Comparative analysis and design of framed structure with different types of infill walls

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ABSTRACT

In the last few decades, the scientific community has been extensively involved in the investigation about the interaction between infill walls and RC frames in the seismic structural behaviour. The infill walls are seldom included in the numerical analysis of reinforced concrete structural Systems since infill panels are generally considered as non-structural components. However, these panels affect the structural response to a large extent, because the complexity they introduce to analysis, kept them unaccounted. Therefore, it is crucial to understand the contribution of infill walls to earthquake response of the Structures. In this study, an attempt is made to do comparative analysis and design of the structure when the structure is modelled using different types of infill walls.

In this study, an R/C frame structure with a different type of infill walls like AAC Block, Clay Brick, are considered to investigate the effect of different types of infill walls on earthquake response of the structures. The RCC frame analyzed & designed by using STAAD-Pro software. The diagonal strut approach is adopted for modelling of infill walls. The analytical results of the building frame will be compared and analyzed to obtain are storey drift, base shear, Lateral displacement, shear force and bending moment when subjected to static earthquake loadings.

Keywords— Infill, Caly bricks, AAC block, Equivalent diagonal strut, Staad pro

1. INTRODUCTION

Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without collapse during its intended life. The primary purpose of a structure is to transmit or support loads. If the structure is improperly designed or fabricated, or if the actual applied loads exceed the design specifications, the device will probably fail to perform its intended function, with possible serious consequences. A well-engineered structure greatly minimizes the possibility of costly failures.
In recent decades, the use of high strength reinforced concrete (H.S.R.C) in buildings is widely spread in buildings. The behaviour and ductility of the high strength reinforced concrete frames with infill wall under the effect of lateral load still need a lot of investigations.

In reinforced concrete frame building, the wall is generally used in as infill’s and specified by architects as partitions in such a way that they do not contribute to the vertical gravity load-bearing capacity of the structure. Infill walls protect the inside of the buildings from environmental hazards and create separation insides. In addition to this infill’s have considerable strength and stiffness and they have a significant effect on the seismic response of the structural systems. Mostly two common structural damages observed caused by infill walls in earthquakes i.e. soft stories and short columns.

2. LITERATURE REVIEW
On the basis of the topic selected various literature was gone through on the reasons and findings related to infill. The literature were studies on

- The behaviour of reinforced concrete frames with infill.
- Study on earthquake analysis of multi-storeyed buildings.
- Modelling methodology of infills
- Study of various infills.

The secondary data from various research journals as well as reports are studied and some important learning are mentioned below

Polyakov (1956) et al\(^1\) the study of the complicated behaviour of masonry infill by suggested that the infill and frame disparate excluding at two compression corners. He established the idea of the equivalent diagonal strut and proposed that transformation of stresses from the frame to infill occurs only in the compression zone of the infill.

Fardis (1996) et al\(^2\) investigated the seismic response of an infilled frame which had weak frames with strong infill material. It was found that the strong infill which was considered as non-structural is responsible for earthquake resistance of weak reinforced concrete frames. However, since the behaviour of infill is unpredictable, with the likelihood of failing in a brittle manner, it was recommended to treat infill as a non-structural component by isolating it from frames. On the contrary, since infill is extensively used, it would be cost effective if the positive effects of infill are utilized.

Nasratullah Zahir, Dr Vivek Garg et al\(^3\) paper present static and dynamic analysis of R.C building frame with infill. The results obtained from the analysis indicates that story shear increase for infill frame models compare to bare frame model by equivalent static method and response spectrum method. This increase in the ratio is found to be more at the roof compared to the base of the structure. The story shear values obtained by Smith and Holmes models are found to be more compared to Paulay and infill panel models.

Rahul P. Rathi, Dr P.S. Pajgade et al\(^3\) In this paper actual building such as college building (G+3) is considered by modelling of frame and Infills. Modelling of infills is done as per the actual size of openings with the help of equivalent diagonal strut method for the various model such as bare frame, infill frame and infill frame with the centre and corner opening. Results indicate that infill panels have a large effect on the behaviour of frames under earthquake excitation. In general, infill panels increase the stiffness of the structure. The increase in the opening percentage leads to a decrease in the lateral stiffness of the infilled frame.

