Seismic Response of RC Frame Structure Due To Effect of Brick Masonry Infilled Wall

Akhil Bhardwaj¹, S.C.Gupta²
PG Student¹, Senior Associate Professor²
Department of Civil Engineering
University of Petroleum and Energy Studies, Dehradun, India

Abstract:
Masonry infilled RC frames are the most common type of structures used for multistoried construction even in seismically active regions. Practicing engineers usually neglect the effects of infill walls on seismic behavior of structures and take it as a non-structural member. But in most of the cases, the ignorance of stiffness of masonry in designing of the RC frame might create an unsafe design. The effect of ground motion on RC frame building has been carried out by considering various models. The masonry infill has been modeled as an Equivalent diagonal strut element using Paulay and Priestley’s formula. Static analysis of various models has been done using ETABS and then compared with bare frame model. Results show that infill walls increases storey stiffness, frequency, base shear and axial forces in columns present at ground storey whereas it reduces Time period, Storey drift, Shear force and bending moment in columns present at ground storey.

Keywords: Stiffness, Equivalent Diagonal Strut, Static Analysis, Base shear, Storey Drift

I. INTRODUCTION

The behaviour of masonry in infilled frame structures has been studied for past many years to develop a rational approach for design of such buildings as this type of building are widely in use in both urban and semi urban areas. Usually the RC frame is filled with bricks as non-structural wall for partition of rooms. Need for vehicle parking, shops, receptions, gym etc compel to provide an open first story in buildings but it is vulnerable to collapse due to earthquake. The main reason behind this is neglecting the stiffness of infilled walls in RC framed structures. As per IS 1893 (part-1) 2002 code (BIS-2002) some design criteria are adopted after carrying out the earthquake analysis, in which the columns and beams of the soft stories are designed for 2.5 times the storey shears and moments calculated under seismic loads. In this paper an attempt to study the response of soft storey frame, bare frame and frame infilled with brick masonry due to earthquake load is done using ETABS. Including stiffness of infills in design can increase the overall strength, lateral resistance and energy dissipation of the structure. It reduces the lateral deflections and bending moments in the frame, thereby decreasing the probability of collapse. Hence, accounting for the infills in the analysis and design leads to safer and more economic structure. The total base shear experienced by a building during an earthquake is dependent on its time period. It also results into stiffer structure thereby reducing the storey drifts (lateral displacement at floor level). This improved performance makes the structural design more realistic to consider infill walls as a structural element in the earthquake resistant design of structures.

II. DISCRIPTION OF STRUCTURAL MODEL

Significant experimental and analytical research is reported in the literature, which attempts to understand the behaviour of infilled frames. Various analytical models based on the physical understanding of overall behavior of an infill panels were developed. The available models can be categorized as:

i) Macro Models and

ii) Micro Models.

Single strut model is the most widely used as it is simple and most suitable for large structures (Das and Murthy, 2004). Hence, RC frames with unreinforced masonry walls can be modeled as equivalent braced frames with infill walls replaced by equivalent diagonal strut. For calculation of width of the diagonal single strut Paulay and Priestley formula has been used –

\[ W = 0.25d \]

Where,

\[ d = \text{Diagonal length of infill panel} \]

\[ W = \text{Depth of diagonal strut} \]

