International Journal of GEOMATE, Nov., 2019 Vol.17, Issue 63, pp. 203 - 209
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.63.72884
Special Issue on Science, Engineering & Environment

SEISMIC BEHAVIOUR OF REINFORCED CONCRETE FRAME BUILDINGS WITH MASONRY INFILL

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ABSTRACT: In most countries situated in seismic regions especially in Morocco, reinforced concrete frame buildings are infilled by brick or concrete-block masonry walls. In Moroccan seismic code RPS2000, infill walls are considered as non-structural elements and their contribution and influence on the seismic response are ignored in the design. In the present study, the seismic behavior of multistory reinforced concrete frame with masonry infill is investigated using the strut model to capture the global effects of the infill. Nonlinear pushover analysis has been used to evaluate the seismic response. An equivalent strut model has been used for masonry infill. The results of numerical simulations show that the infill walls have a strong influence on the seismic response and ignoring their effects is not on the safe side. They should be considered in the seismic design and analysis of buildings with masonry infill.

Keywords: *Seismic, Analysis, Building; Pushover, Infill, Strut model, Reinforced concrete*

1. INTRODUCTION

Reinforced Concrete frames with masonry infills are the most common structural system for multi-story buildings in Morocco and many other parts of the world. The infills are known to change the seismic behavior and failure pattern of the infilled frames under lateral loading significantly, due to infill-frame interaction. In seismic codes, infill walls are considered as non-structural elements and their contribution and influence on the seismic response are ignored in the design. However, earthquakes that have occurred recently in the world and past experimental studies in the domain, have shown that infill interacts with the structure and contribute to the seismic behavior of buildings, requiring that these infills have adequate performance. Social and functional needs for vehicle parking, shops, reception, etc, are compelling to provide a soft storey in multi- storey building. This configuration reduces the stiffness of the lateral load resisting system and a progressive collapse becomes unavoidable in a severe earthquake for such buildings due to the soft storey. Partially infilled frames cause an adverse effect known as short column effect. The column which gets its effective height reduced due to such partial infill walls is termed captive column, or in general, the short column. The shear required to develop flexural yield in the effectively shortened column is substantially higher than shear required developing in the full-length column. If the designer has not considered the short column effect, shear failure may occur before flexural yield and often fail in a brittle manner.

Fig.1 Short column effect [7]

Fig.2 Soft storey mechanism [7]

2. MODELING PARAMETERS

2.1 Nonlinear behavior

The buildings were idealized and analyzed using a two-dimensional finite element model consisting of a series of frame elements using SAP2000 [2]. The column and beam elements are modeled as elastic elements with pairs of plastic zones at each end. In these zones, material nonlinearity was introduced in the model using plastic hinges with a moment-rotation relationship as described in FEMA 356 [3].

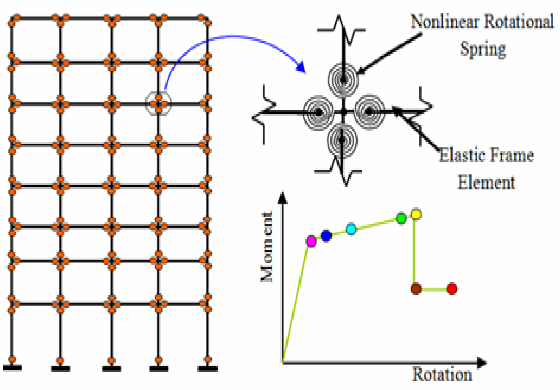

Fig.3 building model, plastic hinges [3]

2.2 Modelling of masonry infill

In the case of an infill wall located in a lateral load resisting frame, the stiffness and strength contribution of the infill is considered by modeling the infill as an equivalent compression strut. Because of its simplicity, several investigators have recommended the equivalent strut concept. In the present study, a trussed frame model is considered. This type of model does not neglect the bending moment in beams and columns. Rigid joints connect the beams and columns, but pin joints at the beam-to-column junctions connect the equivalent struts. Infill parameters are calculated using the method recommended by FEMA306 [4].

3. STRUCTURAL DESCRIPTION

Two reinforced concrete frame buildings B1 and B2 with eight and eleven stories respectively are investigated. The buildings are dimensioned according to the RPS2000 1]. Both buildings were subjected to three seismic ground motions to assess their seismic behavior. The geometric characteristics and parameters of the study are presented in the figures and tables below.

