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Comparison of Shear Walls in Response Spectrum Method by using ETABS-2013

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Abstract : Besides, food and clothing, shelter is a basic human need. India has been successful in meeting the food and clothing requirements of its vast population; however the problem of providing shelter of all is defying solutions. "While there has been an impressive growth in the total housing stock from 65 million in 1947 to 187.05 million in 2001, a large gap still exists between the demand and supply of housing units. The Working Group on Housing for the 9th five-year plan estimated the housing shortage in 2001 at 19.4 million units- 12.76 million in rural area and 6.64 million in urban area. The shortage of housing is acutely felt in urban areas –more so in the 35 Indian cities, which according to the 2001 census have a population of more than a million". Hence in order to overcome this problem construction process should be quick, tall and effective to accommodate huge population in a given area. Hence, an attempt is taken to study the behaviour of a G+13, G+15 and G+18 multi storey building in which some storey's are considered for commercial purpose and remaining storey's are for residential purpose. This paper studies the comparison & seismic analysis of the multi-storey buildings with floating column and without floating column. Finally, analysis & results in the high rise building such as storey drifts, storey displacement, and Base shear were shown in this study. Design and Analysis was carried out by using Extended Three Dimensional Analysis of Building Systems (ETABS) Software.
Keyword: Shear wall, High-rise buildings, seismic analysis, E-TABS.

1. Introduction

1.1 Definition

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

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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 [1]. 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 [3]. Shear walls are especially important in high-rise buildings subjected to lateral wind and seismic forces. In the last two decades, shear walls became an important part of mid and high-rise residential buildings. As part of an earthquake resistant building design, these walls are placed in building plans reducing lateral displacements under earthquake loads. So shear-wall frame structures are obtained [5]. Shear wall buildings are usually regular in plan and in elevation. However, in some buildings, lower floors are used for commercial purposes and the buildings are characterized with larger plan dimensions at those floors. In other cases, there are setbacks at higher floor levels [6]. Shear wall buildings are commonly used for residential purposes and can house from 100 to 500 inhabitants per building.

1.2 Objective

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 [7]. 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[4]. 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. Shear walls are quick in construction, and in a country like India where shelter is very important in a short lapse of time shear walls can be built very quickly [4]. The precision to which they are built is also very high compared to normally built brick structures. Hence the key objective of shear wall is to build a safe, tall, aesthetic building

1.3 High-rise buildings

High-rise buildings in general are defined as buildings 35 meters or greater in height which are divided at regular intervals into accusable levels. Undeniably the high-rise buildings are also seen as a wealth-generating mechanism working in an urban economy. High-rise buildings are constructed largely because they can create a lot of real estate out of a fairly small piece of land [9]. Because of the availability of global technology and the growing demand for real estate, high rise buildings are seen as the most fitting solution to any city that is spatially challenged and can't comfortably house its inhabitants.

1.3 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 [2]. 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. Shear wall buildings are usually regular in plan and in elevation [8]. However, in some buildings, lower floors are used for commercial purposes and the buildings are characterized with larger plan dimensions at those floors. In other cases, there are setbacks at higher floor levels. Shear wall buildings are commonly used for residential purposes and can house from 100 to 500 inhabitants per building.

1.4 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.

2. Design Methodology

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. However, exceptions to the excellent performances of shear walls occur when the height-to- length ratio becomes great enough to make overturning a problem and when there are excessive openings in shear walls. Also, if the soil beneath its footing is relatively soft, the entire shear wall may rotate, causing localized damage around the wall. Following are the design steps of cantilever shear walls.

2.1 General Requirements

(a) The thickness of the shear wall should not be less than 150mm to avoid unusually thin sections. Very thin sections are susceptible to lateral instability in zones where inelastic cyclic loading may have to be sustained.

(b) The effective flange width for the flanged wall section from the face of web should be taken as least of

* Half the distance to an adjacent shear wall web, and

* One-tenth of total wall height.

(c) The minimum reinforcement in the longitudinal and transverse directions in the plan of the wall should be taken as 0.0025 times the gross area in each direction and distributed uniformly across the cross-section of wall. This helps in controlling the width of inclined cracks that are caused due to shear.

(d) If the factored shear stress in the wall exceeds 0.25 $\sqrt{fck}$ or if the wall thickness exceeds 200mm, the reinforcement should be provide in two curtains, each having bars running in both the longitudinal and transverse directions in the plane of the wall. The use of reinforcement in two curtains reduces fragmentation and premature deterioration of the concrete under cyclic loading.

