Analysis of Optimum Positioning With And Without Shear Wall For A Different Zone By Using E-Tab

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Abstract- *Shear walls are vertical elements of the horizontal force resisting system. They can resist forces directed along the length of the wall. Once shear walls are designed and constructed properly. They will have the strength and stiffness to resist the horizontal forces. Four different cases of shear wall position for G+15 storey building with keeping zero eccentricity between mass centre and hardness centre have been analysed and designed as a frame system by computer application software ETAB. ETABS stands for Extended Three dimensional Analysis of Building Systems. ETABS is a special-purpose computer program developed specifically for building structures. The case study in this paper mainly emphasizes on analysis of optimum positioning with or without shear wall for a different zones by using ETABS. Modelling of 15-storey's R.C.C. framed building for shear wall is done on the ETABS software for analysis. The framed structure is subjected to lateral and gravity loading in accordance with IS provision and the results are analysed to determine the optimum positioning of the Shear wall.*

Keywords- Shear wall, horizontal forces, zero eccentricity, ETAB, optimum position

I. INTRODUCTION

In India, reinforced concrete structures are designed and detailed as per the Indian Code IS 456 (2002). However, structures located in high seismic regions require ductile design and detailing. Provisions for the ductile detailing of monolithic reinforced concrete frame and shear wall structures are specified in IS 13920 (1993). After the 2001 Bhuj earthquake, this code has been made mandatory for all structures in zones III, IV and V. Reinforced concrete (RC) buildings often have vertical plate-like RC walls called Shear Walls in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along both length and width of buildings. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse.

Shear wall buildings are a popular choice in many earthquake prone countries, like Chile, New Zealand and USA. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and non-structural elements (like glass windows and building contents.

II. REVIEW OF LITERATURE

Mr.K.LovaRaju et. al conducted nonlinear 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. From the results it was observed that shear walls with openings experienced a decrease in terms of strength. The maximum lateral displacement of complete shear wall is 17% less than that of shear walls with openings at centre whose displacement is found to be 8% less than that of shear walls with openings at right end.

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 seismo 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 raising 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.

Varsha.R.Harne considered a six storey RCC building which is subjected to Earthquake loading in zone II to determine the strength of RC wall by changing the location of shear wall using STAAD Pro. Seismic coefficient method is used to calculate the earthquake load as per IS 1893 – 2002 (Part I). Four different models like structure without shear wall, structure with L type shear wall, structure with shear wall along periphery, structure with cross type shear wall were modeled for analysis. Compared to other models the shear force and bending moment, for structure with shear wall along the periphery is found to be maximum at the ground level and roof level respectively. Hence the shear wall provided along the periphery of the structure is found to be more efficient than all other types of shear wall.

Anuj Chandiwala studied a 10 storey RC building located in seismic zone III which is on medium soil. The different building configurations were i) Shear wall at end of L section ii) L Shear wall at junction of 2 flange portion iii) Two parallel L shear wall at junction of 2 flange portion iv) Tube type shear wall at junction of 2 flange portion v) Two parallel shear wall at end of flange portion. From the analysis, it was observed that compared to other models shear wall placed at end of L section is best suited for base shear since end portion of the flange always oscillate more during earthquake.

Shahabodin. Zaregarizi conducted comparative investigation on using shear wall and infill to improve seismic performance of existing buildings. Static nonlinear analysis was done to compare the effectiveness of both methods. From the results, it was observed that concrete infills have considerable strength while brick one showed lower strength. On the contrary, brick infills accepted large displacement than concrete ones. It was concluded that the combination of brick and concrete infills reduced the negative effects when they both used individually.

Mithesh Surana et al. focused on estimation of seismic performance of shear wall and shear wall core buildings designed for Indian codes. Non-linear pushover analysis was used in this study. For modeling the shear wall, the commonly used models like wide column model and shell element model were validated using experimental results available in earlier literature. Both the models showed identical strength for shear wall and shear wall cores. In case of ductility capacity of shear wall and shear wall cores, wide column model underestimates whereas the shell element model overestimates. It has been found that stiffness obtained from moment-curvature analysis is matched with experimental results. But shell element model showed high stiffness initially and later it is reduced due to cracking and finally matched with experimental results. To evaluate the performance of “Dual systems” which is designed as per Indian code, these models were implemented. It has been noted that buildings with shear walls placed at periphery showed excellent performance than buildings with centrally placed shear wall core.

