Seismic Performance Assessment of the Reinforced Concrete Structure with Masonry Infill wall

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***Abstract* - Masonry infill walls are remarkable in increasing the initial stiffness of reinforced concrete RC frames, and being the stiffer component, attract most of the lateral seismic shear forces on buildings, thereby reducing the demand on the RC frame members. However, behavior of masonry infill is difficult to predict because of significant variations in material properties and because of failure modes that are brittle in nature. As a result, masonry infill walls have often been treated as non-structural elements in building, and the effects are not included in the analysis and design procedure. However, experience shows that MI may have significant positive or negative effects on the global behavior of buildings and, therefore, should be addressed appropriately. This paper reviews and compares the analysis of reinforced concrete structure with masonry infill wall by using different modeling techniques like Diagonal strut method, shell & plate element method etc.**

***Index Terms* - Masonry Infill, RC Structure, Fundamental Natural Period, STAAD PRO V8i**

I. INTRODUCTION

Reinforced concrete (RC) frame structures with brick masonry infill are extensively used in India. Brick masonry is the very common infill material in India because of its low cost, abundance, good sound and heat insulation properties, and the availability of skilled labour in this construction technique.

Performance of the buildings in the resent earthquake (e.g., 2015 Kathmandu-Nepal Earthquake) clearly illustrates that the presence of infill walls has significant effects. Therefore, the contribution of infill walls cannot be neglected in the moderate & high seismic region where, the frame-infill wall interaction may contribute in both stiffness & strength to the structure. The earthquake damage of the in filled frame structures usually results from ignoring the stiffening effect of the infill, which is reported to increase the stiffness of the bare frame 4 to 20 times, [Comite EuroInternational Du Beton, (1996)]

RC structures are normally designed and analyzed as a bare frame without considering the contribution of the infill material to strength and stiffness. However, during earthquakes, infill walls modify the response of the structure which is different from that predicted for bare frame structures. [2]

In this paper, an attempt has been made to predict natural period of a ten-storey building by using different modeling methods of infill wall. Contribution of masonry infill in the positive performance of the infilled structures is widely recognized but no codes provide the clear guidelines on the design of infilled frame structures. Since 1950 a lots of research has been carried out on RC frame infilled with brick masonry, but in this research seismic performance assessment has been conducted to evaluation the natural period of masonry infilled frames

II. DESCRIPTION OF THE STUDIED BUILDING STRUCTURE

In this study, a ten storeyed moment-resisting RC- framed building having the bay length of 5m in both directions with the plan dimension of 15m x 20m & floor height of 3.2m which is shown in fig: 1 & fig: 2 is considered. The column & beam is modeled as beam elements and the slab as the rigid diaphragm.

Figure 1 Elevation of the building

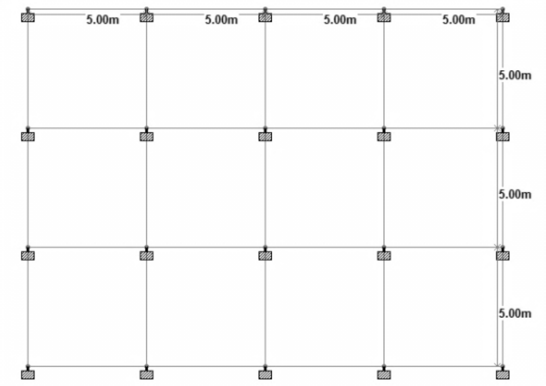

Figure 2 Plan of the building

III. MODELING OF INFILL PANEL

The thickness of the diagonal strut is taken as 230mm, which is the wall thickness and the width of diagonal strut is computed with different proposals researchers. The following are the calculation of the effective width of diagonal strut proposed by various researchers.

1) **Holmes (1961)**

$$w = d/3 \qquad \text{(Eq. 1)}$$

where, w is the width of equivalent strut as shown in fig: 3, d is the diagonal length of infill

$$d = \sqrt{2.75^2 + 4.65^2} = 5.4\text{m}$$

$$w = 5.4/3 = 1.8\text{m}$$

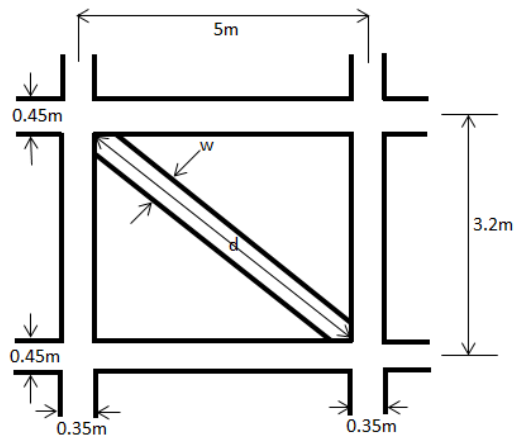

Figure 3 Equivalent Diagonal Strut Model *(homes)*

2) Pauley & Priestley's (1992)

