SEISMIC EVALUATION OF RC FRAME WITH BRICK MASONRY INFILL WALLS

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Abstract

Infill panels are widely used as partition walls as well as external walls of the building to fill the gap between RC frames. Non-structural member may provide considerable stiffness to the building and hence may improve the performance of the RC building during ground motions. But In most of the cases, the ignorance of this property of masonry in designing of the RC frame may get an unsafe design. There are two methods are used to determine the effect of ground motion. The effect of ground motion on RC frame building has been carried out by considering with and without the stiffness of infill wall. A comparative study is carried out with RC building using Equivalent Lateral Force method and Response Spectrum method. The masonry infill has been modeled as an equivalent diagonal strut element using Hendry formula. Pushover analysis is carried out on bare frame and frame with infill wall. The model has been generated using STAAD Pro and results obtained from the analysis are compared in terms of strength and stiffness with bare frame.

Keywords: *Seismic evaluation, Response Spectrum, masonry infill, diagonal strut.*

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1. INTRODUCTION

In many buildings, RC frames is either partially filled with brick masonry having an opening or without openings. Brick masonry infill is used mostly used as interior partition walls and external walls which are protecting from outside environment to the building according to the recommendations. Although this masonry infill contribute to stiffness and strength of the RC frame, however they are generally neglected in the design because of lack of knowledge of composite behavior of the infilled frame. Presently, in current practice of design in India, these infill panels are treated as non-structural member and thus their strength and stiffness contribution is therefore ignored. However proper consideration of stiffening effect of infill on the frame is important as it can considerably alter the behavior of building in elastic range. Infill reduces the lateral deflection of the building, displacement, bending moments in frames and increasing axial forces in columns. This leads to decreasing of probability of collapse [5].

When a sudden change in stiffness take place along the building height, the storey at which this drastic change of stiffness occurs is called soft storey. According to BNBC [1] a soft storey is the one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average stiffness of the three storey above. The structures having relatively flexible lateral load resisting system, infill can play a significant role in total stiffness. The provision of adequate stiffness is a major consideration in the design of building for several important reasons. In terms of serviceability limit state, deflections must first be maintained at sufficiently low to allow proper functioning of non-structural components, to prevent excessive cracking and consequent loss of stiffness. In seismic design atleast a minimum stiffness is ensured through the limitation on drift, i.e., horizontal relative floor displacement per unit storey of height [6].

2. LITERATURE REVIEW

Paulay et al. [7] investigated the seismic performance of buildings which were severely damaged or even collapsed as a result of the structural modifications to the basic structural system induced by the non structural masonry partitions. They found that relatively weak, masonry infill can drastically modify the intended structural response, attracting forces to parts of the structure that had not been designed to resist them.

Kulkarni et al. [8], investigated the performance of RC framed building with infills, having different percentages of opening. He concluded that increase in opening percentage leads to decrease on lateral stiffness of infill frame.

Jamneker et al. [10], studied the effect of masonry infill on the behavior of RC frame building. They concluded that masonry infill have significant effect on the dynamic characteristics, stiffness, strength and seismic performance of the building.

Decanini et al. [3], performed studied seismic analysis on the RC frames with infill walls, They showed that infill walls provide more stiffness resulting a significant decrease in value of top displacement, as natural consequence of the stiffness of the buildings.

Rodrigues et al., [9]), studied the seismic behavior of infill walls in RC frame. They found that Masonry infill panels increased global stiffness of the structure. They concluded that its natural period would decrease and depending on the seismic spectrum values at the vicinity of the bare structure natural period, the seismic forces might be increase.

3. METHODOLOGY

Significant experimental and analytical research is reported in the literature since five decades, which attempts to understand the behavior of infilled frames. Different types of analytical models based on the physical understanding of the overall behavior of an infill panel were developed over the years to mimic the behavior of infilled frames. The available infill analytical models can broadly be categorized as Macro Model and Micro Model. The single strut is the most widely used as it is simple and evidently most suitable for large structures.

