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ADDITION OF SHEAR WALLS TO ENHANCE THE STRUCTURAL STABILITY OF MEDIUM RISE STRUCTURES

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ABSTRACT

Shear wall systems are one of the most commonly used lateral load resisting in high rise building. Shear wall has high plane stiffness and strength which can be used to simultaneously resist large horizontal loads and support gravity loads. Incorporation of shear walls has become inevitable in multi-storey buildings to resist lateral forces. Hence it is very necessary to determine effective, efficient and ideal location of shear wall. Shear wall arrangement must be absolutely accurate, if not, we will find negative effect instead. In this project, a study will be carried out to determine the optimum structural configuration of a multistory building by changing the shear wall locations radically. Four different cases of shear wall position for G+9 storey building with keeping zero eccentricity between mass center and hardness center will be analyzed and designed as a frame system by computer application software ETABS. The framed structure will be subjected to lateral and gravity loading in accordance with IS provision and the results will then be analyzed to determine the optimum positioning of the Shear wall.

KEYWORDS: Shear Wall, Positioning, Optimization, Seismic forces, RCC structures

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).

OBJECTIVES OF THIS STUDY

The principle objective of this project is to analyze 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 center and hardness center have been analyzed and designed as a frame system by computer application software ETABS. The design involves load calculations and analyzing 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.

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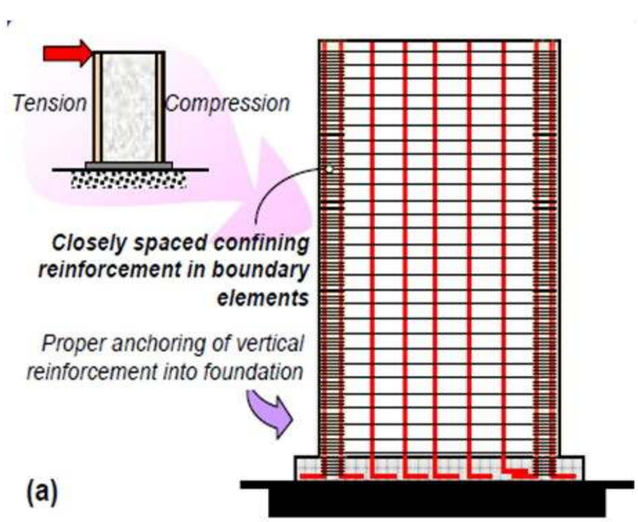
GEOMETRY & DETAILING OF SHEAR WALLS

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. Thin-walled hollow RC shafts around the elevator core of buildings also act as shear walls, and should be taken advantage of to resist earthquake forces. Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids. 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.



