Seismic Analysis of Multi-Storey RCC Building with Circular Shear Wall to Conventional Shear Wall

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Abstract— In the seismic design of multi Storey RCC buildings, reinforced concrete structural walls or shear walls, act as major seismic force resisting members. Structural walls provide efficient lateral stiffness and offer great potential for lateral load resistance. The properties of these seismic shear are important to evaluate the seismic response of the walls. In this project, main focus is to compare the performance of circular shear wall to rectangular shear wall in multi storied RCC building. In this study, Shear-walls are oriented in three different positions for circular and rectangular types of shear walls. The structure is considered as OMRF (ordinary moment resisting frame) structure. The structures are compared on four different parameters namely joint displacement, axial force, bending moment and base shear. The response of bare frame structure (structure with no shear walls) in the analysis of joint displacement, axial force, bending moment and base shear is also considered in comparison to circular and rectangular shear walls. Effectiveness of shear wall has been studied with the help of seven different models. Seismic forces are applied to the structure of Ground+10-storeys located in zone-III. STAAD Pro V8i software is used for the analysis of structures. The structure is considered as public building. The load conditions are taken from IS 1893:2002 (Part 1).

Key words: Shear Wall, STAAD Pro, Circular Shear Wall, Rectangular Shear Wall, Seismic Analysis, Lateral Moment, Shape of Shear Wall

I. INTRODUCTION

High rise building is a structure vertically cantilevered from the ground level subjected to axial loading & lateral forces. It consists of frames, beams, shear walls, core walls, and slab structures which interact through their connected edges to distribute lateral and axial load imposed to the building. Lateral forces generated either due to the inertia forces of the building mass moving through gravity. These types of forces can be resisted with the use of shear wall system which is one of the most efficient methods of ensuring the lateral stability of high rise buildings.

The principle aim of this present study is to analyse the structure using STAAD Pro software and to study the comparison of RCC multi-storey buildings with circular shear wall to conventional shear wall.

The present work deals with the analysis of high rise building with different locations of shear walls with different shapes. The high rise building is analysed for its displacement, axial force, bending moment and base shear using STAAD Pro V8i software. The results of the analysis on the displacement, axial force, bending moment and base shear are compared. The results are presented in tabular and graphical form. Equivalent static analysis has been carried out in this study.

II. NEED OF THE STUDY

Due to frequent occurrences of earthquakes now a days, it is now becoming mandatory to provide optimum stiffness to a structure. It is very necessary to determine optimum and ideal location of shear walls in buildings. By providing shear walls at ideal locations we get,

1. It provide maximum strength and stiffness in the direction of orientation.
2. It reduces large lateral sway in high rise structure.
3. They are efficient both in terms of construction cost and effectiveness in minimizing the seismic damage in structural and non-structural elements.
4. If circular shear wall is used at plans, resistance against earthquake is effective due to equal performance at any direction.
5. Shear wall structural systems are more stable. Because, their supporting area with reference to total plans area of building, is comparatively more, unlike in the case of RCC framed structures.
6. Shear walls are structurally integrated with roofs / floors and other lateral walls running across at right angles, thereby giving the three dimensional stability for the building structures.

III. BUILDING CONFIGURATION

<table>
<thead>
<tr>
<th>Mathematical Modelling</th>
<th>Dimensions</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>A multi storied framed building</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>96</td>
<td>m</td>
</tr>
<tr>
<td>Width</td>
<td>60</td>
<td>m</td>
</tr>
<tr>
<td>No. of storey’s</td>
<td>G+10</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>33</td>
<td>m</td>
</tr>
<tr>
<td>Height of ground storey</td>
<td>3</td>
<td>m</td>
</tr>
<tr>
<td>Height of floor to floor</td>
<td>3</td>
<td>m</td>
</tr>
<tr>
<td>Height of parapet wall</td>
<td>1.2</td>
<td>m</td>
</tr>
<tr>
<td>Spacing of frame along length</td>
<td>6</td>
<td>m</td>
</tr>
<tr>
<td>Spacing of frame along width</td>
<td>4</td>
<td>m</td>
</tr>
<tr>
<td>Grade of concrete</td>
<td>M20</td>
<td></td>
</tr>
<tr>
<td>Grade of steel</td>
<td>Fe 415</td>
<td></td>
</tr>
<tr>
<td>Soil Type</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Zone</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>Frame type</td>
<td>OMRF</td>
<td></td>
</tr>
<tr>
<td>Live Load</td>
<td>3</td>
<td>kN</td>
</tr>
<tr>
<td>Roof Live</td>
<td>1.5</td>
<td>kN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structural properties of Building</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements name</td>
<td>Dimensions</td>
<td>Units</td>
</tr>
<tr>
<td>Total depth of slab</td>
<td>0.14</td>
<td>m</td>
</tr>
<tr>
<td>External wall</td>
<td>0.25</td>
<td>m</td>
</tr>
</tbody>
</table>

