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EFFECT OF MASONRY INFILL WALLS ON SEISMIC RESPONSE OF OPEN GROUND STOREY RC FRAMES

Priyanka [1], Dr. Shobha Ram[2], Dr. Alok Verma[3]
1(Department of civil engineering, Gautam Buddha University, and India
Email: priyankap780@gmail.com)
2 (Department of civil engineering, Gautam Buddha University, and India
Email: shobharam@gbu.ac.in)
2 (Department of civil engineering, Delhi technological University, and India
Email: alokverma0dce@gmail.com)

Abstract:

Masonry infill (MI) walls are well known for its architectural and aesthetical importance and are considered as non-structural element. The great Bhuj earthquake struck India in 2001, from field investigation it was observed that open ground storey buildings were severely damaged as compared to full scale MI buildings. The current study focuses on effect of MI walls on seismic response of open ground storey reinforced concrete (RC) frames. It is important to consider structural importance of infill walls due to increased frequency of earthquake. This study investigated the changed behaviour of building model due presence of less or no infill walls. This research shows base shear, storey drift, storey displacement, natural period, storey shear, internal forces results and numerical simulations of results are presented in form of graphs, figures and tables in comparative way.

Keywords — Masonry infill walls, open ground storey, earthquake analysis, reinforced concrete

I. INTRODUCTION

Masonry infill walls are widely accepted all over the world. Past researches had contributed in understanding the effect of infill walls on seismic response of building.

From structural engineers point of view, MI walls plays important role in resisting seismic forces. With growing need of safety of life and prevention of structural damage, it is important to understand behaviour of infill walls.

For the purpose of parking open ground storey concept in adopted in many countries. During great Bhuj earthquake (2001) several buildings were collapsed collapse with soft storey. Whereas it was observed from field investigation that adjacent buildings with full scale infill walls survived in earthquake. Large no of casualties were reported due to damaged structures.

Study was carried out by performing dynamic analysis response spectrum (RS) method. A well known software package was employed in performing RS method. Behaviour of building models considered herein justifies the performance of buildings in Bhuj which collapsed or survived during earthquake.

This paper presents design and analysis of full scale infill frame and open ground storey frame and results of base shear, storey shear, natural period, internal forces, and storey drift are presented in comparative way. Numerical simulations of results are represented in form of tables, & figures. Brick infills are modeled using equivalent diagonal strut methodology. This work further helps in developing complete understanding to study behaviour of open ground storey infill frame. The study concludes that provision of brick infill walls in RC framed structure affects the stiffness of the structure. With no infill walls at ground storey changed behaviour of building was observed.

II. BACKGROUND OF MASONRY INFILL WALLS

This section reflects some works of past researchers which will help in understanding behaviour of MI walls.

Durrani, A. J., & Haider, S. et al.,(1996) introducing reinforced MI walls in bare frame structures increases lateral strength & stiffness of structures up to 2.5 times. Mosalam K. et al., (2009) mentioned about tensile strength of bricks or units which depends upon absorption rate of brick units. He also reported that reinforced masonry infill walls have greater strength as compared to unreinforced masonry infill walls. Basha, S. H., & Kaushik, H. B. et al., (2013) stated that with increase in strength of brick masonry stiffness of building increases and they also observed that bonding between masonry unit and mortar also affects stiffness of structure.

Murty, C. V. R., & Jain, S. K. et al., 2000, January) performed experimental results on cyclic test of RC masonry infill frames and concluded that they are susceptible to short column effect, soft storey effect, torsion effect, and OOP collapse.

Humar J. M. et al. (2001) & Sudhir K. Jain et al. (2001) reported on performance of RC buildings during Bhuj earthquake that were damage during earthquake. They both individually investigated that the open storey RC frames were severely damage as compare to that of infill storey. Hemant B. Kaushik and Sudhir K. Jain et al. (2004) carried out field investigations during great Sumatra earthquake and reported that soft storeys are more susceptible to undergo collapse. Kaplan H. et al. (2010) carried out research and conveyed about positive affect of MI walls on RC bare frame.

