Abstract
Constructions methods being practiced in urban centers are with reinforced concrete (RC) frames being in-filled with brick or concrete block masonry. The behavior of RC frames under gravity loads is well understood and hence only the mass of MI is being considered in the analysis of such frames. The lateral load response of MI-RC frame resulting due to wind or seismic loads is largely influenced due to the high lateral stiffness and strength contributed by MI and they also influence the post yield response of the structural system significantly. This thesis highlights the influence of brick masonry infill on the design values of MI-RC frames under various load combinations as prescribed by the Indian seismic code depending on the type of modeling technique adopted to model the MI-RC frames. Analytical modelling has been discussed for various types of masonry infills and feasible one is modelling as diagonal strut element is recommended using finite element software.
I. INTRODUCTION

Buildings are structurally designed to support anticipated loads adequately and safely in addition to fulfill clients’ needs which include functional and aesthetic requirements. Many reinforced concrete (RC) buildings are constructed with masonry infill. Masonry infill (MI) are often used to fill the void between the vertical and horizontal elements of the building frames with the assumption that these MI will not take part in resisting any kind of load either axial or lateral; hence its significance in the analysis of RC frame is generally neglected. Moreover, non-availability of realistic and simple analytical models of MI becomes another hurdle for its consideration in analysis. In fact, an infill wall enhances considerably the strength and rigidity of the structure. It has been recognized that RC frames with MI have more strength and rigidity in comparison to the bared frames and the ignorance of MI has become the cause of failure of many multi-storied buildings.

The primary function of MI is either to protect the inside of the structure from the environment (rain, snow, wind, etc.) or to divide inside spaces. In either case, common practice has always been to ignore MI during the design and analysis of steel/reinforced concrete frame structures. However, MI tends to interact with the surrounding RC frame when the structure is subjected to lateral loads.

II. LITERATURE SURVEY

The concept of modeling MI as a diagonal strut was first visualized by Smith (1962), Smith (1966), Smith (1967), Smith and Crater (1970) by proposing a method to evaluate the stiffness and the width of the diagonal strut to be used in the MI-RC frame analysis. From the study, it has been noted that the failure of masonry in-filled frame may occur in any of the following modes:

a) Failure of the RC frame elements due to excessive bending moments or shear force or axial forces.

b) Diagonal tension crack through the mortar joints and the masonry

c) Local crushing of MI or the mortar at one or either of the compression corner of the in-fill

d) Shear cracking along the mortar bed joints.

Further, studies by Abolghasem Saneinejad and Brian Hobbs (1995) had proposed an equivalent diagonal strut to transform the in-filled frame into an equivalent braced frame which needed adjustments to take care of the induced BM and shear concentrations at the finite lengths of bearing of the in-fills with the neighboring frame. Khalid. M. Mosalam et al (1997) proposed to replace MI with an equivalent diagonal strut whose width was more towards the centre of the in-fill. The study also revealed that the ultimate capacity of the MI-RC frame depended on the mode of failure of the MI. Studies by Liborio Cavaleri et al (2004) have indicated that the tensile strength of mortar plays an important role about the frame-in-fill contact length. The experimental investigations indicated that the ensuredment of a continuous joint between MI and the
RC frame would limit the detachment length which makes the MI to behave as a shell element rather than as a diagonal strut. The effect of MI investigated experimentally by Craig Henderson. R et al (1993) revealed that MI panels with prior damage responded to the loads in a less brittle fashion than those with no prior damage which is a clear indication of a brittle mode of failure of the MI-RC frame under lateral loads. The response of MI-RC frames studied experimentally by Ghassan Al-Chaar et al (2002) showed enhanced shear capacity of MI which was linked to confinement of MI within the RC frames. Also, it was found that the shear capacity of MI increased with increase in the number of bays.