Chun Ni et al. described the performance of shear walls with diagonal or transverse lumber sheathing. A total of 16 full-scale shear walls were tested to determine the effects of hold-owns, vertical load and width of lumber sheathing on in-plane shear capacity. The in-plane shear capacities of shear walls with double diagonal lumber sheathing are 2-3 times higher than that of shear walls with single diagonal lumber sheathing.

Michael R. Dupuis et al. analyzed seismic performance of shear wall buildings with gravity-induced lateral demands using OpenSees software. The inelastic response of concrete shear wall buildings was investigated. From the result, it was demonstrated that a seismic ratcheting effect can develop and amplify inelastic displacement demands. But the effect is more prevalent in coupled shear walls than cantilevered shear walls.

Wen-I Liao et al. conducted an experimental investigation on high seismic performance shear wall. The test results of four large-scale shear walls, (two shear walls under shake table tests and two shear walls under reversed cyclic loading) were presented. The response time histories for accelerations and displacements as well as the hysteretic loops were presented for the shear walls under dynamic loading induced by shake table. The force-displacement hysteretic loops were presented for the shear walls under reversed cyclic loading. From the experimental results, it was found that the tested high performance shear walls have better ductility than that of conventional shear walls

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III. OBJECTIVES OF THIS STUDY

Here The principle objective of this project is to analyse different models with Shear walls and compare them using ETABS, to get the optimum positioning of Shear walls inside the structure. Four different cases of shear wall position for G+10 storey building with keeping zero eccentricity between mass centre and hardness centre have been analysed and designed as a frame system by computer application software ETABS. The design involves load calculations and analysing the whole structure by modelling software and the design method used for analysis is Limit State Design conforming to Indian Standard Code of Practice. ETABS features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite element and dynamic analysis capabilities. From model generation, analysis and design to visualization and result verification, ETABS is the professional's choice. It has a very interactive user interface which allows the users to draw the frame and input the load values and dimensions. Then according to the specified criteria assigned it analyses the structure and designs the members with reinforcement details for RCC frames. Shear walls are oblong in cross-section, i.e., one dimension of the cross-section is much larger than the other. While rectangular cross-section is common, L- and U-shaped sections are also used. The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called curtains. Horizontal reinforcement needs to be anchored at the ends of walls. The minimum area of reinforcing steel to be provided is 0.0025 times the cross-sectional area, along each of the horizontal and vertical directions. This vertical reinforcement should be distributed uniformly across the wall cross-section. Under the large overturning effects caused by horizontal earthquake forces, edges of shear walls experience high compressive and tensile stresses. To ensure that shear walls behave in a ductile way, concrete in the wall end regions must be reinforced in a special manner to sustain these load reversals without losing strength. End regions of a wall with increased confinement are called Boundary elements. This special confining transverse reinforcement in boundary elements is similar to that provided in columns of RC frames. Sometimes, the thickness of the shear wall in these boundary elements is also increased. RC walls with boundary elements have substantially higher bending strength and horizontal shear force carrying capacity, and are therefore less susceptible to earthquake damage than walls without boundary elements.

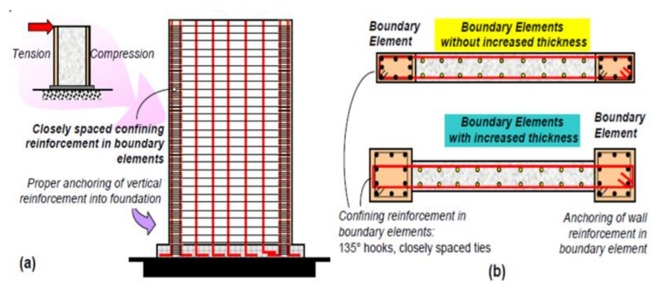


Figure 1: Layout of Main Reinforcement in Shear Wall as per IS:13920:1993

IV. PROBLEM STATEMENT

G+15 storied buildings are modelled using conventional beams, columns & slabs. These buildings were given square geometry with plan dimensions of 18m x 18m. They are loaded with Dead, Live and Seismic Forces (according to IS:1893:2002). These models are then analysed using response spectrum method for earthquake zone V of India (Zone Factor = 0.36). The details of the modelled building are listed below. Modal damping of 5% is considered with OMRF having Shear Walls.