III. MODELING OF MI WALLS

Technical literature in last five decades shows analytical and experimental research, this helps in understanding behaviour of MI walls. The available infill analytical models are categorized as micro-model and macro model. This paper carries out modeling of infill walls using macro modeling method. The single strut models are most widely preferred as it is simple and requires less time in frame modeling. Thus RC frames with unreinforced masonry walls can be modeled as equivalent braced frames with infill walls replaced by equivalent diagonal strut which can be used in rigorous response spectrum analysis.

MI walls are modeled as equivalent diagonal strut following provision of Indian Standard (IS) 1893 (part-1). Properties of struts are kept same as that of MI walls. Width of strut is calculated using provisions of IS 1893.

$$E_m = 550f_m$$

$$f_m = 0.433f_b^{0.64}f_{mo}^{0.36}$$

$$w_{ds} = 0.175\ \alpha^{-0.4}L_{ds}$$

$$\alpha = 4 \times \sqrt[4]{\frac{Em\ t\ Sin2\theta}{4Ef\ Ic\ h}}$$

Where,

E_f is modulus of elasticity of RC moment resisting frame in MPa (MRF),
I_c is moment of inertia of adjoining column,
t is thickness of infill wall,
Ɵ is angle between diagonal strut and adjacent horizontal member,
h is clear height between top beam and bottom floor slab,
E_m is modulus of elasticity of masonry infill walls (MPa),
Lds is length of diagonal compression strut

IV. DESCRIPTION OF STRUCTURAL BUILDING MODEL

This paper carries out research on G+5 residential building. The building considered herein is assumed to be symmetrical in both directions in order to avoid torsional affect.

The building model considered here in has plan dimension of 12 m × 12 m in both lateral and longitudinal directions. Building model has 3 bay in N-S direction and 3 bays in E-W direction. Present building model is assumed to have 3 m floor to floor height. Plan and elevation of current building model is represented in Fig. 1 below.

Dimensions of building model are assumed to be same throughout the building. Beam dimensions were 250 mm × 400 mm and column dimension were 400 mm × 400 mm. Unit weight of RCC is taken as 25kN/m^3. Compressive strength of brick is assumed to be 20MPa, mortar is assumed to have 10MPa compressive strength, & concrete having 30MPa compressive strength was employed in modeling.

To study the effect of earthquake building was subjected to vertical loads. Model is designed as residential building hence 3 kN/m^2 live load was considered. Keeping architectural importance of building in view and in order to prevent it from surrounding environment weight of partition wall was assumed to be 2 kN/m^2. Weight of floor load is assumed to be 1.5 kN/m^2.

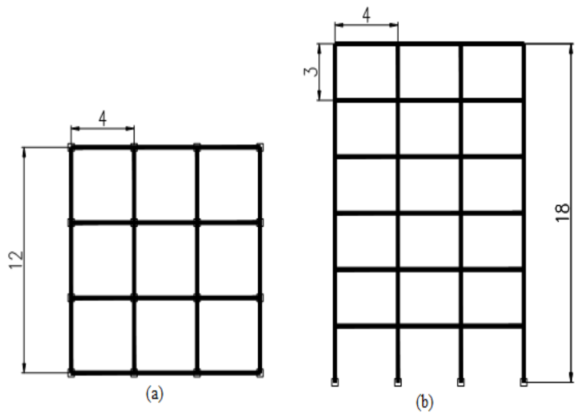

Fig. 1 Schematic representation: (a) plan (b) elevation of 6 storey building

Schematic representation of elevation of full scale infill frame and open ground storey frame is shown in Fig. 2 below.