The detrimental effect caused due to the presence of MI in the frames has been discussed by Christiana Dymiotis et al (2001) who has revealed that at the ultimate limit state of the structure, the columns in MI-RC frames would fail due to inadequate rotational capacity. Further it was found that the bare frames were less severely loaded than the MI-RC frame during earthquakes because of their lower stiffness and hence has lower probability of failure when compared with MI-RC frames. Parametric studies by Asteris P. G (2003) indicate that there is a reduction in the performance of the MI-RC frames due to the presence of openings in MI. Further, the investigation has revealed that the presence of in-fills leads to decreased SF on the frame columns but in case of MI-RC frames with soft ground storey these SF on the columns will be higher when compared with the values obtained from bare frame analysis. Experimental investigations conducted by Girish K. B and Achyutha. H (1996) had indicated that the total base shear resisted by MI-RC frame is more than three times that of the bare RC frame clearly indicating the participation of MI is resisting lateral loads. From the investigations it was noticed that, the failure pattern is spread throughout in the case of bare RC frames while the failure pattern in the MI-RC frame is concentrated at the base which is greatly influenced by the yielding, slip and separation of MI and the frame etc.

The parametric study by Jaswant et al (1997) has highlighted the errors involved in modeling of MI-RC structures with soft first storey. The study indicated higher storey drifts in the frames with soft first storey than the fully in-filled frames. Further, the study also suggests that the stiffness of the soft storey should be at least 50% of the stiffness of the fully in-filled storey so as cater for the higher strength and drift demands of the MI-RC frames with soft storey. With this literature, in the present paper discussing following parameters.

- Using equivalent diagonal strut method, finding the width of the strut by different formulas.
- Modal analysis of MI-RC frame to get natural frequency and mode shapes using ETABS.
- To investigate the influence of MI on the design lateral forces on the frames for different load combinations depending on the modeling technique used.
- To investigate the effect of MI on the responses for MI-RC frames with 7 different cases.
II. ANALYSIS

- Equivalent static analysis is carried out for zone-II; parameters such as storey shear, displacement, bending moment are obtained.
- Using finite element software programmer, the generation of response spectra and time history as per IS 1893-2002.
- Time history analysis is carried out to get joint displacement and acceleration.

III. MODELING, ANALYSIS AND DESIGN OF BUILDING SYSTEM

One of the most wide-ranging Software used for the Modeling, Analysis and Design of Building system is done using finite element software which is extensively used building information and modelling software, because of its simplicity. Software is available in two versions, mainly software Plus and Nonlinear both versions are consisting of the following modules included into and controlled by a single Windows-based graphical user interface. The software programs were the first which make allowances for the unique properties which inherent in a mathematical model of a building, allowing a computer representation to be constructed in the same manner as a real building: floor by floor, storey by storey. Column, beam, brace, and wall, are the terminologies used in this program rather than nodes and finite elements. To make the various processes fast and convenient such as, for creation of model, its analysis and design software provides automation and specialized options. And for laying out floor framing, columns, frames and walls, in concrete or steel, and the techniques for quick generation of gravity and lateral loads software provides tools. According to the requirements of the selected building codes, the Seismic and wind loads are generated automatically. With a wide range of steel and concrete design features, these modeling and analysis options are completely incorporated.

IV. DESCRIPTION OF THE PROBLEM

A 10 story MI-RC building having the plane dimension of 25X20m with bay length of 5m in both direction and floor height of 3.2m as shown in fig, is considered for the work.

4.1 column and beam size:
- 1st to 4th floor = 350mm X 750mm
- 5th to 7th floor = 300mm X 600mm
- 8th to 10th floor = 230mm X 450mm
- thickness of slab = 125mm

the structure is modeled as 3D frame using ETABS 2015 the masonry infill is modeled as equivalent - diagonal strut member, quadrilateral shell element and as membrane element (with in-plane stiffness) of uniform thickness (230mm).