$$w = 0.25d \qquad \text{(Eq. 2)}$$

where, w is the width of equivalent strut as shown in fig: 3, d is the diagonal length of infill

$$d = \sqrt{2.75^2 + 4.65^2} = 5.4\text{m}$$

$$w = 0.25 \times 5.4 = 1.35\text{m}$$

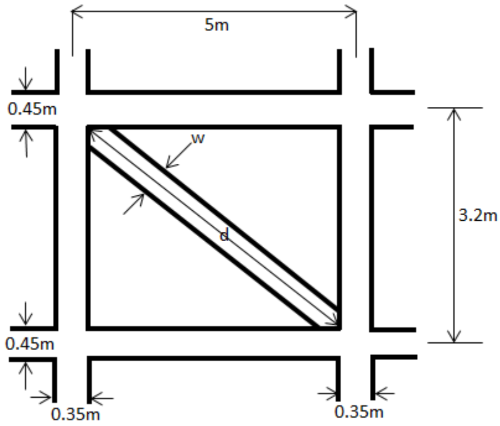

Figure: 4 Equivalent Diagonal Strut Model *(pauley and priestey)*

3) Smith's (1968)

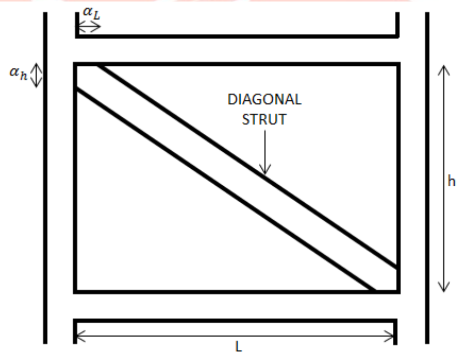

Figure: 5 Equivalent Diagonal Strut Model *(Smith)*

$$\text{Effective width (w)} = \frac{1}{2}\left[\sqrt{(\alpha_h^2 + \alpha_L^2)}\right] \qquad \text{(Eq. 3)}$$

$$w = 1.9966\text{m}$$

Where,

$$\alpha_h = \pi \sqrt[4]{(4\, E_f I_b L \,/ E_m\, t\, \sin 2\theta)} \qquad \text{(Eq. 3.1)}$$

$$\alpha_h = \pi/2 \sqrt[4]{(4\, E_f I_c L \,/ E_m\, t\, \sin 2\theta)} \qquad \text{(Eq. 3.2)}$$

$$E_m = K f_m \qquad \text{(Eq. 3.3)}$$

Where, w = width of equivalent struts; E_m, E_f = elastic moduli of the masonry & frame materials, respectively; h = height of the infill wall; t = thickness of the infill wall; L = length of the infill wall; f_m = compressive strength of masonry; I_c = moment of inertia of column & I_b = moment of inertia of beam.

4) Mainstone's (1971)

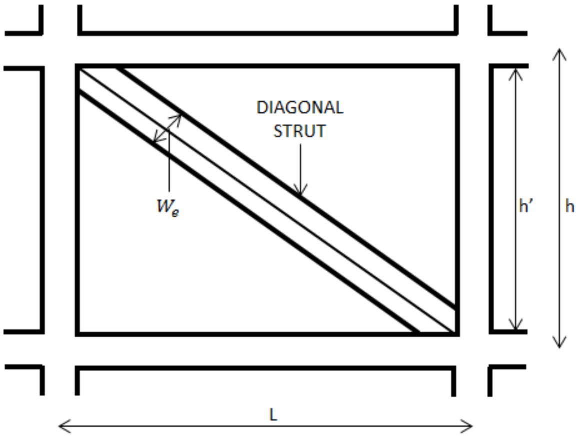

Figure: 6 Equivalent Diagonal Strut Model *(Mainstone)*

$$w_e = 0.175(\beta h)^{-0.4}\, w \qquad \text{(Eq. 4)}$$

$$w_e = 0.764m$$

$$\beta = \sqrt[4]{(E_i\, t\, \sin 2\theta \,/\, 4\, E_f I_c h')} \qquad \text{(Eq. 4.1)}$$

Where, w = width of equivalent struts; E_f, E_i = elastic moduli of the frame & infill panel, respectively; h = height of the frame ; h' = height of the infill ; t = thickness of the infill panel; L = length of the frame; I_c = moment of inertia of column, θ = slope of infill diagonal to the horizontal.

5) Demir and Sivri's (2002)

$$W_{ef} = 0.175(\beta_h H)^{-0.4} \sqrt{H^2 + L^2} \qquad \text{(Eq. 5)}$$

$$W_{ef} = 0.764m$$

$$\beta_h = \sqrt[4]{(E_i\, t\, \sin 2\theta \,/\, 4\, E_c I_c H_t)} \qquad \text{(Eq. 5.1)}$$

Where, W_{ef} = width of equivalent struts; E_c, E_i = elastic moduli of the column & infill panel, respectively; H = height of the frame; H_t = height of infill panel ; t = thickness of the infill panel; L = length of the frame; f_m = compressive strength of masonry; I_c = moment of inertia of column, θ = angle defining diagonal strut.