3.1 Equivalent Diagonal Strut Method

The frames with unreinforced masonry can be modeled as equivalent braced frames by replacing infills with equivalent diagonal strut. Many investigators proposed various approximations for the width of equivalent diagonal strut. The width of diagonal strut depends on length of contact between the wall & the columns (α_h) and between wall & beams (α_L). The formulation for α_h & α_L on the basis of beam on an elastic foundation was given by Stafford Smith (1966). Hendry (1998) proposed the following equation to determine effective strut width w, where the strut is assumed to be subjected to uniform compressive stress.

$$\alpha_h = \frac{\pi}{2}\sqrt[4]{\frac{4E_f I_c h}{E_m t \sin 2\theta}} \qquad \text{..................} \qquad (1)$$

$$\alpha_L = \pi\sqrt[4]{\frac{4E_f I_b L}{E_m t \sin 2\theta}} \qquad \text{..................} \qquad (2)$$

$$w = \sqrt{\alpha_h^2 + \alpha_L^2} \qquad \text{....................} \qquad (3)$$

Where, E_m is Elastic Modulus of masonry wall, E_f is Elastic Modulus of masonry of frame material, t is Thickness of the in-fill wall, h is Height of the in-fill wall, L is Length of the in-fill wall, I_c is Moment of Inertia of the column of the frame, I_b is Moment of Inertia of the beam of the frame, θ is $\tan^{-1}$ (h/L) and w is Width of the Equivalent Strut.

3.2 Equivalent Static Method

Equivalent Static method of analysis is a linear static procedure, in which the response of building is assumed as linear static manner. The analysis is carried out as per IS: 1893-2002 (Part 1).

3.3 Response Spectrum Method

The response spectrum represents an interaction between ground acceleration and the spectral system, by an envelope of several different ground motion records. For the purpose of seismic analysis the design spectrum given in IS:1893-2002 (Part 1) is used. This spectrum is based on strong motion records of eight Indian earthquakes.

4. MODEL DESCRIPTION

The frame is modeled as per the parameters as given in Table 1. Two types of models are considered for the analysis as given below:

Model 1: Bare frame model, however masses of the infill walls are included in the model.

Model 2: Full infill masonry model. Building has one full brick masonry infill wall in all storeys except the ground floor.

Model 1 and 2 are shown in Fig. 2. Plan of building is shown in Fig. 1.

Table 1- Model Description

Number of Storey	4
Zone	III
Live Load	3 kN/m^2
Columns	450 x 450 mm
Beams	250 x 400 mm
Number of Storey	4
Each Storey Height	3 m
Thickness of Slab	150 mm
Thickness of Wall	120 mm
Importance Factor	1.0
Structure Type	OMRF building
Soil Type	Medium
Live load	3 kN/m^2

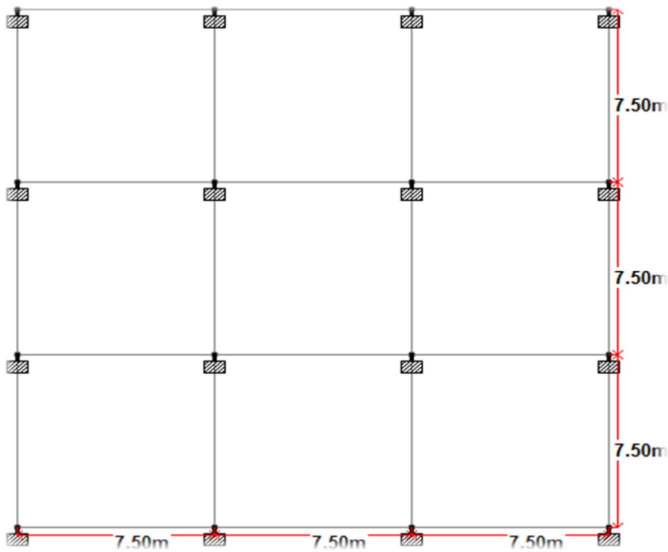
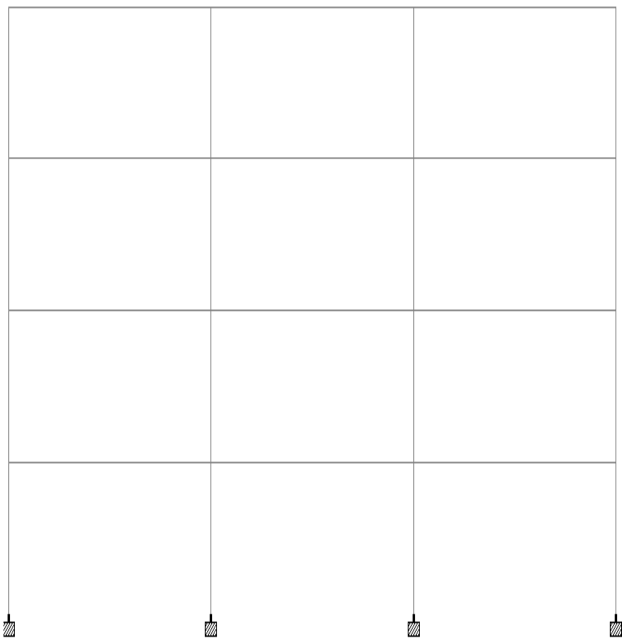