2.2 Materials and Properties:

- Type of frame: Special RC moment resisting frame fixed at the base
- Seismic zone: II
- Number of storey: Thirteen
- Floor height: 3.0 m
- Depth of Slab: 150 mm
- Size of beam: (200 × 600) mm
- Size of column : (450 × 450) mm
- Spacing between frames: 5 m along x and 5m along y- directions
- Live load on floor: 2 KN/m2
- Floor finish: 1.5 KN/m2
- Wall load: 10 KN/m
- Materials: M 30 concrete, Fe 500 steel Material
- Thickness of wall: 200 mm
- Thickness of shear wall: 200mm
- Density of concrete: 25 KN/m^3
- Density of infill: 20 KN/m^3
- Type of soil: Hard

Response spectra: As per IS 1893(Part-1):2002percent

3. Analysis

Firstly click on the ETABS icon .A window appears which shows a different tip every time you open the software. This window provides us 3 options. You can click on previous or next tip to checkout some more tips or else click ok to move further. Change the units at the right bottom to KN-m or any other as per your convenience. Click on file option to create a new file or to open an already existing file. When you open a new file another window appears which again contain 3 options as shown in below.

Fig 1: New model section

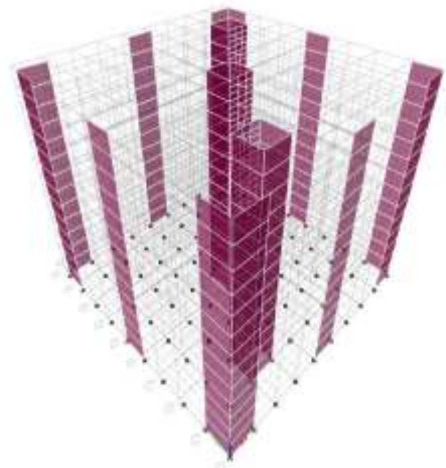

Fig 2: Shear walls after they assigned

3.1 Assigning of loads:

*After the columns, beams, walls and slabs are assigned now the loads are to be applied to the structure. There are different load combinations used in this software. For shear walls, lateral loads and seismic loads play a vital role.

*To assign any particular load, click Define=>Static load cases. In this window dead load and live load are already assigned. To assign any other loads change the name of the load in load option, select the load type in type option, add the self weight multiplier as required. The auto lateral load options provide different code books that are used across the world. We use IS 1893-2002 code.

*After we have defined the loads that are required to be provided for the structure, now the loads are need to be assigned. For the loads that are acting on beams, select all the beams and then

click assign=>frame/line loads =>distributed=>select the load that is to be to assigned and then

click ok

3.2 Design Load Combinations

The design loading combinations are the various combinations of the pre- scribed response cases for which the structure is to be checked / designed. The program creates a number of default design load combinations for a concrete frame design. Users can add their own design load combinations as well as modify or delete the program default design load combinations. An unlimited number of design load combinations can be specified.

To define a design load combination, simply specify one or more response cases, each with its own scale factor. The scale factors are applied to the forces and moments from the analysis cases to form the factored design forces and moments for each design load combination. There is one exception to the pre- ceding. For spectral analysis model combinations, any correspondence between the signs of the moments and axial loads is lost. The program uses eight design load combinations for each such loading combination specified, reversing the sign of axial loads and moments in major and minor directions.

As an example, if a structure is subjected to dead load, D, and live load, L, only, the IS 456:2000 design check may need one design load combination only, namely, 1.5 D+1.5 L. However, if the structure is subjected to wind, earthquake or other loads, numerous additional design load combinations may be required.

For the IS 456:2000 code, if a structure is subjected to dead (D), live (L), pat- tern live (PL), wind (W), and earthquake (E) loads, and considering that wind and earthquake forces are reversible, the following load combinations may need to be defined (IS 36.4.1, Table 18):

1.5D	(IS 36.4.1)
1.5D + 1.5L	(IS 36.4.1)
1.5D + 1.5(0.75PL)	(IS 31.5.2.3)
1.5D ± 1.5W	
0.9D ± 1.5W	(IS 36.4.1)
1.2D ± 1.2L ± 1.2W	
1.5D ± 1.5E	
0.9D ± 1.5E	(IS 36.4.1)
1.2D + 1.2L ± 1.2E	

In the preceding equations,

D = The sum of all dead load (DL) cases defined for the model.
L = The sum of all live load (LL) and reducible live load (RLL) cases de- fined for the model. Note that this includes roof live loads as well as floor live loads.
W = Any single wind load (WL) case defined for the model.
E = Any single earthquake load (E) case defined for the model.