The building is deliberately kept symmetric in both orthogonal directions in plan to avoid torsional response under lateral forces. Since it is a regular building with height less than 40m so according to IS: 1893(Part-1):2002 Dynamic analysis is not required and hence Equivalent Static Analysis has been carried out using the ETABS.
TABLE 1. SPECIFICATIONS OF FRAMED STRUCTURE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Structure</td>
<td>G+5</td>
</tr>
<tr>
<td>Plan Dimension</td>
<td>9m X 9m</td>
</tr>
<tr>
<td>Size of Beams</td>
<td>300mm X 450mm</td>
</tr>
<tr>
<td>Size of Columns</td>
<td>350mm X 500mm</td>
</tr>
<tr>
<td>Total Height</td>
<td>18.5</td>
</tr>
<tr>
<td>Zone</td>
<td>IV</td>
</tr>
<tr>
<td>Foundation level to plinth level</td>
<td>1.5m</td>
</tr>
<tr>
<td>Foundation level to ground level</td>
<td>1m</td>
</tr>
<tr>
<td>Ground level to plinth level</td>
<td>0.5m</td>
</tr>
<tr>
<td>Live Load</td>
<td>3kN/m²</td>
</tr>
<tr>
<td>Dead Load</td>
<td>Self weight + 1.5kN/m²</td>
</tr>
<tr>
<td>Intermediate Storey height</td>
<td>3m</td>
</tr>
<tr>
<td>Type of soil</td>
<td>Medium</td>
</tr>
<tr>
<td>Material</td>
<td>M25 Grade concrete</td>
</tr>
<tr>
<td>Unit weight a) Concrete</td>
<td>25 kN/m³</td>
</tr>
<tr>
<td></td>
<td>b) Masonry</td>
</tr>
<tr>
<td>Damping ratio</td>
<td>0.05</td>
</tr>
<tr>
<td>Response Reduction Factor</td>
<td>5</td>
</tr>
<tr>
<td>Importance Factor</td>
<td>1</td>
</tr>
<tr>
<td>Calculated Equivalent width of</td>
<td>1.06m</td>
</tr>
<tr>
<td>Modulus of Elasticity of</td>
<td>5500 MPa (550fm)</td>
</tr>
<tr>
<td>Masonry</td>
<td>(Desdela et al. (1993))</td>
</tr>
<tr>
<td>Poisson’s Ratio of masonry</td>
<td>0.15</td>
</tr>
<tr>
<td>Modulus of Elasticity of</td>
<td>25000 MPa</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.3</td>
</tr>
<tr>
<td>Slab Depth</td>
<td>150 mm</td>
</tr>
</tbody>
</table>

III. ANALYTICAL MODEL

1. Model 1 (BARE FRAME): SMRF infill frame without including the effect of masonry walls as shown in fig. 3.
2. Model 2 (SOFT STOREY): SMRF infilled frame with masonry wall effect considered in all storeys except ground Storey as shown in fig. 4.
3. Model 3 (INFILLED FRAME): SMRF infilled frame with masonry wall effect considered in all stories as shown in fig. 4.

IV. ANALYSIS OF RESULT AND DISCUSSION

STOREY STIFFNESS

From graph 4.1.1 and 4.1.2 obtained from ETABS it is clear that from 5th storey to 2nd storey soft storey and infilled frame shows nearly same amount of stiffness but is greater than bare frame model. But at ground storey infilled frame gives the maximum stiffness as compared to other two models which is nearly 3.11 times that of bare frame in X-direction and 3.64 times in Y-direction. For X and Y direction there is a difference due to column orientation.
TIME PERIOD
Natural time period in case of bare frame is maximum and minimum in case of infilled frame. As time period is inversely proportional to stiffness so as stiffness increases time period decreases. Infilled frame has highest stiffness and hence lowest time period. Bare frame idealization leads to overestimation of natural periods and under estimation of the design lateral forces.

GRAPH-3

NATURAL FREQUENCY
Natural frequency is inversely proportional to time period of the structure. In this case natural frequency of infilled frame is maximum and is 90\% more than bare frame.

GRAPH-4

STOREY FORCES
Lateral force on structure is more in case of infilled frame for all the stories as the time period is less in case of infilled frame so it resulted into more lateral storey forces. At ground level Base she for infilled frame is 93\% more than bare frame where as Base shear for Soft Storey model at ground level is 58\% more than bare frame for X- direction. In Y-direction Base shear for infilled frame is 106\% more than bare frame. This shows that providing walls can increase base shear.

GRAPH-5

STOREY DRIFT
In X-direction and Y-direction response in terms of drift is nearly the same. At ground level soft storey has maximum drift and infilled frame has minimum drift but as height is increased storey drift in case of infilled frame it increases till ground storey and then decreases gradually. Bare frame increases till 1\textsuperscript{st} storey and then start decreasing as height increases. But in any case it does not exceed the specified value of IS 1893 (part-1) 2002, i.e., 0.004 X H, where H=Storey height. It comes out to be 0.012m.