4.2 properties of the concrete:
- modulus of elasticity = 25000MPa
- Poisson ratio = 0.2
- Grade = M25 (25MPa)
Density = 25 KN/m³
Mass per unit volume = 2.55 Kg/m³

4.3 Property of reinforcement steel:
Modulus of elasticity = 210000 MPa
Poisson ratio = 0.3
Grade Fe415 (415MPa)

Property of masonry
Modulus of elasticity = 3500 MPa
Poisson ratio = 0.2
Density = 20 KN/m³
Mass per unit volume = 2.03 Kg/m³

4.4 Load on the structure:
Self-weight of frame (Beams, columns, slabs) and live load of 3 KN/m³ is considered this analysis (structure) frame. The structure is analyzed for the seismic loads and load combination as per the Indian standards; (IS-1893 (part 1) 2002).
Seismic zone = zone V
Important factor = I
Soil type = II
Live load = 3.0 KN/m² and design as per IS - 456-2000.
Full dead load (Self weight) and 25% of live (imposed) load contribute the seismic weight as per IS-1893-2002.

4.5 Load Combinations
The following load combinations as per IS 875-1987 (Part 5-Special loads and combinations) “Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures”.

a. 1.5 (DL + LL)
b. 1.2 (DL + LL ± EL)
c. 1.5 (DL ± EL)
d. 0.9 DL ± 1.5 EL

![Figure 1 - Typical plan considered for the analysis](image-url)
The width of the equivalent diagonal strut \( (w) \) can be found out by using many expressions given by different researchers. Smith and Carter (1969) proposed a theoretical relation for the width of the diagonal strut based on the relative stiffness of the infill and frame.

\[
w = 0.58 \left( \frac{1}{H} \right)^{-0.445} \cdot \left( \lambda \cdot H_{\text{inf}} \right)^{0.335(\frac{1}{H})^{0.064}}
\]

Where: \( t \), \( H_{\text{inf}} \), and \( E_{\text{inf}} \) are the thickness, the height and the modulus of the infill respectively, \( \Theta \) is the angle between diagonal of the infill and the horizontal, \( E_c \) is the modulus of elasticity of the column, \( I_c \) is the moment of inertia of the columns, \( H \) is the total frame height, and \( h_{\text{inf}} \) is a dimensionless parameter (which considers the effect of relative stiffness of the masonry panel to the frame).

a) 1\(^{st}\) to 4\(^{th}\) floor- \( \lambda_{h} = 0.72653 \) and \( W = 0.68m \)

b) 5\(^{th}\) to 7\(^{th}\) floor- \( \lambda_{h} = 0.72358 \) and \( W = 0.69m \)

c) 8\(^{th}\) to 10\(^{th}\) floor- \( \lambda_{h} = 0.72153 \) and \( W = 0.7m \)
4.6 Considering seven different cases of the building

i) Bare RC frame model
(ii) RC frame model with diagonal strut, and (iii) MI-RC frame model
The responses of the structural elements have been analysed considering fully in-filled exterior frames along the two orthogonal axes. These frames have been analysed as 2D plane frame. The exterior frames have been modeled in seven different ways as described below.

(i) **Bare RC frame model** - This frame comprises of beams and columns modeled as 2-D-beam elements. Only the mass of the infill is considered on the beams along with other dead loads and live loads. The finite element modeling is shown in figure-4.

(ii) **RC frame model with diagonal strut** - The frame consists of beams and columns modeled as 2-D-beam elements along with diagonal struts modeled as 2-D spar elements. The dimension of the diagonal struts which replaces MI in the analysis has been calculated using the expression developed by Liauw and Kwan. The modeling is represented in figure-5.

(iii) **MI-RC frame model** - In this type, the frame elements have been modeled as 2-D beam along with 230 mm thick brick masonry wall on the beams modeled as plane stress elements wherein the nodes of the RC frame and the MI are merged at the interfaces. The modeling is represented in figure-6.