These are also the default load combinations in the program whenever the In- dian IS 456-2000 code is used. The user should use other appropriate design load combinations if roof live load is separately treated, or if other types of loads are present. The pattern loading is approximately, but conservatively, performed in the program automatically. Here PL is the approximate pattern load that is the live load multiplied by the Pattern Live Load Factor. The Pat- tern Live Load Factor can be specified in the Preferences. While calculating forces for the specified pattern load combination, the program adds forces for the dead load, assuming that the member geometry and continuity are un- changed from the model, and the forces for the pattern live load, assuming the beam is simply supported at the two ends. The Pattern Live Load Factor normally should be taken as 0.75 (IS 31.5.2.3). If the Pattern Live Load Factor is specified to be zero, the program does not generate pattern loading.

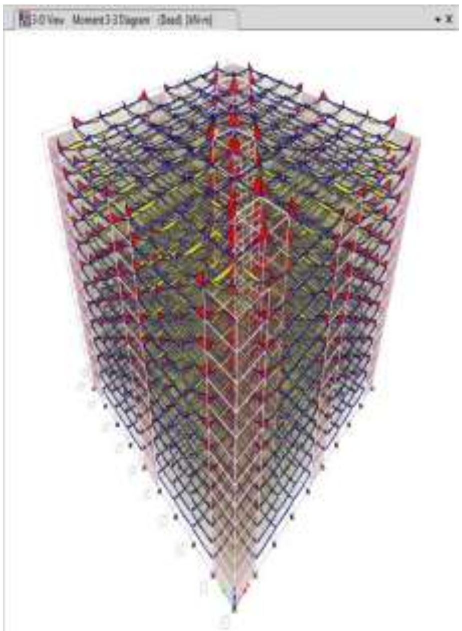

Fig 3: after analysis moment 3-3 diagram for dead load

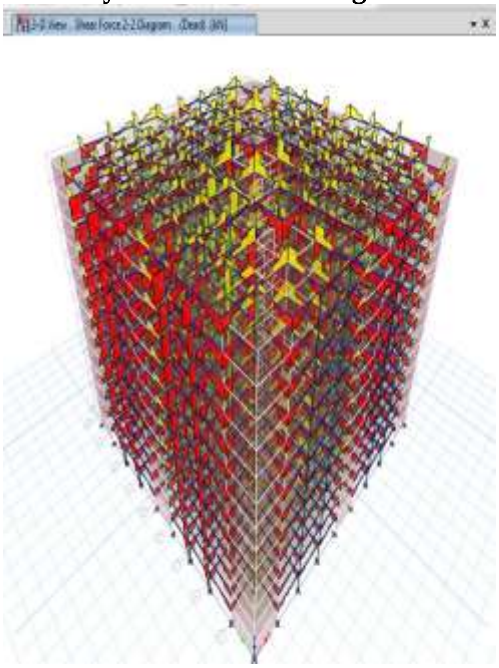

Fig 4: after analysis Shear force 2-2 diagram for dead load.