V. MODELLING IN ETAB

The following assumptions were made before the start of the modelling procedure so as to maintain similar conditions for all the four models:

1. Only the main block of the building is considered. The staircases are not considered in the design procedure.
2. The building is to be used for residential purposes, but no walls are provided as the study focuses only on the response of Frame configuration.

3. At ground floor, slabs are not provided and the plinth is resting 2m above the ground.
4. The beams are resting centrally on the columns so as to avoid the conditions of eccentricity. This is achieved automatically in ETABS.
5. For all structural elements, M25 & Fe 500 are used.
6. The footings are not designed. Supports are assigned in the form of fixed supports.
7. Seismic loads are considered in the horizontal direction only (X & Y) and the loads in vertical direction (Z) are assumed to be insignificant.
8. Sizes of the members are as follows:

Sr. No.	Specification	Size
1.	Length X width	24m X 24m
2.	Number of stories	G+15
3.	Support conditions	Fixed
4.	Storey height	3 m
5.	Grade of concrete	M-30
6.	Grade of steel	Fe-415
7.	Type of Structure	OMRF having Shear Wall
8.	Response Reduction Factor	5
9.	Importance Factor	1
10.	Seismic Zone Factor	0.36 (Zone V)
11.	Time Factor	0.963
12.	Size of columns	500mm x 500mm
13.	Size of beams	300mm x 500mm
14.	Slab thickness	150 mm
15.	Thickness of main wall	230mm
16.	Soil Type (as per IS: 1893-2002)	Medium
17.	Density of Concrete, Y'c	25KN/m³
18.	Density of Brick wall, Y'brick	20KN/m³

Exact seismic analysis of the structure is highly complex and to tackle this complexity, numbers of researches have been done with an aim to counter the complex dynamic effect of seismic induced forces in structures, for the design of earthquake resistant structures in a refined and easy manner. For this project, four models were made. Their description is as follows:

Case [1] Conventional Frame
Case [2] Building with Shear Walls on Periphery at Corners
Case [3] Building with Shear Walls on Periphery at Centers
Case [4] Building with Box-type Shear Wall at the center of the geometry

VI. ANALYSIS

The behaviour of all the framing systems is taken as a basic study on the modelled structure. The lateral drift/deflection ratio is checked against the clause 7.11.1 of IS-1893:2002 i.e. under transient seismic loads. The following parameters were considered to present a comparison between the different frames:

1. Maximum Storey Drift
2. Maximum Storey Displacement
3. Storey Shears
4. Storey Overturning Moment The following load combinations are considered during the analysis of the model:

1. 1.5 DL + 1.5 LL
2. 1.2 DL + 1.2 LL
3. 1.2 DL + 1.2 LL + 1.2 EQX
4. 1.2 DL + 1.2 LL - 1.2 EQX
5. 1.2 DL + 1.2 EQX
6. 1.2 DL - 1.2 EQX

For asserting the simplest yet reliable method for analysis, the combined action of DL, LL & EQ forces are considered i.e. 1.2 DL + 1.2 LL + 1.2 EQX. The structure with different framing system has been modelled using ETABS software with the above mentioned load conditions and combinations.

VII. MODELLING OF RCC FRAMES

Modelling means the formation of structural body in the structure software and assigning the loads to the members as per loading consideration. Here we considered a 3-D RC frame with the dimensions of 6 bays @ 4m in x-axis and 6 bays @ 4m in y-axis. The z-axis consisted of G+15 floors. The ground floor height was 3m and rest of the 15 floors also had a height of 3m.