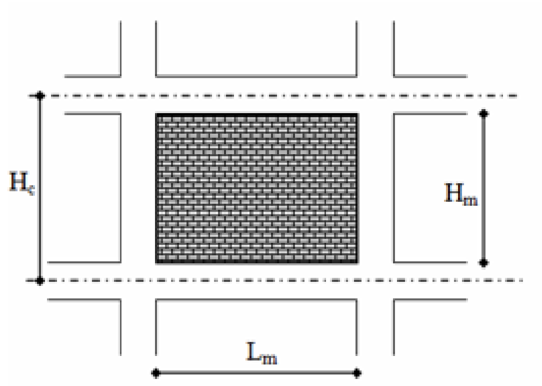

Fig. 4 Masonry infill [4]

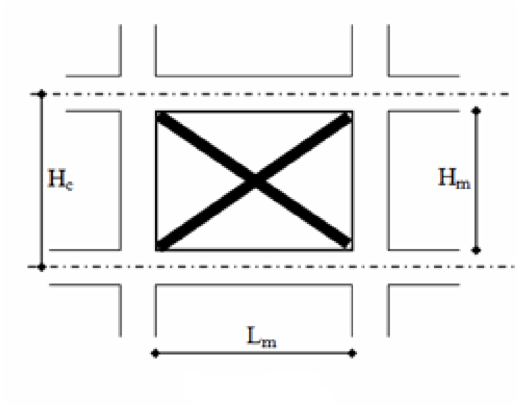

Fig. 5 Strut model of infill [4]

The two buildings are modeled and analyzed for static response and pushover analyses using the finite element software SAP2000 [2]. The analytical models of the buildings include all components that influence the mass, strength and stiffness. The non-structural elements and components that do not significantly influence the building behavior were not modeled. For each building, two models are generated, M0: model without masonry infill, M1: a model with masonry infill.

Table 1 parameters of the study

parameter	data	unit
compressive strength of concrete	25	MPa
young modulus of concrete	32164	MPa
yield limit of bars	500	MPa
dead load	2	KN/m2
live load	1.5	KN/m2
seismic intensity	0.16	g
site S2	1.2	****
young modulus of steel	200000	MPa
infill thickness	15	cm
compressive strength of infill	4	MPa