Fig. 1 Plan of Building

Model 1



Model 2

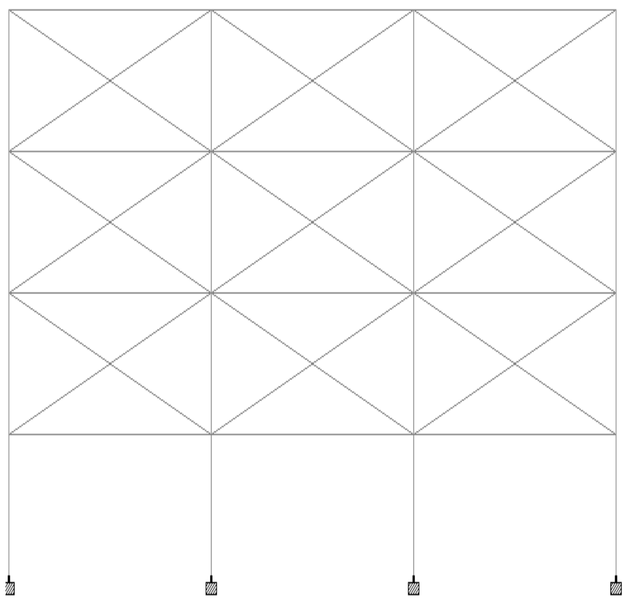


Fig. 2 Model of Building

4.1 Analysis of Building

Empirical formula (as per IS: 1893- 2002 (Part 1) and Dynamic Response Spectrum Method is used to carry out the research. Dead Load is provided according to the self weight of the building. Width of equivalent diagonal strut is calculated according to the formula as given by Stafford Smith. Unit weight of concrete and masonry are taken as 25 kN/m^3 and $20kN/m^3$ respectively. Elastic Modulii for concrete and masonry 22360000 kN/m^2 and 2035000 kN/m^2 and their Poisson ration as .20 and .15 respectively. In seismic weight calculations, 25% of the floor live load are considered, according to IS code recommendation.

4.2 Inter-Storey Drift

The inter storey drift one of the commonly used damage parameter. The inter storey is defined as:

$$SD_i = \frac{\delta_i - \delta_{i-1}}{h_i}$$

Where, δ_i - δ_{i-1} is the relative displacement between successive storey and h_i is the storey height [4]. IS: 1893-2002 (Part 1) specifies storey drift in any storey due minimum specified design lateral load, with partial load factor of 1.0, shall not exceed 0.004 times the storey height.

5. RESULTS AND DISCUSSION

5.1 Fundament Time Period of the Buildings

Fundamental natural time period as per Equivalent Static and Response Spectrum analysis using software STAAD Pro for the models is given in Table 2. It is seen that fundamental time period decreases for RC frame with infill wall when compared to bare RC frame.