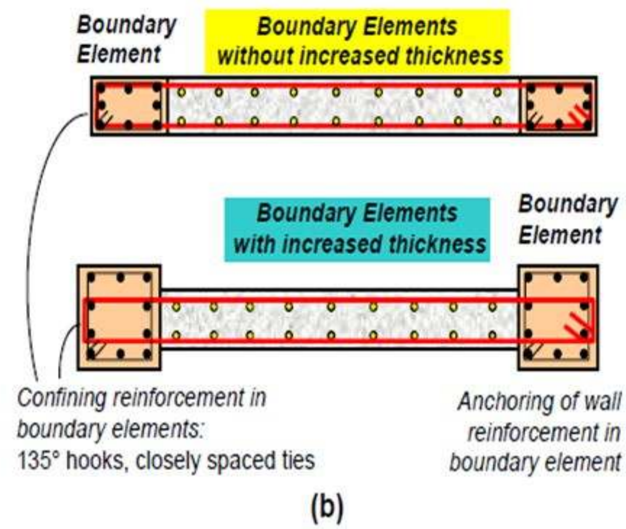


Figure 1: Layout of Main Reinforcement in Shear Wall as per IS:13920:1993

MODELLING & ANALYSIS

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

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

Table 1: Details of design parameters

<table>
<tr><td>SN</td><td colspan="3">Specifications</td><td>Size</td></tr>
<tr><td>1</td><td colspan="3">Plan dimensions</td><td>18m x 18m (X*Y)</td></tr>
<tr><td>2</td><td colspan="3">No. of Bays in both directions</td><td>6 Bays</td></tr>
<tr><td>3</td><td colspan="3">Floor to floor height</td><td>3.0 m</td></tr>
<tr><td>4</td><td colspan="3">Plinth Level</td><td>2 m</td></tr>
<tr><td>5</td><td colspan="3">Total height of Building (G+10)</td><td>35 m</td></tr>
<tr><td>6</td><td colspan="3">Slab Thickness</td><td>200 mm</td></tr>
<tr><td>7</td><td colspan="3">Type of Structure</td><td>OMRF having Shear Walls</td></tr>
<tr><td>8</td><td colspan="3">Soil Type (as per IS:1893-2002)</td><td>Medium</td></tr>
<tr><td>9</td><td colspan="3">Response Reduction Factor</td><td>5</td></tr>
<tr><td>10</td><td colspan="3">Importance Factor</td><td>1</td></tr>
<tr><td>11</td><td colspan="3">Seismic Zone Factor</td><td>0.36 (Zone V)</td></tr>
<tr><td>12</td><td colspan="3">Time Factor</td><td>0.963</td></tr>
<tr><td>13</td><td colspan="3">Grade of concrete</td><td>M25</td></tr>
<tr><td>14</td><td colspan="3">Grade of Steel</td><td>Fe 415</td></tr>
<tr><td>15</td><td colspan="3">Plinth Beam Size</td><td>0.23 m x 0.23 m</td></tr>
<tr><td>16</td><td colspan="3">Floor Beam Size</td><td>0.23 m x 0.48 m</td></tr>
<tr><td>17</td><td colspan="3">Column Size</td><td>0.30 m x 0.70 m</td></tr>
<tr><td rowspan="4">18</td><td rowspan="4">Loads Applied</td><td rowspan="2">DL</td><td>Dead Load</td><td>Calculated as per Self Weight</td></tr>
<tr><td>Floor Finish</td><td>1 kN/m^2</td></tr>
<tr><td>LL</td><td>Live Load</td><td>2.5 kN/m^2</td></tr>
<tr><td>EQX</td><td>Seismic Load (X direction)</td><td>Calculated as per IS:1893-2002</td></tr>
<tr><td>19</td><td colspan="3">Load Combination</td><td>1.2 DL + 1.2 LL + 1.2 EQX</td></tr>
</table>

Design parameters are shown in table1.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 (Fig. 2)

Case [2] Building with Shear Walls on Periphery at Corners (Fig. 3)

Case [3] Building with Shear Walls on Periphery at Centers (Fig. 4)

Case [4] Building with Box-type Shear Wall at the center of the geometry (Fig. 5)

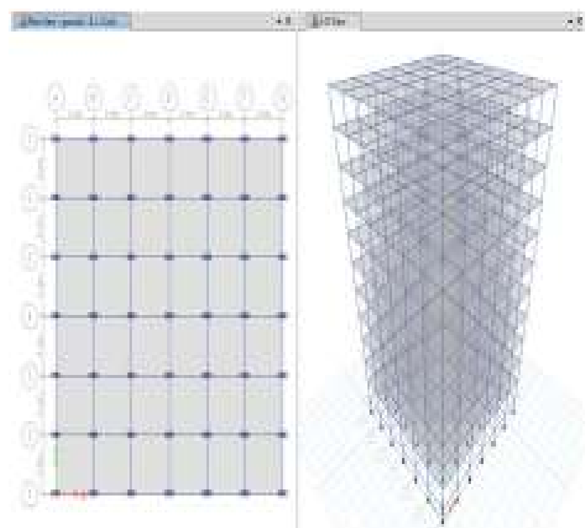


Figure 2: Case [1]

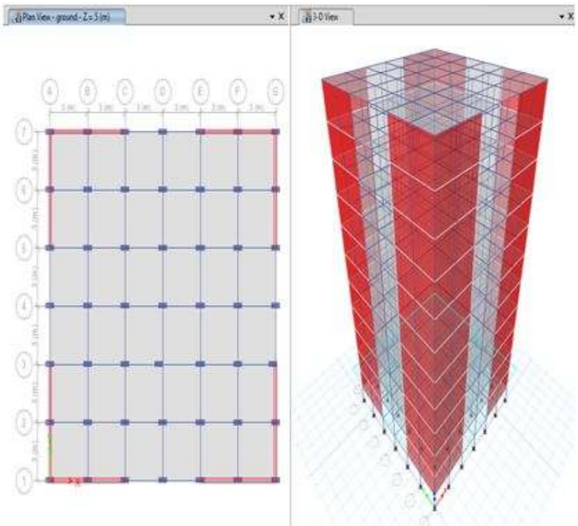


Figure 3: Case [2]

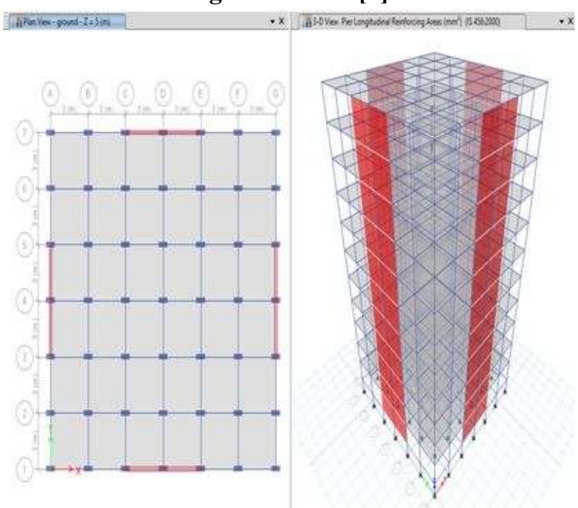


Figure 4: Case [3]