Table 1: Configuration
Seismic Analysis of Multi-Storey RCC Building with Circular Shear Wall to Conventional Shear Wall (IJSRD/Vol. 3/Issue 05/2015/244)

<table>
<thead>
<tr>
<th>thickness</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal wall thickness</td>
<td>0.175 m</td>
</tr>
<tr>
<td>Size of column</td>
<td>0.6 m</td>
</tr>
<tr>
<td>Size of column inside shear wall</td>
<td>0.2 m</td>
</tr>
<tr>
<td>Size of beam in longitudinal and transverse direction</td>
<td>0.55 m</td>
</tr>
<tr>
<td>Shear wall thickness</td>
<td>0.2 m</td>
</tr>
<tr>
<td>No. of columns under consideration</td>
<td>10 number</td>
</tr>
</tbody>
</table>

Table 2: Configuration

The following load combinations are considered,
- 1.2(DL+LL+EQX)
- 1.2(DL+LL+EQZ)
- 1.2(DL+LL-EQX)
- 1.2(DL+LL-EQZ)
- 1.5(DL+EQX)
- 1.5(DL+EQZ)
- 1.5(DL-EQX)
- 1.5(DL-EQZ)
- 0.9DL+1.5EQX
- 0.9DL+1.5EQZ

IV. LOCATION & SHAPES OF SHEAR WALLS

A. Types of Models:

Following are the types of models prepared and analysed in STAAD Pro,
- Bare Frame Model
- Rectangular Shear Wall Model 1
- Rectangular Shear Wall Model 2
- Rectangular Shear Wall Model 3
- Circular Shear Wall Model 1
- Circular Shear Wall Model 2
- Circular Shear Wall Model 3

Fig. 1: Plan of Structure

1) Two types of shear walls are provided i.e.
   - Rectangular Shear Wall (RSW) &
   - Circular Shear Wall (CSW)

2) Three different shear wall orientation is considered,
   - Shear walls at inner edges of structure.
   - Shear walls at outer edges of structure.
   - Shear walls at central core of structure.

Fig. 2: Bare Frame Model

2) Rectangular Shear Wall Model 1:

Fig. 3: Rectangular Shear Wall Model 1

3) Rectangular Shear Wall Model 2:
4) **Rectangular Shear Wall Model 3**:

5) **Circular Shear Wall Model 1**:

6) **Circular Shear Wall Model 2**:

7) **Circular Shear Wall Model 3**:
V. ANALYSIS OF STRUCTURES

In this project I extensively referred IS 1893:2002 for the analysis of shear walls. Various clauses which I ponder upon are as follows,

A. IS 1893(part 1): 2002 - Criteria for Earthquake Resistant Design of Structures:

1) Clause No. 6.4.2 - The design horizontal seismic coefficient $A_h$ for the structure shall be determined by the following expression:

$$A_h = \frac{ZIS_a}{2R_g}$$

Provided that for any structure with $T < 0.1$s, the value of $A_h$ will not be taken less than $Z/2$ whatever be the value of $I/R$.

Where,

- $Z$ = Zone factor given in Table 2
- $I$ = Importance Factor given in Table 6
- $R$ = Response reduction factor taken from Table 7, however the ratio $(I/R)$ shall not be greater than 1.0.
- $S_a/g = $ Average response acceleration coefficient taken from fig 2 and table 3.