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### V. RESULTS AND DISCUSSIONS

Linear static analysis has been performed on the frames for the mentioned load combinations. A comparison of the maximum structural responses like maximum bending moments in the columns and beams, maximum value of shear force developed in the columns and beams are presented graphically, some important results are highlighted here under;

#### 5.1 Story shear

**Table-1 : Storey shear due to all load combination**

<table>
<thead>
<tr>
<th>Story level</th>
<th>RC Frame</th>
<th>RC Frame with strut</th>
<th>RC frame with masonry infill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Story10</td>
<td>18.341</td>
<td>54.092</td>
<td>43.925</td>
</tr>
<tr>
<td>Story9</td>
<td>27.4082</td>
<td>105.117</td>
<td>94.574</td>
</tr>
<tr>
<td>Story8</td>
<td>33.25</td>
<td>146.255</td>
<td>137.682</td>
</tr>
<tr>
<td>Story7</td>
<td>38.155</td>
<td>181.248</td>
<td>173.879</td>
</tr>
<tr>
<td>Story6</td>
<td>43.804</td>
<td>211.644</td>
<td>203.166</td>
</tr>
<tr>
<td>Story5</td>
<td>48.031</td>
<td>237.409</td>
<td>225.192</td>
</tr>
<tr>
<td>Story4</td>
<td>51.708</td>
<td>259.581</td>
<td>240.833</td>
</tr>
<tr>
<td>Story3</td>
<td>55.684</td>
<td>277.899</td>
<td>250.751</td>
</tr>
<tr>
<td>Story2</td>
<td>60.804</td>
<td>291.102</td>
<td>255.795</td>
</tr>
<tr>
<td>Story1</td>
<td>64.04</td>
<td>297.595</td>
<td>257.433</td>
</tr>
</tbody>
</table>

The story shear is large in base story and the force is gradually decreasing in all cases with respect to subsequent story heights. For lateral load, all combination effects the bare RC frame exhibits lesser base shear but with infill in all cases is comparatively increasing trend, it implies that the infill contribution resist the lateral force by intern
increasing mass contribution of infill in structures. The RC infill with strut shows a better performance compare to all cases, the table-1 represents all the cases.

5.2 Story drift

![Graph showing RC Frame, RC-IF, and RC Frame with strut story drift vs. story height.]

Figure-8: Representation of storey drift v/s storey height

The story drift is large in base story and the force is gradually decreasing in all cases with respect to subsequent story heights. For lateral load, all combination effects the bare RC frame exhibits higher story drift but with infill in all cases is comparatively decreasing trend, it implies that the infill contribution resist the drift by inter increasing mass contribution of infill in structures. The RC infill with struct shows a better performance compare to all cases represented in figure-8.

5.3 Story displacement

![Graph showing RC Frame and RC Frame with Strut load vs. displacement.]

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Figure-9: Representation of storey drift v/s Load (KN)

The story displacement is nullified in base story and the force is gradually increases in all cases with respect to subsequent story heights. For lateral load, all combination effects the bare RC frame exhibits higher story displacement but with infill in all cases is comparatively decreasing trend, it implies that the infill contribution resist the drift by intern increasing mass contribution of infill in structures. The RC infill with struct shows a better performance compare to all cases represented in figure-9.

VI. CONCLUSION

This paper focused on the structural response of MI-RC structure under in-plane static lateral loads. The results clearly indicate the contribution of MI in resisting the in-plane lateral loads irrespective of the interfacial properties. The base shear and story shears calculated by equivalent lateral load method have been found to be higher than that calculated using modal participation method. The lateral load resisting capacity of MI-RC frame model is more than that of bare RC frame model which can be realized only when the connectivity of the RC frame and MI is properly ensured. The struct modelling ensures better performance compare to all varieties of masonry infill modelling systems. The effective finite element modelling of struct and masonry -infill element modelling is proposed with analytical work. The effect of soft story in earthquake prone areas create majorly damaged in the absence of masonry-infill can be arrived easily with this work.

VII. REFERENCES


TO CITE THIS PAPER