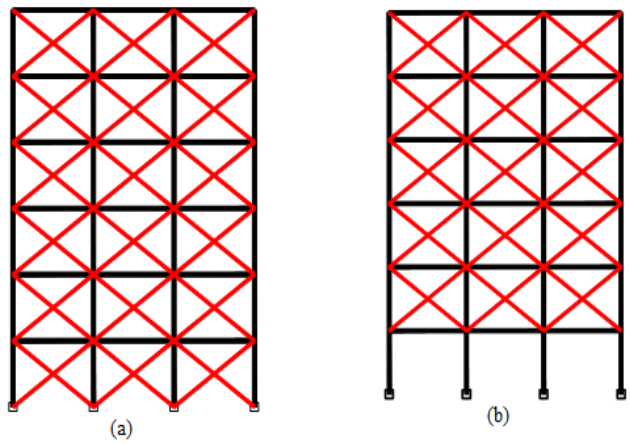

Fig. 2 Schematic representation: (a) full scale MI frame & (b) Open ground storey RC frame

V. EARTHQUAKE ANALYSIS METHOD- RESPONSE SPECTRUM METHOD

In this research work, study is carried out using response spectrum (RS) analysis method with the help of STAAD Pro software. This method helps in calculation seismic response of structure.

The building is assumed to be located in seismic zone IV and in medium subsoil condition. Damping ratio is considered as 5%. Building model is designed as moment resisting RC frame (MRF).

VI. DYNAMIC ANALYSIS RESULTS AND DISCUSSION

With the help of STAAD software analysis of building model is carried and results of various dynamic parameters are calculated and presented in form of tables and figures for seismic assessment of building.

Fig. 3 below shows base shear results and from results it can be concluded that base shear result in case of soft storey is found get reduced by 2.7 percent.

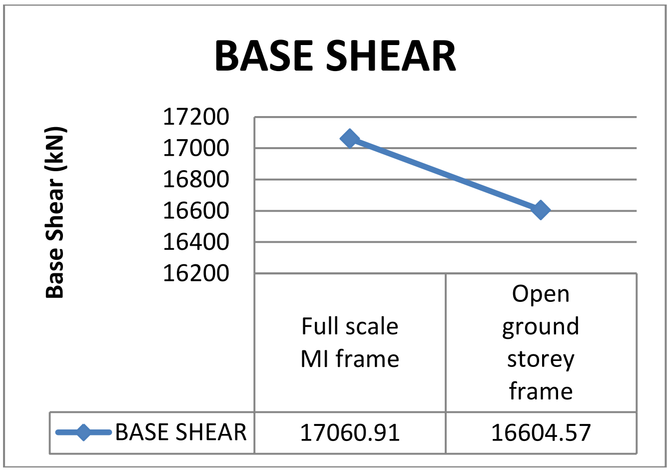

Fig. 3 Base shear results under RS

Natural period of both the building models are shown below in Fig. 4 and a decreasing trend is observed in full scale MI frame as compared to open ground storey frame. From percentage point of view, first modal natural period of building is pronounced by 28.85% due to incorporation of less infill walls. Hence from natural period curves it is clearly evident that stiffness of frame gets decreased in case of soft storey as natural period gets increased. Last modal natural period was found to get reduced by 12%.

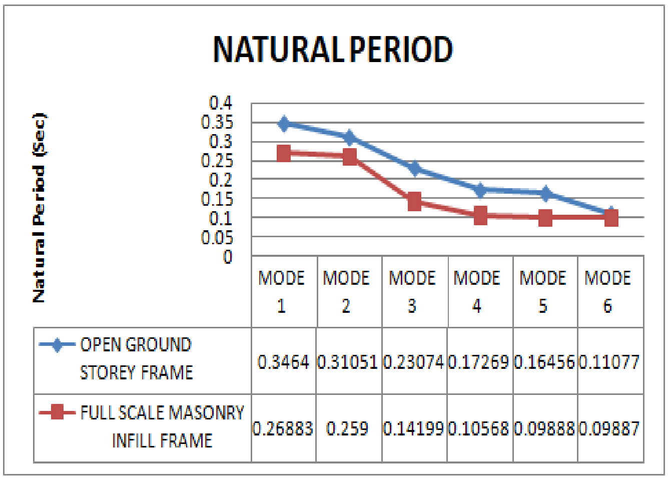

Fig. 4 Natural period of building under RS

Resultant displacements of lateral and longitudinal directions are calculated. In open ground storey frame storey displacement of upper storey is increased by 67.2% whereas at bottom most storey open ground storey frame shows greater displacement. Results of storey displacement are shown in Fig. 5 below.