2) Clause No. 6.3.1.2 – in limit state design of reinforced and prestressed concrete structures, the following load combinations can be accounted for:-

- 1.5 (DL+IL)
- 1.2 (DL+IL+EL)
- 1.5 (DL+EL)
- 0.9DL+1.5 EL

3) Clause No. 7.5.3 – Design Seismic Base Shear: The total design lateral force or design seismic base shear ($V_B$) along any principal direction shall be determined by the following expression,

$$V_B = A_hW$$

Where, $W$ = Seismic weight of the building

I also used IS 13920:1993 to understand certain shear wall requirements as follows,

B. IS 13920: 1993 Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces:

- Clause no. 9.1: It gives general requirements for shear walls.
- Clause no. 9.2: It gives shear strength of shear wall.
- Clause no 9.3: It gives flexural strength of shear wall.

C. IS 1893: 1984 – Criteria for Earthquake Resistant Design of Structures:

1) Clause No. 4.1.1 - For various loading classes as specified in IS 875: 1960, the horizontal earthquake force shall be calculated for the full dead load and the percentage of live loads as given below:

- Load Percentage of design live load
- Below 3KN 25%
- Above 3KN 50%

2) Clause No. 4.1.2 – For calculating the earthquake force on the roofs, the live load may not be considered.

D. IS 456: 2000- Plain and Reinforced Concrete - Code of Practice (Fourth Revision):

1) Clause No. 19.2.1- Dead Load may be calculated on the basis of unit weights of materials given in IS 875 (Part 1). The unit weight of concrete may be taken as 25 KN/m$^3$.

a) Analysis:

1) Displacement:

Analysis and results are obtained on the basis of analysis carried out in STAAD Pro for lateral displacements are as follows,

<table>
<thead>
<tr>
<th>Model</th>
<th>Bare Frame</th>
<th>RSW 1</th>
<th>RSW 2</th>
<th>RSW 3</th>
<th>CSW1</th>
<th>CSW2</th>
<th>CSW3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX Displacement</td>
<td>123.481</td>
<td>67.796</td>
<td>91.276</td>
<td>71.674</td>
<td>89.422</td>
<td>93.685</td>
<td>97.133</td>
</tr>
</tbody>
</table>

Fig. 9: Displacement

2) Axial Force:

Analysis and results are obtained on the basis of analysis carried out in STAAD Pro for axial force are as follows,

<table>
<thead>
<tr>
<th>Model</th>
<th>Bare Frame</th>
<th>RSW 1</th>
<th>RSW 2</th>
<th>RSW 3</th>
<th>CSW1</th>
<th>CSW2</th>
<th>CSW3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX Axial Force</td>
<td>5628.289</td>
<td>4875.223</td>
<td>5271.519</td>
<td>4944.928</td>
<td>4965.679</td>
<td>5239.637</td>
<td>5398.863</td>
</tr>
</tbody>
</table>

Fig. 10: Models

3) Bending Moment:

Bending Moment in Y-Direction:

Analysis and results are obtained on the basis of analysis carried out in STAAD Pro for bending moment in Y-direction are as follows,

<table>
<thead>
<tr>
<th>Model</th>
<th>Bare Frame</th>
<th>RSW 1</th>
<th>RSW 2</th>
<th>RSW 3</th>
<th>CSW1</th>
<th>CSW2</th>
<th>CSW3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX Bending Moment Y</td>
<td>497.657</td>
<td>270.907</td>
<td>371.733</td>
<td>269.553</td>
<td>375.655</td>
<td>351.989</td>
<td>388.79</td>
</tr>
</tbody>
</table>

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VI. RESULTS AND DISCUSSIONS

Following are the results I got from studying the graphs and bar charts for parameters namely lateral displacement, axial force, bending moments and base shear are as follows,

A. Displacement Results:
1) Comparing Bare Frame (BF) with all models:
   - BF has 45% more displacement than RSW1.
   - BF has 26% more displacement than RSW2.
   - BF has 42% more displacement than RSW3.
   - BF has 28% more displacement than CSW1.
   - BF has 24% more displacement than CSW2.
   - BF has 21% more displacement than CSW3.