The structure was subjected to self-weight, dead load, live load and seismic loads under the load type details of ETABS. Seismic load calculations were done following IS 1893:2000. We have adopted three cases by assuming different shapes for the same structure, as explained below;

1. Rectangular Plan
2. L-shape Plan
3. C-shape Plan

Fig. 4.1 shows the Plan and 3D view of the Rectangular-shape building for all the cases is shown in the following figure;

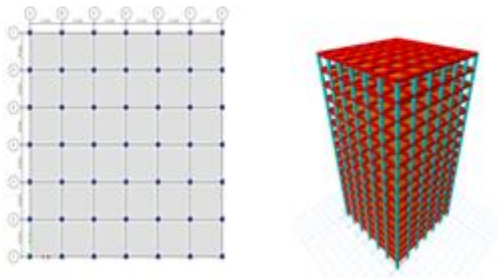


Fig. 4.1: Rectangular Shape Plan and 3D View

Fig. 4.2 shows the Plan and 3D view of the L-shape building for all the cases is shown in the following figure;

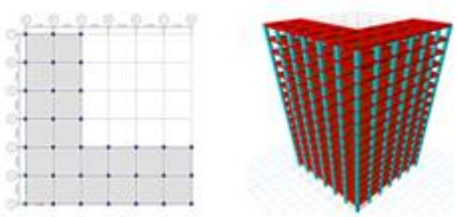
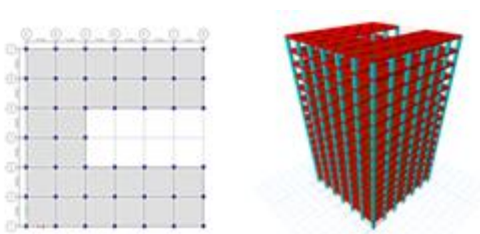


Fig.4.2: L-Shape Plan and 3D View

Fig. 4.3 shows the Plan and 3D view of the C-shape building for all the cases is shown in the following figure;



VIII. LOAD DETAILS

The structures are acted upon by different loads such as dead load (DL), Live load and Earthquake load (EL).

A. Self-weight of the structure comprises of the weight of the beams, columns and slab of the structure.

B. Dead load of the structure consists of Wall load, Parapet wall load and floor load, according to IS 875 (Part1).

- Wall load: weight unit of brick masonry X thickness of wall X height of the wall

  = 20 KN/m3 X 0.23m X 3m= 13.8 KN/m (acting on the beam)
- Parapet Wall load: weight unit of brick masonry X thickness of wall X height of the wall

  = 20 KN/m3 X 0.115m X 1m= 2.3 KN/m (acting on the top beam)

C. Live load: It consists of Floor load which is taken as 4KN/m2 and Roof load as 2 KN/m2, according to IS 875 (Part 2).

D. Seismic Load: Earthquake loads have been defined and assigned on the building as per IS 1893:2002 (Part-I).

▪ Seismic zone (Zone Factor): III (z = 0.16), IV (z = 0.24) and V (z = 0.36)
▪ Soil type: Medium soil
▪ Importance factor: 1
▪ Response reduction factor: 5 (SMRF)
▪ Damping: 5%

A) Fundamental Natural Period [Clause 7.6.2 of IS 1893: 2002]

The approximate fundamental natural period of vibration (Ta), in seconds, of all other buildings, including moment-resisting frame buildings with brick infill panels, may be estimated by the empirical expression:

$$Ta = \frac{0.09\ h}{\sqrt{d}}$$

For Rectangle-shape (both directions), L-shape (both directions) and C-shape (X-direction);

$$Ta = \frac{0.09\ h}{\sqrt{d}} = \frac{0.09 \times 48}{\sqrt{24}} = 0.8818$$

For C-shape (Y-direction);

$$Ta = \frac{0.09\ h}{\sqrt{d}} = \frac{0.09 \times 48}{\sqrt{16}} = 1.08$$

B) AVERAGE RESPONSE ACCLERATION COEFFICIENT [Clause 6.4.5 of IS 1893: 2002]