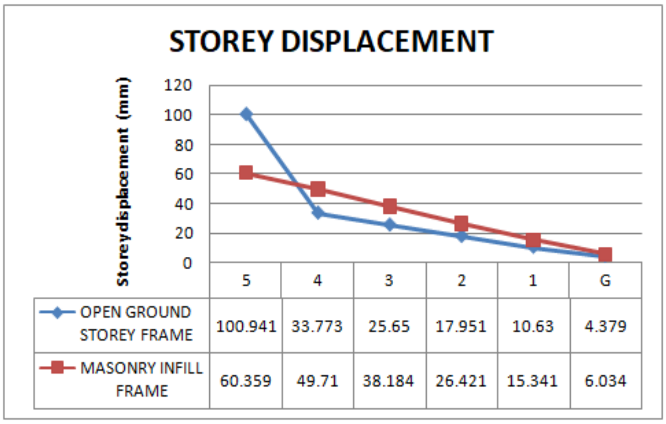

Fig. 5 Storey displacement under RS

Fig. 6 below shows resultant profile of storey drift. Storey drift is considered as most important factor while judging seismic response of MI buildings. From Fig. 6 it is clearly evident that storey drift at top most storey in open ground storey building model is found to get increased by 6 times as compared to full scale masonry infill model.

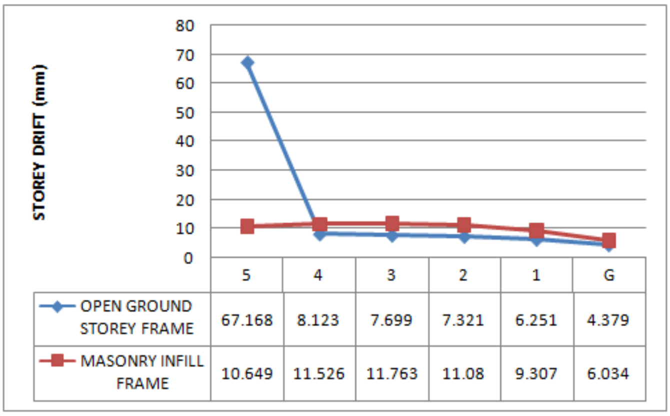

Fig. 6 Storey drifts result under RSM

From structural engineer's point of view storey shear is most important dynamic parameter for seismic assessment of buildings. Fig. 7 below shows peak storey shear results under RS.

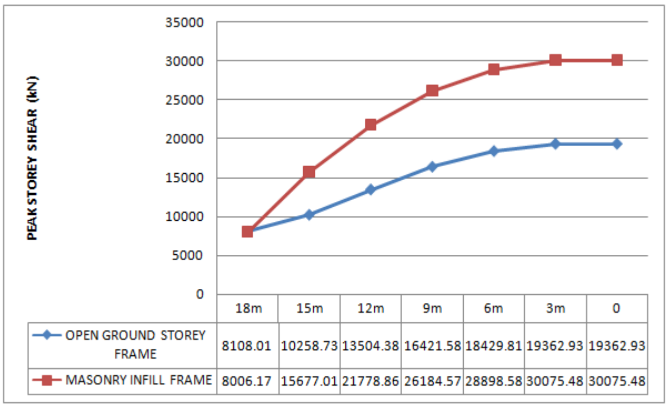

Fig. 7 Peak storey shear results

Above Fig. shows underestimation of peak storey shear results in case of open ground storey as compared to masonry infill frames which is primarily shows decreased strength and stiffness of building models.