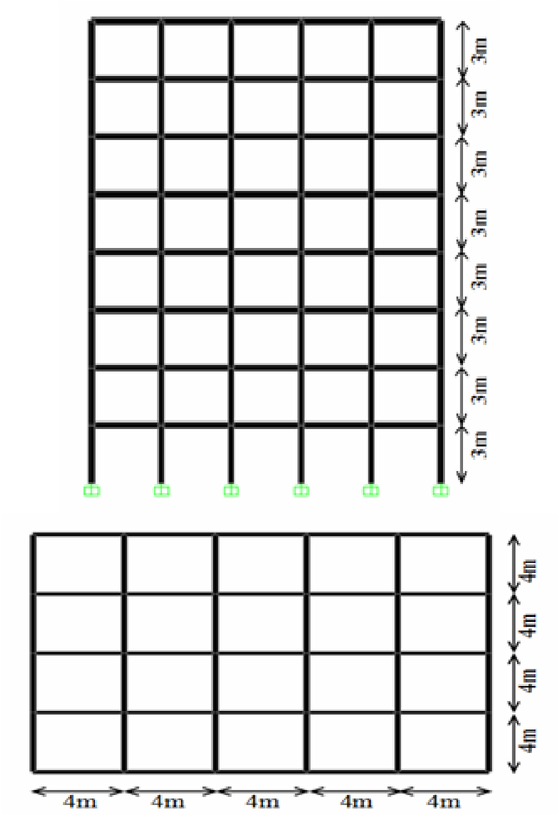

Fig.6 Geometric characteristics. Building B1

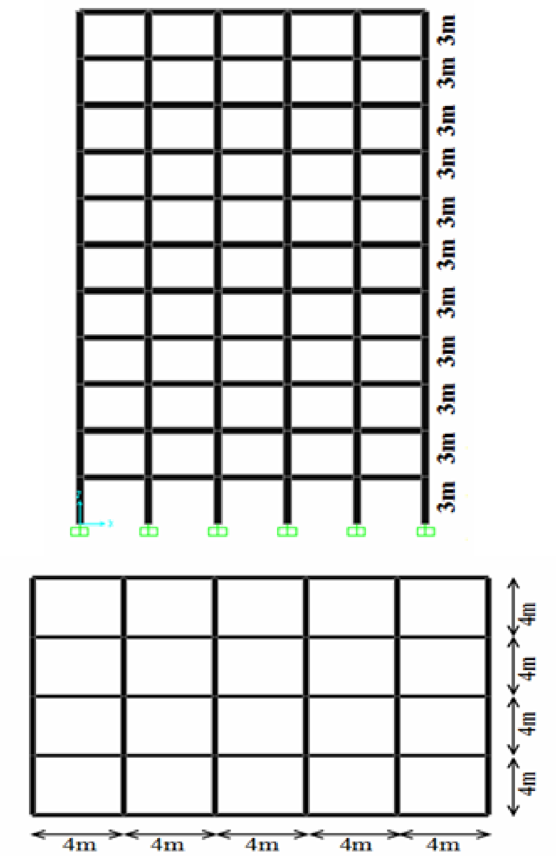

Fig.7 Geometric characteristics. Building B2

4. RESULTS

4.1 Modeling parameters

The structure was analyzed using SAP2000 [2]. The superstructure was modeled as a spatial frame, considered fixed at the base of the ground floor. The reinforced concrete floor has substantial stiffness and resistance to take over the stresses produced by the lateral forces, and due to the regularity and homogeneity of the structure, it can be considered non-deformable in its plan. The column and beam elements are modeled as elastic elements with pairs of plastic zones at each end. In these zones, material nonlinearity was introduced in the model using plastic hinges with a moment-rotation relationship as described in FEMA 356 [3]. To assess the seismic performance of buildings with and without infill, three seismic intensities are considered, EQ1=0.16g, EQ2=0.24g, EQ3=0.35g.

4.2 Performance of the buildings

For each building, two pushover analysis was conducted, with and without masonry infill. Both buildings were subjected to three seismic ground motions to assess their seismic behavior. The results of pushover analysis are shown in figures 8 and 9.

Figures 14 and 15 show the results of plastic hinges distribution under various seismic intensities. In tables 2 and 3, the seismic demands of the buildings are presented. In figures 10, 11, 12 and 13, the roof displacements and base shear versus the seismic intensities are presented.