2) Comparing all Rectangular Shear wall models:
   - RSW1 has 26% less displacement than RSW2.
   - RSW1 has 5% less displacement than RSW3.
   - RSW2 has 21% more displacement than RSW3.

3) Comparing all Circular Shear wall models:
   - CSW1 has 5% less displacement than CSW2.
   - CSW1 has 8% less displacement than CSW3.
   - CSW2 has 4% less displacement than CSW3.

4) Comparing RSW models with CSW models:
   - RSW1 has 24% less displacement than CSW1.
   - RSW2 has 3% less displacement than CSW2.
   - RSW3 has 26% less displacement than CSW3.

B. Axial Force Results:
1) Comparing Bare Frame (BF) with all models:
   - BF has 13% more axial force than RSW1.
   - BF has 6% more axial force than RSW2.
   - BF has 12% more axial force than RSW3.
   - BF has 11.78% more axial force than CSW1.
   - BF has 7% more axial force than CSW2.
   - BF has 4% more axial force than CSW3.

2) Comparing all Rectangular Shear wall models:
   - RSW1 has 8% less axial force than RSW2.
   - RSW1 has 1.5% less axial force than RSW3.
   - RSW2 has 7% more axial force than RSW3.

3) Comparing all Circular Shear wall models:
   - CSW1 has 5% less axial force than CSW2.
   - CSW1 has 8% less axial force than CSW3.
   - CSW2 has 3% less axial force than CSW3.

4) Comparing RSW models with CSW models:
   - RSW1 has 1.82% less axial force than CSW1.
   - RSW2 has 0.6% less axial force than CSW2.
   - RSW3 has 8% less axial force than CSW3.

C. Bending Moment in Y-direction Results:
1) Comparing Bare Frame (BF) with all models:
   - BF has 46% more bending moment than RSW1.
   - BF has 25% more bending moment than RSW2.
   - BF has 46% more bending moment than RSW3.
   - BF has 25% more bending moment than CSW1.
   - BF has 29% more bending moment than CSW2.
   - BF has 22% more bending moment than CSW3.

2) Comparing all Rectangular Shear wall models:
   - RSW1 has 27% less bending moment than RSW2.
   - RSW1 has 0.5% more bending moment than RSW3.
- RSW2 has 28% more bending moment than RSW3.

3) Comparing all Circular Shear wall models:
- CSW1 has 6% more bending moment than CSW2.
- CSW1 has 3% less bending moment than CSW3.
- CSW2 has 10% less bending moment than CSW3.

4) Comparing RSW models with CSW models:
- RSW1 has 28% less bending moment than CSW1.
- RSW2 has 5% more bending moment than CSW2.
- RSW3 has 31% less bending moment than CSW3.

D. Bending Moment in Z-direction Results:

1) Comparing Bare Frame (BF) with all models:
   - BF has 60% more bending moment than RSW1.
   - BF has 48% more bending moment than RSW2.
   - BF has 47% more bending moment than RSW3.
   - BF has 25% more bending moment than CSW1.
   - BF has 50% more bending moment than CSW2.
   - BF has 32% more bending moment than CSW3.

2) Comparing all Rectangular Shear wall models:
   - RSW1 has 24% less bending moment than RSW2.
   - RSW1 has 24% less bending moment than RSW3.
   - RSW2 has 1% less bending moment than RSW3.

3) Comparing all Circular Shear wall models:
   - CSW1 has 34% more bending moment than CSW2.
   - CSW1 has 10% more bending moment than CSW3.
   - CSW2 has 27% less bending moment than CSW3.

4) Comparing RSW models with CSW models:
   - RSW1 has 47% less bending moment than CSW1.
   - RSW2 has 5% more bending moment than CSW2.
   - RSW3 has 23% less bending moment than CSW3.