Table 2- Natural Time Period of Building

Fundamental time period (Sec.)		
Model No.	Equivalent Static Method	Response Spectrum Analysis
1.	0.4836	0.2277
2.	0.48356	0.48356

5.2 Storey Shear

Storey shear is the distribution of design base shear along height of the structure. The storey shear is more for RC frame with masonry infill and least for bare frame. Storey shear depends upon the stiffness in the frame. The struts resist the lateral seismic forces through axial compression along the strut. The contribution of infill increases the stiffness of the frame, resulting increase in seismic force than bare frame. Table 3 shows the values for storey shear in X- direction. Shear obtained from Response Spectrum method comes out to be more that Equivalent Static method which shows that IS: 1893- 2002 (Part 1) method gives conservative value and that Response Spectrum value is more actual response. Fig. 3 (a & b) shows the graphical representation of base shear for both method and the corresponding trends of increase in base shear value for RC frame with infill.

Table 3 Base Shear Values for Models

Storey	Equivalent Static Method		Response Spectrum Method	
	Bare Frame	Infill Frame	Bare Frame	Infill Frame
	(kN)	(kN)	(kN)	(kN)
4	425.369	436.536	363.040	200.790
3	735.985	788.790	662.070	677.081
2	874.037	945.348	867.534	938.301
1	908.550	984.480	986.752	1170.381

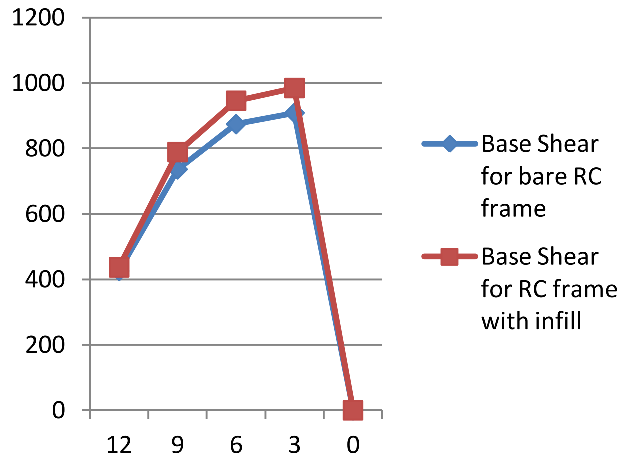


Fig. 3(a) Base Shear by Equivalent Static Method

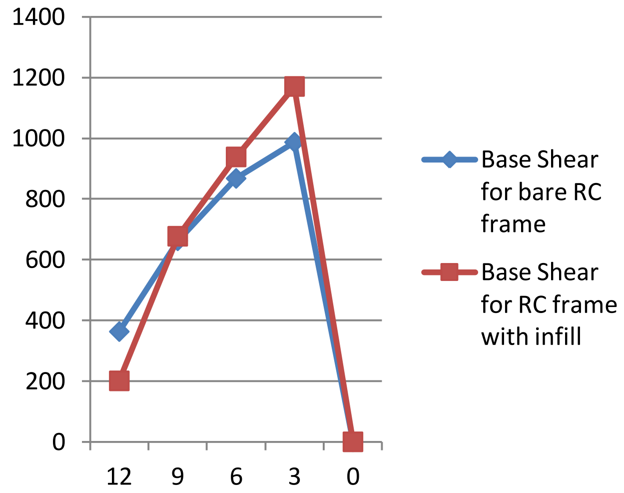


Fig 3(b) Base Shear by Response Spectrum Method

5.3 Lateral Force

Due to presence of infill, as stiffness increases, lateral forces also increases at each storey level. Table 3 shows lateral force in X- direction. Observations show that for Equivalent Static method, lateral force value goes on increasing with the floor level, absolute value being more in frame with infill walls, shown in Fig. 4 (a).

But there is no general trend for lateral force values by Response Spectrum method. While the values for bare RC frame is most at 1st floor level, but in case of frame with infill, lateral force value is most at 2nd floor level. Also it seen from Fig. 4 (b) that forces values decreases with increase in floor levels.