The average response acceleration coefficient for medium soil sites may be estimated by the empirical expression:

$$\frac{Sa}{g} = \frac{1.36}{T}\ (0.55 \leq T \leq 4.00)$$

For Rectangle-shape (both directions), L-shape (both directions) and C-shape (X-direction);

$$\frac{Sa}{g} = \frac{1.36}{T} = \frac{1.36}{0.8818} = 1.54$$

For C-shape (Y-direction);

$$\frac{Sa}{g} = \frac{1.36}{T} = \frac{1.36}{1.08} = 1.26$$

C) DESIGN HORIZONTAL SEISMIC COEFFICIENT [Clause 6.4.2 of IS 1893: 2002]

The design horizontal seismic coefficient (Ah) for a structure shall be determined by the following expression:

$$Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g}$$

For Rectangle-shape (both directions), L-shape (both directions) and C-shape (X-direction);

Zone III, $Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.16}{2} \times \frac{1}{5} \times 1.54 = 0.02464$

Zone IV, $Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.24}{2} \times \frac{1}{5} \times 1.54 = 0.03696$

Zone V, $Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.36}{2} \times \frac{1}{5} \times 1.54 = 0.05544$

For C-shape (Y-direction);

Zone III, $Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.16}{2} \times \frac{1}{5} \times 1.26 = 0.02016$

Zone IV, $Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.24}{2} \times \frac{1}{5} \times 1.26 = 0.03024$

Zone V, $Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} = \frac{0.36}{2} \times \frac{1}{5} \times 1.26 = 0.04536$

D) SEISMIC WEIGHT OF THE STRUCTURE [Clause 7.4 of IS 1893: 2002]

The seismic weight of each floor is its self-weight plus dead load plus appropriate amount of imposed load. Since amount of imposed load is greater than 3 KN/m2 so 50% imposed load is considered. The sums of total seismic weight of different structure are described below;

Rectangular-shape, W = 104369.805 KN
C-shape, W = 95740.261 KN
L-shape, W = 69711. 6988 KN

IX. SUMMARY & CONCLUSIONS

It is clear to all that the seismic hazard has to be carefully evaluated before the construction of important and high-rise structures. Based on the above analytical study carried out on 4 models, it is evident that buildings with shear walls behave more effectively than conventional frames when subjected to seismic loads. The following deductions are made from the obtained results:

1. The frame with Shear Walls clearly provides more safety to the designers and although it proves to be a little costly, they are extremely effective in terms of structural stability.
2. Due to the falling of the zone, the earthquake hazard will also increase. In such cases, use of shear walls become mandatory for achieving safety in design.
3. In all the systems, the Storey Drift is within the permissible limits as per IS:1893 (Part 1). However CASE 4, closely followed by CASE 2, showed better results when compared to other models. This lead us to believe that when Shear Walls are placed at the center of the geometry in the form of a box or at the corners, the structures behave in a more stable manner. This practice of providing Box-type Shear Walls is becoming more popular now-a-days as high rise structures generally have a lift system and these box-type shear walls serve the dual purpose of Shear walls and also as a vertical duct or passage for the movement of the lifts.
4. The Storey Displacement also follows a similar pattern as storey drifts. Best results are obtained for CASE 4, followed closely by CASE 2, proving again that the optimum position of shear walls is either at the centre of the building or at the corners.
5. The main difference in the behaviours of CASE 4 and CASE 2 can be noted when comparing Storey Shear. CASE 2 displayed very higher values of storey shear as compared to the other models. Here again CASE 4 proved to be the best.
6. Overturning Moments are minimum in conventional buildings. However the lower performance of CASE 1 in terms of Storey Drifts, Storey Displacements and Lateral Loadings make it unfit for use in higher seismically active zones.
7. To further increase the effectiveness of the structure, earthquake resisting techniques such as Seismic Dampers & Base Isolation can be used. It is hence safe to conclude that among all other possibilities, CASE 4 (Building with Box-type Shear Wall at the center of the geometry) is the ideal framing technique for high rise buildings.

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