Study of internal forces is carried out in selected column members and location of those members is represented in fig. 7 below.

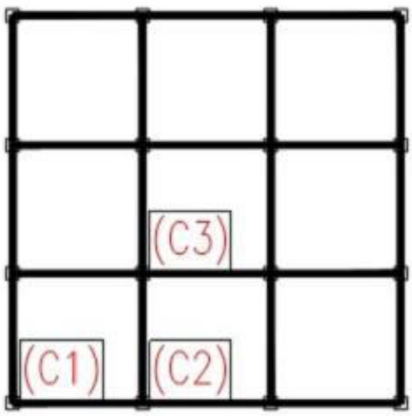

Fig. 7 typical plan of building representing column positions

Shear force and bending moment results are represented in Fig. 8 below. From results of shear force and bending moment it is clearly indicated that internal forces in case of open ground storey frame is increased as compared to full scale masonry infill frame which is primarily due to more storey displacement.

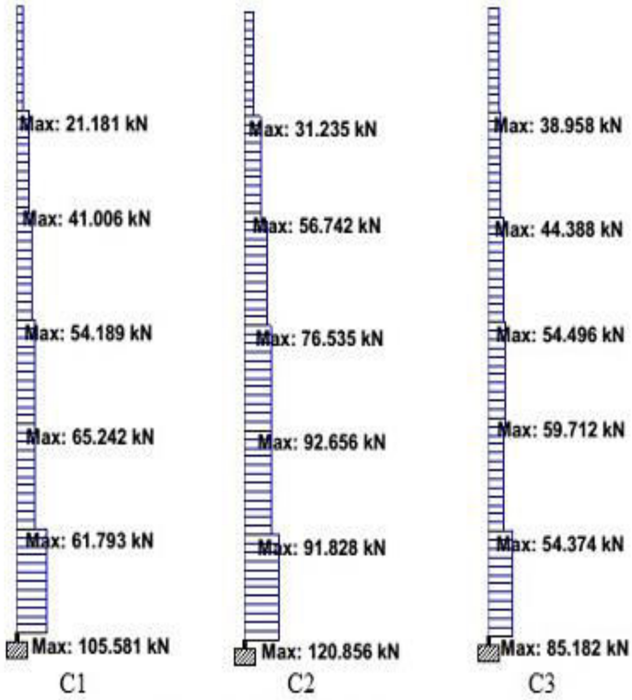

Fig. 8(a) Shear force: Full scale MI frame

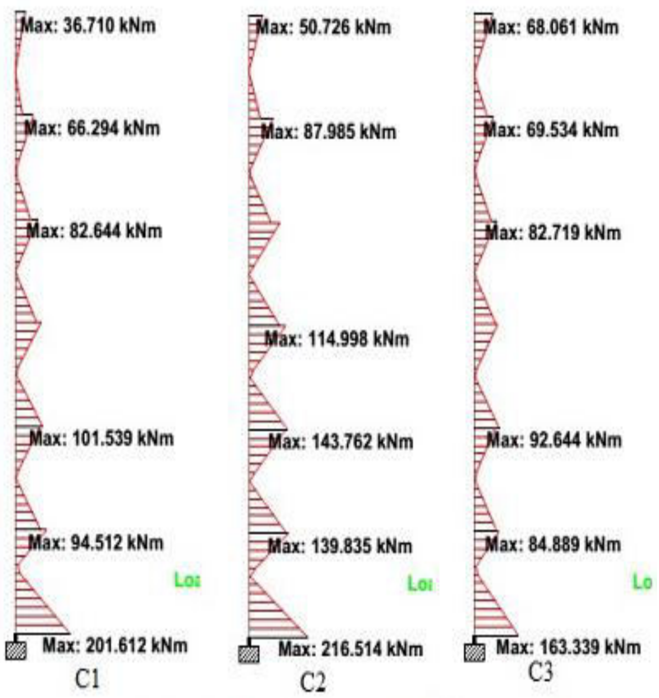

Fig. 8(b) Bending moment: Masonry infill frame