E. Base Shear Results

1) Comparing Bare Frame (BF) with all models:
   - BF has 6% more base shear than RSW1.
   - BF has 4% more base shear than RSW2.
   - BF has 6.5% more base shear than RSW3.
   - BF has 1% less base shear than CSW1.
   - BF has 2% less base shear than CSW2.
   - BF has 1% less base shear than CSW3.

2) Comparing all Rectangular Shear wall models:
   - RSW1 has 2% less base shear than RSW2.
   - RSW1 has 1% more base shear than RSW3.
   - RSW2 has 2.8% more base shear than RSW3.

3) Comparing all Circular Shear wall models:
   - CSW1 has 1% less base shear than CSW2.
   - CSW1 has nearly same base shear as CSW3.
   - CSW2 has 1% less base shear than CSW3.

4) Comparing RSW models with CSW models:
   - RSW1 has 7% less base shear than CSW1.
   - RSW2 has 6% less base shear than CSW2.
   - RSW3 has 8% less base shear than CSW3.

VII. CONCLUSIONS

From the analysis and results of various parameters under consideration I have concluded that,

A. Displacement Conclusions:
- Comparing Bare Frame (BF) with all models:
  - RSW1 is the most efficient model in comparison with bare frame.
- Comparing all Rectangular Shear wall models:
  - RSW1 is the most efficient model in comparison of all rectangular shear wall models.
- Comparing all Circular Shear wall models:
  - CSW1 has less displacement as compared to other circular shear wall models.
- Comparing RSW models with CSW models:
  - RSW1 is the most efficient model by comparing all considered models.

B. Axial Force Conclusions:
- Comparing Bare Frame (BF) with all models:
  - RSW1 is the most efficient model in comparison with bare frame.
- Comparing all Rectangular Shear wall models:
  - RSW1 is the most efficient model in comparison of all rectangular shear wall models.
- Comparing all Circular Shear wall models:
  - CSW1 has less displacement as compared to other circular shear wall models.
- Comparing RSW models with CSW models:
  - RSW1 is the most efficient model by comparing all considered models.

C. Bending Moment-Y Conclusions:
- Comparing Bare Frame (BF) with all models:
  - RSW3 is the most efficient model in comparison with bare frame.
- Comparing all Rectangular Shear wall models:
  - RSW1 is the most efficient model in comparison of all rectangular shear wall models.
- Comparing all Circular Shear wall models:
  - CSW2 has less bending moment as compared to other circular shear wall models.
- Comparing RSW models with CSW models:
  - RSW3 is the most efficient model by comparing all considered models.

D. Bending Moment-Z Conclusions:
- Comparing Bare Frame (BF) with all models:
  - RSW1 is the most efficient model in comparison with bare frame.
- Comparing all Rectangular Shear wall models:
  - RSW1 is the most efficient model in comparison of all rectangular shear wall models.
- Comparing all Circular Shear wall models:
  - CSW2 has less bending moment as compared to other circular shear wall models.
- Comparing RSW models with CSW models:
  - RSW3 is the most efficient model by comparing all considered models.

E. Base Shear Conclusions:
- Comparing Bare Frame (BF) with all models:
  - RSW3 is the most efficient model in comparison with bare frame.
- Comparing all Rectangular Shear wall models:
RSW3 is the most efficient model in comparison of all rectangular shear wall models.
- Comparing all Circular Shear wall models:
  - CSW1 has less bending moment as compared to other circular shear wall models.
- Comparing RSW models with CSW models:
  - RSW3 is the most efficient model by comparing all considered models.

Finally I conclude that,
1) RSW1 model has the minimum lateral displacement.
2) RSW1 model has the minimum axial force in comparison to all considered models.
3) RSW3 model is the most efficient model as it has minimum bending moment in Y-direction by comparing all considered models.
4) RSW1 model is the most efficient model as it has minimum bending moment in Z-direction by comparing all considered models.
5) RSW3 model is the most efficient model as it has minimum base shear by comparing all considered models.

The rectangular shear wall models are found to be more stable than circular shear wall models in all considered parameters. Model RSW1 is found to be more stable as compare to all other models. As I considered partial circular models instead of full circular core model, the performance of shear wall is less than core CSW models. RSW models are more stable than CSW model and bare frame model.

REFERENCES