4. Results and Discussion

4.1 Lateral displacement due to EQPX

STOREY	WITHOUT SW	WITH SW
18 STOREY	0.004593	0.003037
15 STOREY	0.004045	0.002525
13 STOREY	0.001956	0.001027

Table 1: lateral displacements different stories due to EQPX

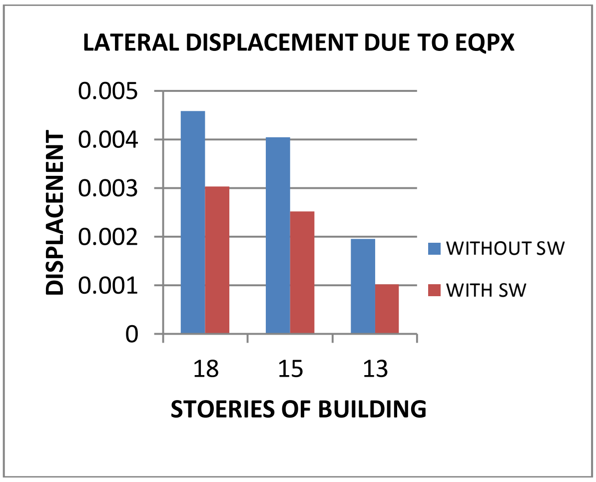

Fig 1: Comparison of lateral displacements due to EQPX

4.2 Lateral displacements due to EQPY:

STOREY	WITHOUT SW	WITH SW
18	0.004092	0.002518
15	0.003955	0.002052
13	0.003515	0.002136

Table 2: lateral displacements of different stories

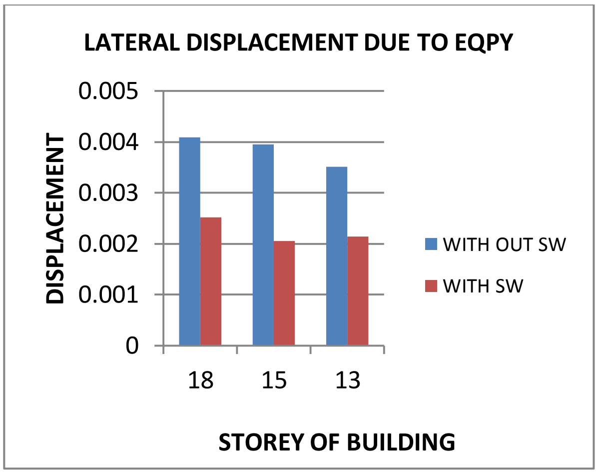

Fig 2: Comparison of lateral displacements due to EQPY

4.3 Storey Drift due to EQPX:

STOREY	WITHOUT SW	WITH SW
18	0.007588	0.005553
15	0.004465	0.002937
13	0.004839	0.003021

Table 3: Storey Drift due to EQPX

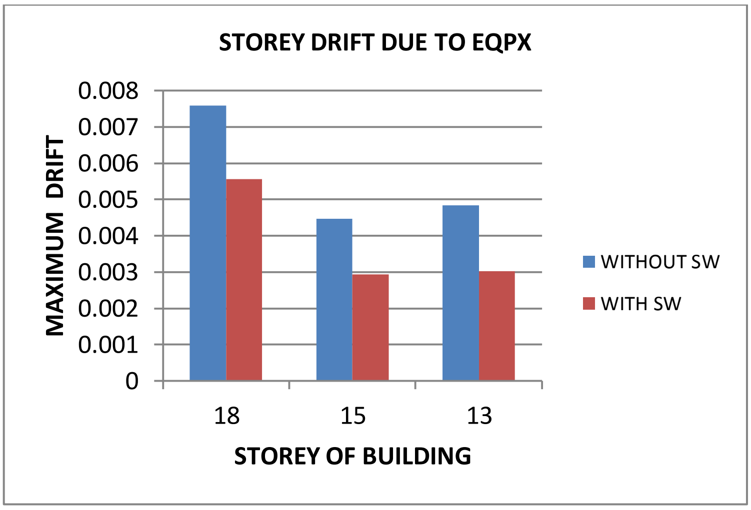

Fig 3: Comparison of Storey Drift due to EQPX

4.4 Storey Drift due to EQPY:

STOREY	WITHOUT SW	WITH SW
18	0.006089	0.004313
15	0.003588	0.002255
13	0.003522	0.002485

Table 4: Drift due to EQPY of different stories

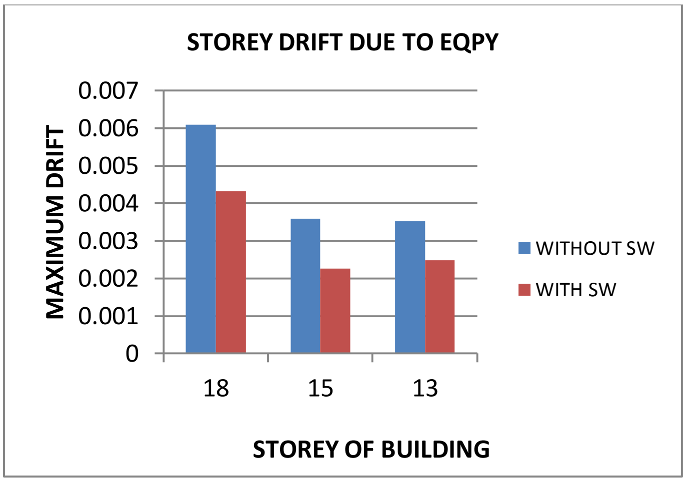

Fig 4: Comparison of Drift of different Stories due to EQPY

4.5 Maximum Storey Shear:

STOREY	WITHOUT SW	WITH SW
18	2179.5	1250.3
15	2148.84	1239.6
13	2128.94	1235.6

Table 5: Maximum Shear of different stories

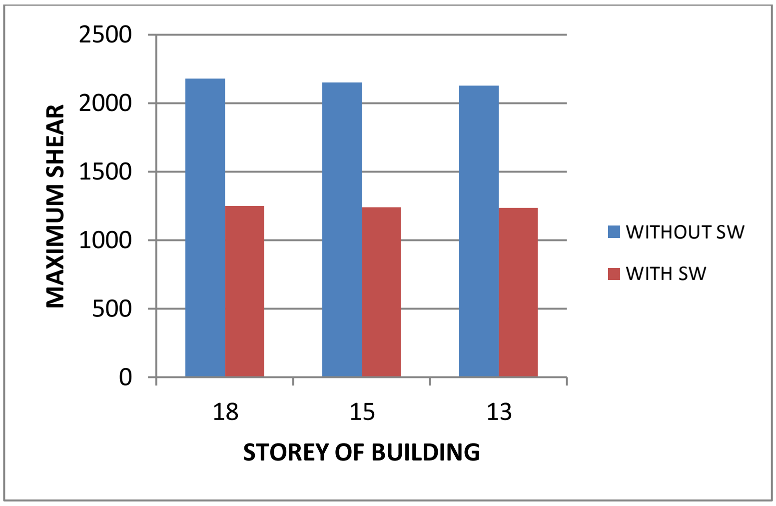

Fig 5: Maximum shear of different stories

5. Conclusions

1. The work presented in the thesis compares the difference between normal building and a shear wall building. The following conclusions were taken based on the investigation.
2. By the application of lateral loads in X and Y direction at each floor, the lateral displacements of shear wall building in X and Y directions very less compared to that of a normal building, So, the construction of shear wall is very safe when compared to a normal building without shear wall.
3. By the calculation of storey drift at each floor for the buildings 13, 15, and 18 it is observed that normal building will suffer extreme storey drift than shear wall building. The storey drift is maximum at middle storey levels in both cases.
