/m	Y-Dir KN/m
Story9	27	Top	507659.824	0	0	414091.716
Story8	24	Top	562331.337	0	0	458289.07
Story7	21	Top	581311.727	0	0	478639.399
Story6	18	Top	588687.542	0	0	491261.766
Story5	15	Top	590397.971	0	0	500621.916
Story4	12	Top	585353.712	0	0	506328.208
Story3	9	Top	565938.396	0	0	500045.847
Story2	6	Top	515264.472	0	0	450184.917
Story1	3	Top	415890.189	0	0	316299.502
Base	0	Top	0	0	0	0

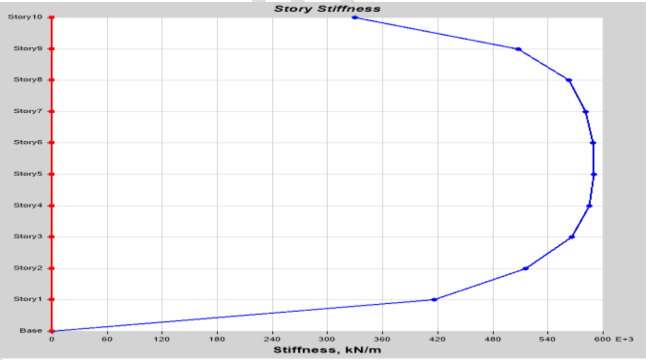

Figure: Maximum storey stiffness of (BASE+ G+9) without shear wall for EQ X

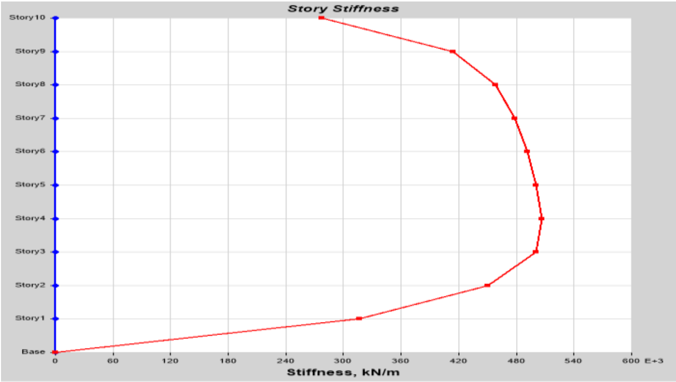

Figure: Maximum storey stiffness of (BASE+ G+9) without shear wall for EQ Y

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Table: Storey stiffness of (BASE+ G+9) with shear wall

Story	Elevation m	Location	For EQ X		For EQ Y	
			X-Dir KN/m	Y-Dir KN/m	X-Dir KN/m	Y-Dir KN/m
Story9	27	Top	853724.584	0	0	712299.374
Story8	24	Top	1174240.152	0	0	979403.405
Story7	21	Top	1417289.661	0	0	1185115.454
Story6	18	Top	1629065.848	0	0	1365306.465
Story5	15	Top	1852920.811	0	0	1556638.226
Story4	12	Top	2147388.53	0	0	1808384.698
Story3	9	Top	2627859.758	0	0	2219172.082
Story2	6	Top	3655278.959	0	0	3109958.646
Story1	3	Top	6715136.619	0	0	5849353.439
Base	0	Top	0	0	0	0

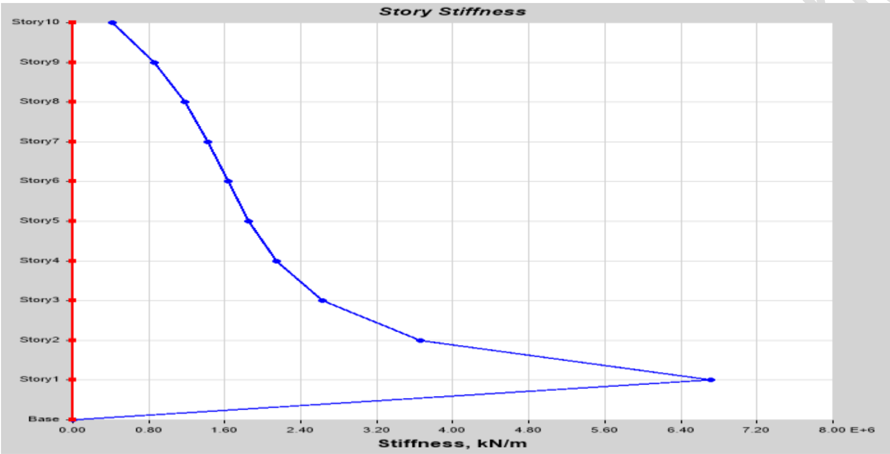

Figure: Maximum storey stiffness of (BASE+ G+9) with shear wall for EQ X

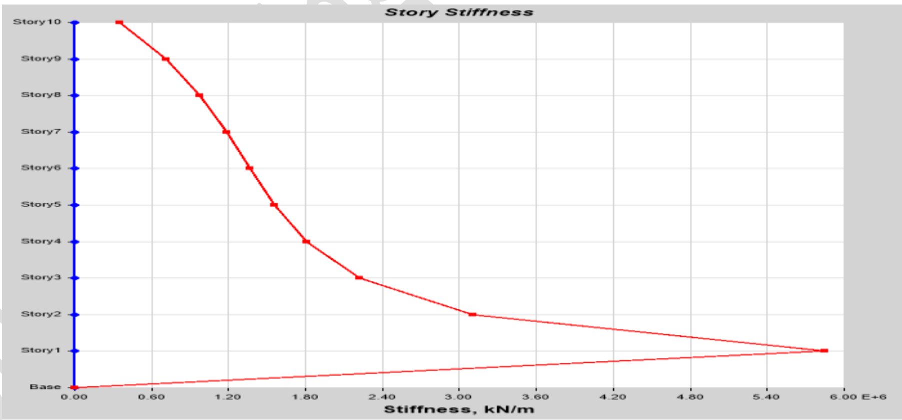

Figure: Maximum Storey stiffness of (BASE+ G+9) with shear wall for EQ Y

CONCLUSIONS

The conclusions drawn from the analysis of a (BASE+ G+9) building with and without shear wall are as follows

- Fundamental frequencies of structure with shear wall is increased by 20% as compared to that in structure without shear wall, so it's about increasing of stiffness by providing shear walls.
- The storey shears of structure with shear walls is more as compared to structure without shear walls.
- Lateral seismic load distributions in structure with shear wall are greater than in the structure without shear wall.
- The storey shears and lateral loads for EQ X and EQ Y in the structure with shear wall are equal.
- The values of storey displacements, drifts, shears, stiffness and lateral loads for EQ X of structures are greater than EQ Y values.

- Parameters like storey displacements, story drifts are found to be gradually decreasing in structure with shear wall as compared to structure without shear wall.
- The rebar percentage is found to be more in the model without shear wall, therefore comes with the concept of economy and stability adjacently.
- Provision of shear walls may not effective in reducing punching shear on intermediate story's but effective in top and bottom story's as shear wall attracts lateral moments from columns.

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