Table 4 Lateral Force values for Models

Storey Level	Equivalent Static Method		Response Spectrum Method	
	Bare Frame	Infill Frame	Bare frame	Infill Frame
	(kN)	(kN)	(kN)	(kN)
0. 0.00	0.000	0.000	0.000	0.000
3.00	34.513	39.139	418.248	707.891
6.00	138.052	156.558	568.500	462.891
9.00	310.616	352.254	299.036	476.291
12.00	425.369	436.536	363.045	200.790

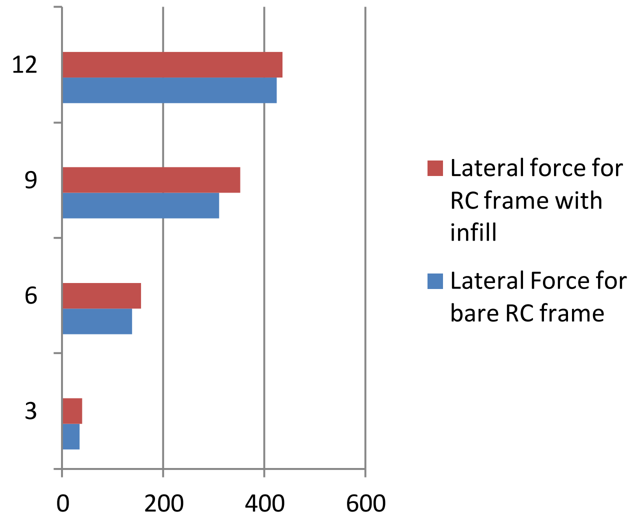


Fig. 4 (a) Equivalent Static Method for Lateral Force

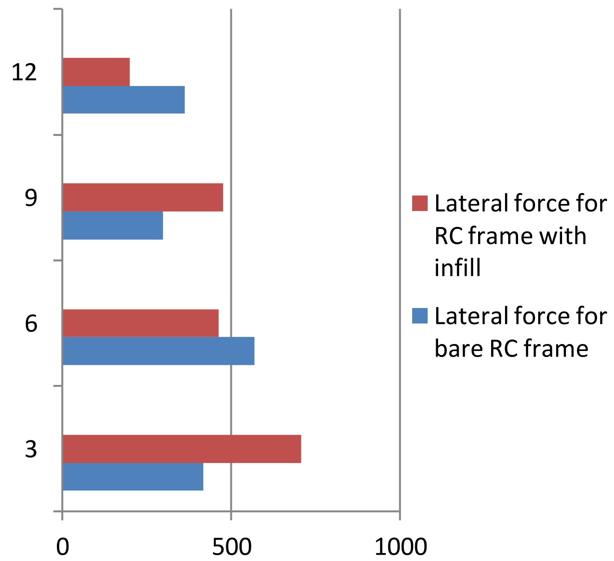


Fig. 4 (b) Response Spectrum Method for Lateral Force

5.4 Storey Drift

The inter storey drift is one of the most important parameter for serviceability of structures. The infills increase the stiffness of the RC frame and therefore the storey drift values decreases for RC frame with infill. Table 4 give the inter storey drift in X- direction, at various levels. From Fig. 5 (a & b), it is concluded that the storey drift values are more in case bare frame then the frame with infill walls. However, we can also observe that in case of Equivalent Static method, the drift values for bare frame is very large, and when infilled, the drift values almost drops about 90%, which is very large variation as compared to variations observed in drift values by Response Spectrum method.