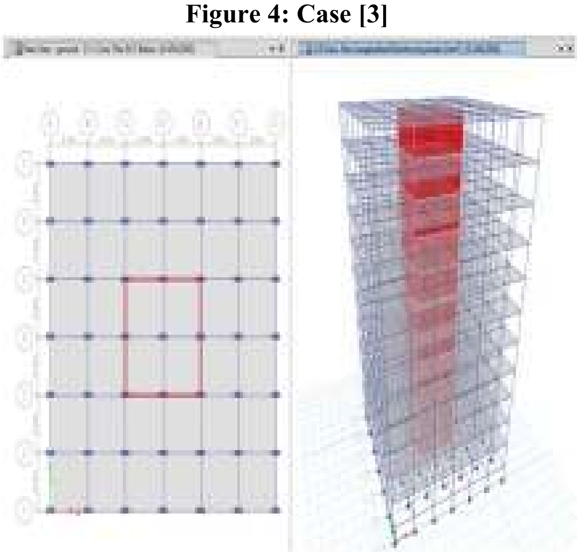


Figure 5: Case [4]

The behavior of all the framing systems is taken as a basic study on the modeled 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:

- Maximum Storey Drift
- Maximum Storey Displacement
- Storey Shears
- Storey Overturning Moment

The following load combinations are considered during the analysis of the model:

- 1.5 DL + 1.5 LL
- 1.2 DL + 1.2 LL
- 1.2 DL + 1.2 LL + 1.2 EQX
- 1.2 DL + 1.2 LL - 1.2 EQX
- 1.2 DL + 1.2 EQX
- 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 modeled using ETABS software with the above mentioned load conditions and combinations.

RESULTS & CONCLUSION

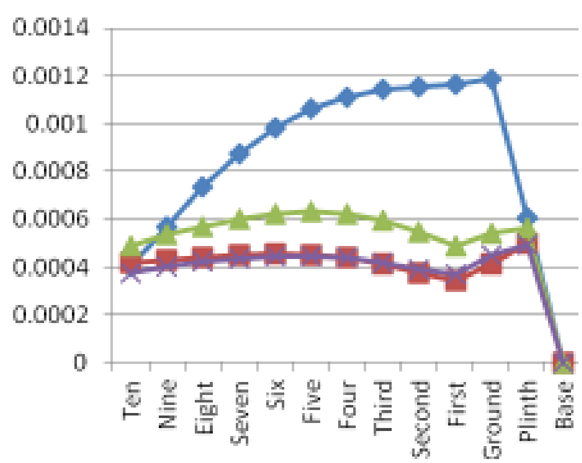


Figure 6: Storey Drift

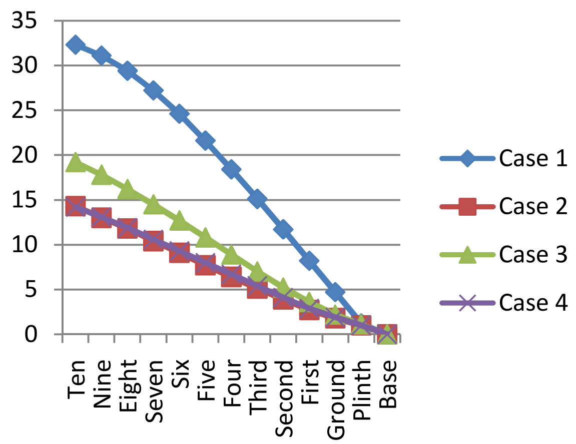


Figure 7: Storey Displacements

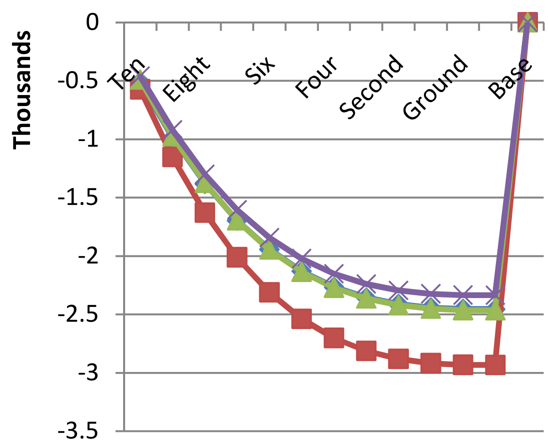


Figure 8: Storey Shear

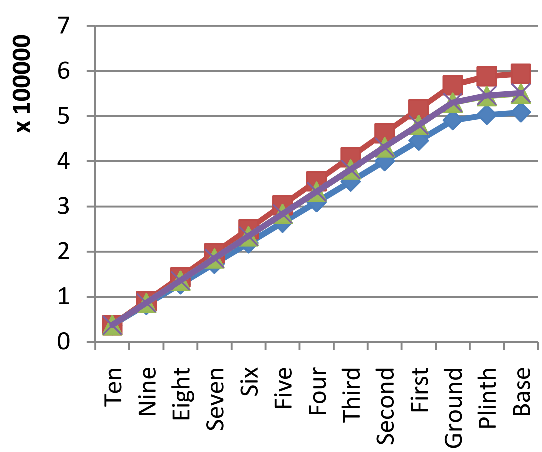


Figure 9: Storey Overturning Moments

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:

- 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.
- 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.
- 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.
- 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 center of the building or at the corners.
- The main difference in the behaviors 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.
- 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.
- 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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