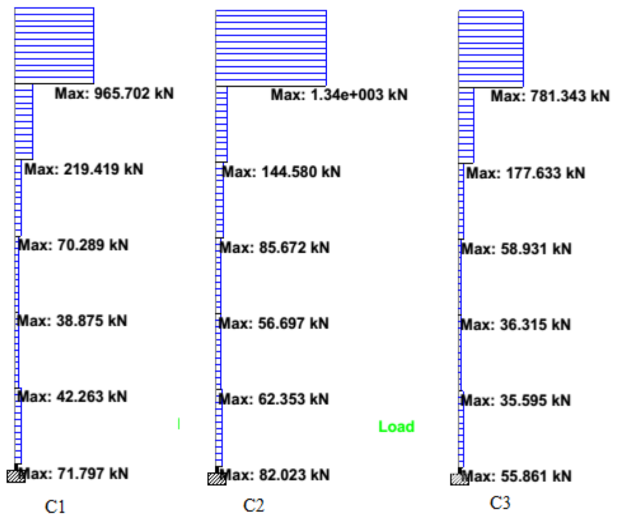

Fig. 8(c) Shear Force: Open ground storey

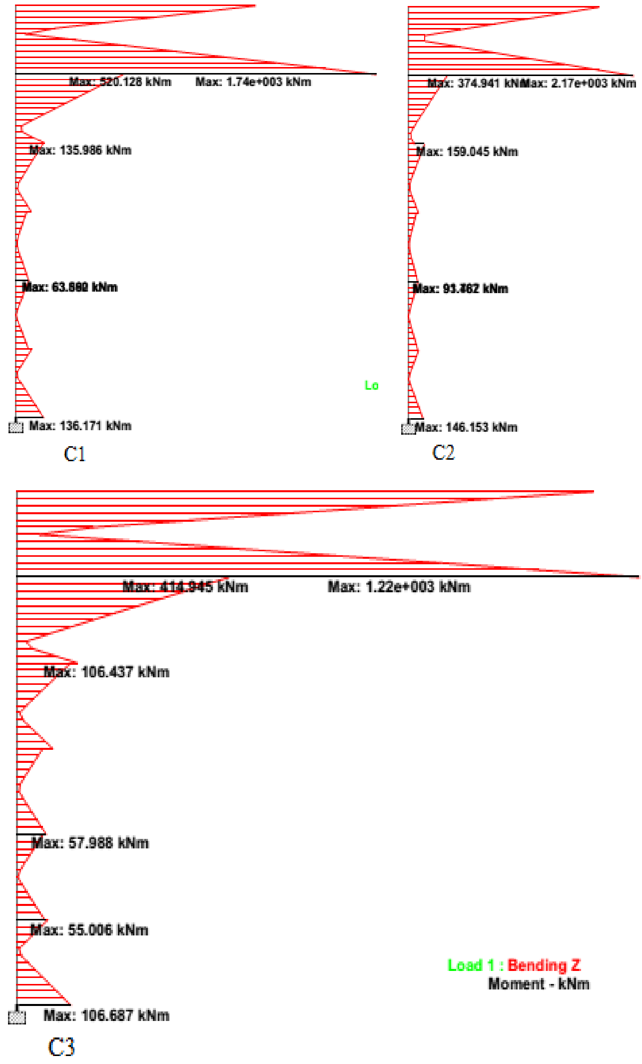

Fig. 8(d) Bending moment: Open ground storey frame

VII. CONCLUSIONS

From results it is clearly evident that with incorporation of infill walls in all storey base shear and peak storey shear increases and internal forces, natural period, storey displacement, and storey drift decreases. Due to degradation of these values structure becomes more susceptible to ground storey collapse. This study clearly justifies the reason behind ground storey collapse during Bhuj earthquake. Hence construction of soft storeys should not be preferred.

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