IV.ANALYTICAL ANALYSIS

The masonry infill walls are modeled as the diagonal strut. The diagonal strut is modeled as 'compression only' member in STAAD PRO V8i which is shown in figure 6

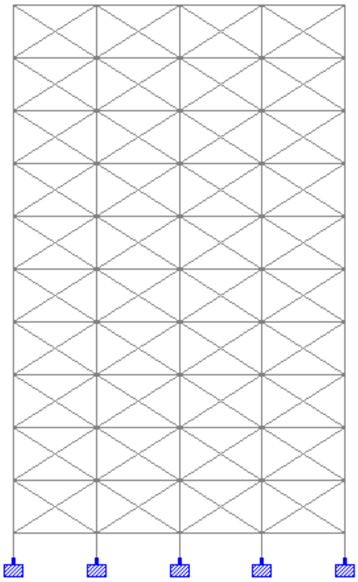

Figure 7 Building with Diagonal Struts

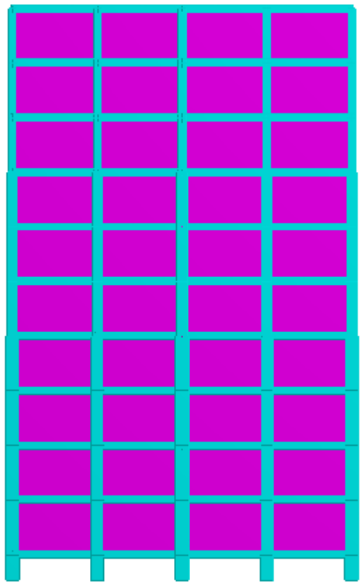

Figure 8 Building with Shell & plate Element

The structure is modeled as 3D frame using STAAD PRO V8I. The masonry infill is modeled as equivalent diagonal strut member, quadrilateral shell element and also as membrane element (with in-plane stiffness) of thickness 230mm. The following are the properties of concrete & brick masonry.

Properties of the concrete
Grade = M25
Density = 25KN/m^3
Modulus of elasticity = 25000 Mpa
Poisson's ratio = 0.2

Properties of the masonry
Density = 20KN/m^3
Modulus of elasticity = 3500 Mpa
Poisson's ratio = 0.2

Live load of 3 KN/m^2 is considered for the analysis of the structure. The analyzed seismic loads & load combinations as per the Indian standard, IS 1893-2002, Seismic Zone = V, Important factor = 1, Soil type= II, Full Dead load & 25% of live load constitute the seismic weight as per IS-1893-2002. The fundamental natural period of the structure calculated by using different methods of infill masonry are compared in the table 1

Table 1 Comparison of the Fundamental Natural Period of the Structure using different method of Infill Masonry

Natural Period (sec)							
Direction	**Equivalent Diagonal Strut**					**Shell Element**	**Membrane Element**
	Holmes	**Pauley & Priestley**	**Staffor d smith**	**Demir & sivri**	**Mainstone**		
X	0.4547	0.494	0.4423	0.5921	0.6125	0.3719	0.3721
Z	0.4116	0.4559	0.3962	0.5611	0.5826	0.3352	0.3358

The fundamental natural period for framed structure without considering the stiffness of masonry infill but considering the weight of the wall which are shown in table 2

Table 2 Fundamental Natural Period of the Framed Structure

Direction	Fundamental Natural Period (sec)
X	2.1567
Z	1.7389

V.CONCULSION

To achieve the safety of the structure against the earthquake, there is need to predict true seismic response of the building & the parameter which affect the seismic response are mass, stiffness, stiffness to Mass ratio, frequency, amplitude, deformation, ductility & fundamental natural period of the building etc. Since 1950s, lot of research has been carried out on the masonry infill wall and the various researchers have proposed different diagonal strut models, but no one has compared the important parameter viz, what is the fundamental natural period of the structure after incorporating different diagonal strut models, shell & plate elements ??

1. The fundamental natural period of the structure using diagonal strut model proposed by various researchers does not differ significantly with reference to the shell or membrane element modeling, except the proposals by Demir & Sivri, and Mainstone. From all the proposed models mentioned above, the Stafford smith model is closer to the shell or membrane element model.
2. Short natural period or high natural frequency indicates a very stiff (light mass resisted by stiff spring) structure. The frequency ratio $\rho = \omega/\omega_n$ is very small.
3. Mass will move more or less wholly with the ground since the transmissibility is nearly one.
4. The maximum relative displacement is nearly zero.
5. The structure with more stiffness has small drift or lateral displacement.

VI. REFERENCES

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