3. METHODOLOGY
This research work on the comparison of seismic analysis and design of G+15 building using different types of infill walls. Which include
1. Bare frame model
2. Conventional Clay Bricks Masonry model
3. AAC Block model

4. DETAILS OF STRUCTURAL ELEMENTS AND MATERIAL USED

<table>
<thead>
<tr>
<th>Type of Structure</th>
<th>G+15 RC Frame Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan dimensions</td>
<td>13.62 m × 16.30 m</td>
</tr>
<tr>
<td>The total height of building</td>
<td>51.20 m</td>
</tr>
<tr>
<td>Height of each storey</td>
<td>3.2 m</td>
</tr>
<tr>
<td>Foundation Level to ground</td>
<td>3 m</td>
</tr>
<tr>
<td>Level</td>
<td></td>
</tr>
<tr>
<td>Size of beams</td>
<td>300mm×450mm</td>
</tr>
</tbody>
</table>
Size of columns 750mm×750mm
The thickness of slab 125mm
Grade of Concrete M25
Grade of Steel Fe415
Design Philosophy Limit State Method Conforming (IS456-2000)
Ductility Design IS 13920-1993
Seismic zone II
Response reduction factor (R) 5
The soil type of medium
Importance Factor (I) 1
Damping 5%

4.1 Concrete
Density of Concrete 25 kN/m³
Modulus of Elasticity 5000/\(\sqrt{f_{ck}}\) = 25000 N/mm²
Poisson’s ratio for concrete 0.17
Compressive strength 25 N/mm²

4.2 Masonry clay brick infill
Size 210 mm x 100 mm x 75 mm
Density 19 kN/m³
Poisson’s ratio 0.16
Compressive strength 3.745 N/mm²
Modulus of Elasticity 8675 N/mm²

4.3 AAC Block infill
Size 200 mm x 200 mm x 624 mm
Density 5.5 kN/m³
Poisson’s ratio 0.25
Compressive strength 2.2 N/mm²
Modulus of Elasticity 1600 N/mm²

5. BUILDING PLAN

Fig. 2: Building Plan
6. CALCULATION OF THE WIDTH OF EQUIVALENT DIAGONAL STRUT

In this method, the analysis is carried out by simulating the action of infills similar to that of diagonal struts bracing the frame. The infills are replaced by an equivalent strut of length $D$, and width $W$ and the analysis of the frame-strut system is carried out using usual frame analysis methods. Second stage analysis and design have been carried out by software STAAD-Pro then different parameters have been computed. The relationships proposed by Mainstone Walls have to resist the shear forces that try to push the walls over for computing the width of the equivalent diagonal strut, is widely used in the literature and is given by.

\[
\lambda = \sqrt{\frac{E_t \sin(2\theta)}{4E f I_t h'}}
\]

Where
- $\lambda$ = Stiffness reduction factor
- $E_t$ = the modules of elasticity of the infill material, N/mm²
- $E_f$ = the modules of elasticity of the frame material, N/mm²
- $I_t$ = the moment of inertia of column, mm⁴
- $t$ = the thickness of infill, mm
- $H$ = the centre line height of frames
- $h$ = the height of infill
- $L$ = the centre line width of frames
- $l$ = the width of infill
- $D$ = the diagonal length of the infill panel
- $\theta$ = the slope of infill diagonal to the horizontal.
- Width of strut ($W$) = 0.175 ($\lambda$ $H) ^ {0.4}$ $D$

7. INTRODUCTION OF ANALYTICAL MODELS CONSIDERED

1) Model 1: Bare Frame (RC frame without considering infill)
2) Model 2: RC frame building model with brick infill.
3) Model 3: RC frame building with AAC block infill.

8. RESULTS

Result obtained from StaadPro analysis are discussed below.