4. The building with shear wall experienced fewer shear than normal building. This is due to the use of more quantity of materials than a normal building. So the shear wall building is uneconomical to that of a normal building.
5. While comparing all the values of 13, 15, and 18 with each other we observe that if the number of stories increases in building definitely the values of lateral displacement, drift and shear force increases.
6. The construction of shear wall in building it performs like a backbone for the building and makes the structure more stable however it is uneconomical.
7. So the use of shear walls shall be recommended only when they are absolutely necessary.

References

1. U.H. Varnayi in his second edition of "Design of structures."
2. S.K. Duggal in his "Earth quake resistant design of structures" Page no: 301, 8.12 about Shear walls.
3. S.K. Duggal in his "Earth quake resistant design of structures "pg.no:305 on flexural strength 8.14.1 Case: 1, case: 2.

4. S.K. Duggal in his “Earth quake resistant design of structures” 8.16 Design of Shear walls which is also given in IS code 13920:1993.
5. Mr. A.P. Jadhav Associate Professor Rajarambapu Institute of technology rajaramnagar, Islampur has given a detailed report on the form work used for the construction of shear walls.
6. A report on effects of openings in shear walls on seismic response of structure by sharminriza chowdhary, department of civil engineering dhake-1208, Bangladesh mostly focused on the design of shear walls with openings on seismic response using E- Tabs
   I.S 456:2000.
7. As per clause 32, design for wall describes, design of horizontal shear in clause 32.4 given details of how shear wall have to be constructed.
8. I.S:1893 Criteria of Earth Quake resistant Buildings Part (3) page 23, clause 4.2 gives the estimation of earth quake loads.
9. In IS: 13920:1993 it gives the ductile detailing of shear wall as per clause 9, where 9.1 gives general requirements.
   9.2 Shear strength
   9.3 Gives flexural strength
   9.6 Gives openings in shear walls.
   Ductile detailing, as per the code IS: 13920:1993 is considered very important as the ductile detailing gives the amount of reinforcement required and the alignment of bars.

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