GRAPH-7

AXIAL FORCES IN GROUND STOREY COLUMNS
Axial force for all 16 columns at ground storey are shown in graph. It shows that all external columns at corner like C\textsubscript{1}, C\textsubscript{4}, C\textsubscript{13}, C\textsubscript{16} experiences nearly same axial force. Infilled frame experiences the greatest amount of axial force in comparison to other two models. It is 50\%-53\% more than bare frame in case of infilled frame while it 37\%-40\% more than bare frame in case of soft storey. For rest of the columns there is very less difference in percentage i.e. Axial force is 1\%-10\% more than bare frame in case of infilled frame and 1\%-7\% more than bare frame in case of soft storey.

GRAPH-6

SHEAR FORCES IN COLUMNS AT GROUND STOREY
In X-direction for External columns like C\textsubscript{1} Shear Forces are more in case of soft Storey and least in case of Infilled frame. Infilled frame experiences shear force nearly 80\% less than Bare frame and Soft Storey experiences Shear force nearly 52\% more than that of bare frame. For columns similar in
behaviour to Column C2 which are present at outer edge of the frame above graph shows that Infilled frame experiences shear force nearly 50% to 53% less that bare frame and Soft storey experiences shear force 50% more than that of bare frame. For Interior columns like C7 Shear force is nearly 18% less than bare frame in case of infilled frame and nearly 48% more than bare frame in case of soft storey. In Y-direction for External columns like C1 infilled frame experiences shear force nearly 55% less than Bare frame and Soft Storey experiences shear force nearly 47% more than that of bare frame. For columns similar in behaviour to Column C2 Infilled frame experiences shear force nearly 18% to 20% less that bare frame and Soft storey experiences shear force 55% more than that of bare frame. For Interior columns like C7 Shear force is nearly 30% -32% less than bare frame in case of infilled frame and nearly 47% more than bare frame in case of soft storey.

BENDING MOMENT IN COLUMN AT GROUND STOREY

Bending Moment in columns at ground Storey, infilled frame experiences minimum bending moment and soft storey experience maximum bending moment. In X- direction for External columns like C1, Infilled frame experiences bending moment nearly 60% less than Bare frame and Soft Storey experiences Bending moment nearly 30% more than that of bare frame. For columns similar in behaviour to Column C2 which are present at outer edge of the frame above graph shows that Infilled frame experiences bending moment nearly 25% less that bare frame and Soft storey experiences moment 33% more than that of bare frame. For Interior columns like C7 bending moment is nearly 32% less than bare frame in case of infilled frame and nearly 33% more than bare frame in case of soft storey. In Y- direction for External columns like C1 bending moments are more in case of Soft Storey and least in case of Infilled frame. Infilled frame experiences bending moment nearly 80% less than Bare frame and Soft Storey experiences Shear force nearly 19% more that of bare frame. For columns similar in behaviour to Column C2 which are present at outer edge of the frame above graph shows that Infilled frame experiences bending moment nearly 60% to 63% less that bare frame and Soft storey experiences shear force 27% more than that of bare frame. For Interior columns like C7 bending moment is nearly 25% less than bare frame in case of infilled frame and nearly 25% more than bare frame in case of soft storey.

V. CONCLUSION

1. It shows that Brick Masonry infill walls imparts a good amount of stiffness to particular storey. This result also shows the disadvantage of not providing infilled wall at ground storey which reduces the stiffness of the ground storey.
2. Time Period is least in case of infill frame which shows that as stiffness is increases, time period decreases which result into increase in base shear.
3. Base shear in case of infilled frame is maximum. So providing Infill walls leads to increase in base shear value.
4. Story drift in all cases is within limits so there is no substantial effect due to infill walls.
5. Axial force is more in case of infill frame than soft storey and bare frame which shows that designers are underestimating the amount of axial load actually acting when there is presence of infill walls.
6. Shear force and bending moments are reduced due to infill walls. So, designer is over-safe in this case because he is actually designing it as bare frame which can resist more shear force and moment. But it also proves that providing soft storey is very harmful as it increases the magnitude of bending moment and shear force as compare to bare frame. So, providing infill wall at ground makes the building over safe.

VI. REFERENCES