<table>
<thead>
<tr>
<th>Lateral Displacement (mm)</th>
<th>Model No 1</th>
<th>Model No 2</th>
<th>Model No 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>X (mm)</td>
<td>21.1100</td>
<td>0.2320</td>
<td>4.0850</td>
</tr>
<tr>
<td>Z(mm)</td>
<td>34.3900</td>
<td>2.5730</td>
<td>6.6040</td>
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</table>

<table>
<thead>
<tr>
<th>Storey no</th>
<th>Height m</th>
<th>X (cm)</th>
<th>Z(cm)</th>
<th>X (cm)</th>
<th>Z(cm)</th>
<th>X (cm)</th>
<th>Z(cm)</th>
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</thead>
<tbody>
<tr>
<td>Base 1</td>
<td>0</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
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<td>0.0000</td>
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<tr>
<td>2</td>
<td>3</td>
<td>0.0445</td>
<td>0.0597</td>
<td>0.0704</td>
<td>0.0765</td>
<td>0.0473</td>
<td>0.0539</td>
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<tr>
<td>3</td>
<td>6.2</td>
<td>0.0993</td>
<td>0.1408</td>
<td>0.1335</td>
<td>0.1482</td>
<td>0.0936</td>
<td>0.1095</td>
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</table>
### Table 3: Base Shear Vb

<table>
<thead>
<tr>
<th>Model</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tbody>
<tr>
<td></td>
<td>552.7 kn</td>
<td>940.08 kn</td>
<td>629.08 kn</td>
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### Table 4: Shear Force

<table>
<thead>
<tr>
<th>Shear Forces (kN)</th>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Storey No.</th>
<th>Member No.</th>
<th>Model 1 (+ve)</th>
<th>Model 1 (-ve)</th>
<th>Model 2 (+ve)</th>
<th>Model 2 (-ve)</th>
<th>Model 3 (+ve)</th>
<th>Model 3 (-ve)</th>
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<tr>
<td>1</td>
<td>105.701</td>
<td>-108.999</td>
<td>70.322</td>
<td>-165.706</td>
<td>68.371</td>
<td>-108.910</td>
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<tr>
<td>2</td>
<td>75.292</td>
<td>-82.485</td>
<td>48.248</td>
<td>-83.916</td>
<td>35.222</td>
<td>-53.064</td>
<td></td>
</tr>
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<td>3</td>
<td>61.873</td>
<td>-73.259</td>
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<tr>
<td>4</td>
<td>62.490</td>
<td>-70.838</td>
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<td>5</td>
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### Table 5: Bending Moment

<table>
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<tr>
<th>Storey No.</th>
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<th>Model 2 (+ve)</th>
<th>Model 2 (-ve)</th>
<th>Model 3 (+ve)</th>
<th>Model 3 (-ve)</th>
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</tr>
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</table>
9. CONCLUSIONS
9.1 Lateral Displacement & Storey Drift
From the observation of the results in table 1 and table 2, In addition to that, the total horizontal displacement and the storey drift of the structure are greatly reduced by the introduction of infill in moment resisting reinforced concrete frame. Here it is seen that strut model buildings have less displacement and drift than bare-frame buildings which can say those strut model buildings are stiffer and safer during the earthquakes than the bare-frame models. From table 1 it’s observed that the conventional brick have minimum lateral displacement then AAC block infill model because the diagonal compressive strength of conventional brick is more than AAC Block as AAC blocks are lightweight and less compressive strength. Its show presence of infill contributes to the stiffness of the building. This effect is clear from Model 1.

9.2 Base Shear
From the observation of the results in table 3, it’s concluded that due to infill walls in building the base shear is increased because of increased in seismic weight of the structure. Model 2 conventional infill model has maximum base shear as its seismic weight is more compared to model 3 and model 3 AAC infill model have less base shear as its seismic weight is less than model 2. The lateral force is distributed along with the building height of all model. Similarly, model 2 has a maximum lateral force as it has maximum base shear.

9.3 Shear Force and Bending Moment
From the observation of the results in table 4 & 5, it’s concluded the response of the structure in terms of bending moments and shear forces is greatly enhanced by the introduction of the infill. Both bending moment and shear force in beams and columns are reduced appreciably due to infill. Again from the observation, it's observed that the bare frame model have the maximum shear force and bending moment in structural members, on the other hand, conventional brick infill model have the minimum shear force and bending moment as compared to all other models.

10. REFERENCES
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[4] IS 2185 Concrete masonry units (Part 1): 1979 Hollow and solid concrete blocks (Second revision)
[8] Illustrated Design of Reinforced Concrete Building (Seventh edition), Dr.V.L.Shah & S.R Karve