Table 5 Storey Drift Values for Models

Storey Level	Equivalent Static Method		Response Spectrum Method	
	Bare Frame	Frame with Infill	Bare Frame	Frame with Infill
	(mm)	(mm)	(mm)	(mm)
12	19.276	0.058	0.089	0.012
9	24.455	0.127	0.071	0.065
6	24.038	0.020	0.068	0.059
3	12.297	2.795	0.031	0.025
0	0.000	0.000	0.000	0.000

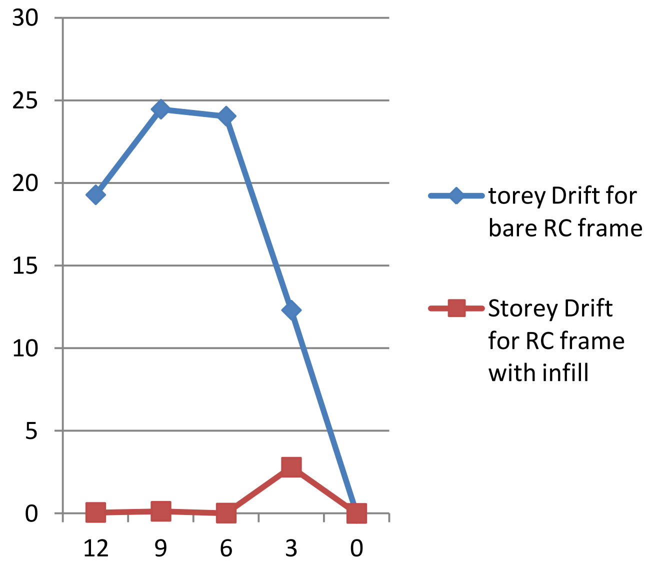


Fig. 5 (a) Storey Drift by Equivalent Static Method

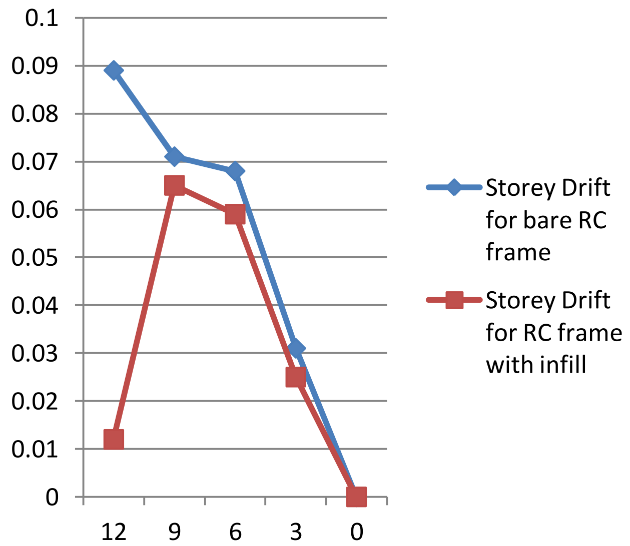


Fig. 5 (b) Storey Drift by Response Spectrum Method

6. CONCLUSION

It is observed that Model 1 has higher time period that Model 2 as given by Equivalent Static Method. But no changes in time period are observed for both models when analyzed by Response Spectrum Method. The provision of infill wall clearly justifies the reduction in time period for empirical formula. The seismic base shear values increases in case of RC frame provided with infill walls. However there in wide increase in base shear by for bare frame and frame with infill. Thus the value obtained from IS code method and by Response Spectrum method are in good agreement. But values obtained from Response Spectrum method is more effective base shear value as compared to Equivalent Static method.

The Storey drift for Model 2 decreases when compared to Model 1; in both cases i.e. for IS Code method and Response Spectrum method. The change in percentage for drift is very large i.e. about 95% in Equivalent Static method which is very large and thus percentage change given by Response Spectrum i.e. 80% is much more dependable result. This decrease in storey drift values thus verifies the effect of infill whose stiffness plays vital role in absorbing shocks.

Thus the IS: 1893- 2002 (Part 1) method describes very insufficient guidelines about infill wall design procedures. Software like STAAD Pro is a tool for analyzing the effects of infill on the structural behavior. It is seen that STAAD Pro provided overestimated value of fundamental time period for bare frame model. The lateral stiffness in models under consideration is increasing with the addition of infill compared to situation when infill is not provided. The storey drifts for all models satisfy the permissible limit of 0.004h, where h is the storey height, as per IS 1893. According to relative values of all parameters, it can be concluded that provision of infill wall enhances the performance in terms of storey displacement and drift control and increase in lateral stiffness.

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