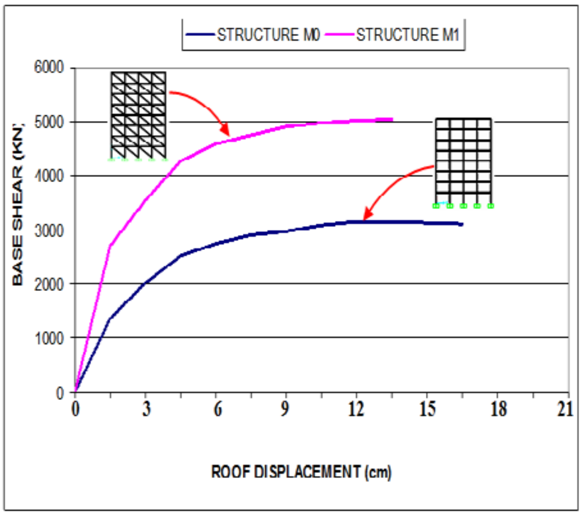

Fig.8 Pushover curve. Building B1

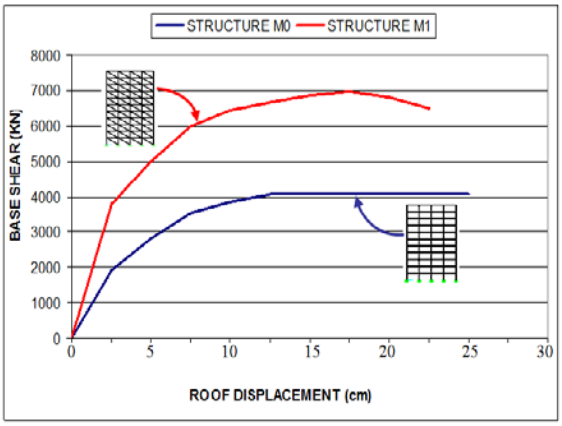

Fig.9 Pushover curve. Building B2

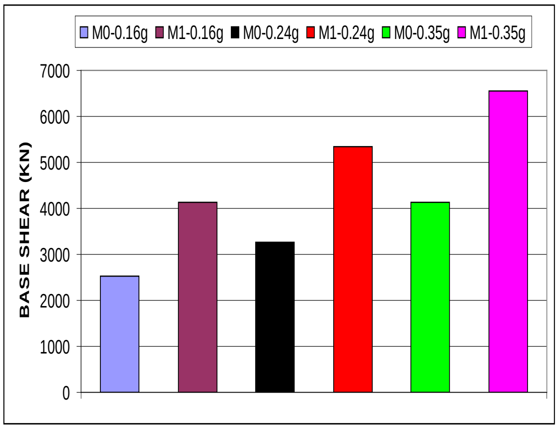

Fig.12 Base shear versus seismic intensity.B2

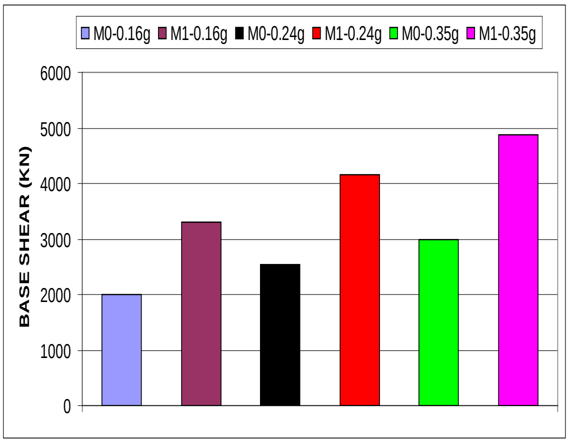

Fig.10 Base shear versus seismic intensity. B1

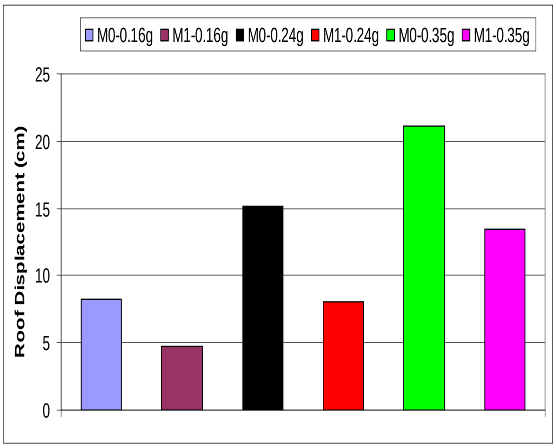

Fig.13 Roof displacement vs seismic intensity. B2

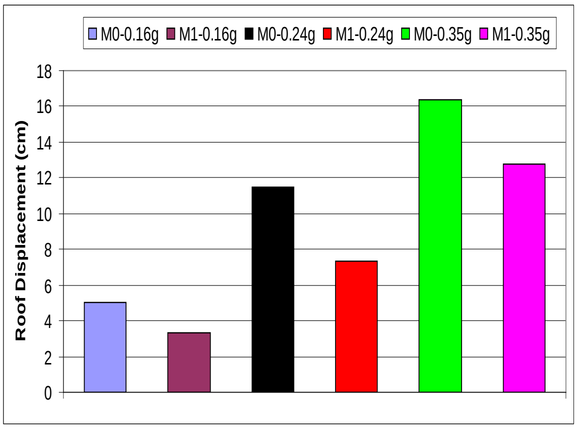

Fig.11 Roof displacement vs seismic intensity. B1

Table 2 Seismic demands for building B1

Seismic demand .EQ1=0.16g				
	V (KN)	d (cm)	S_a(g)	S_d(cm)
Model M_0	1996.14	5.05	0.34g	3.64
Model M_1	3293.32	3.35	0.43g	2.6
Seismic demand .EQ2=0.24g				
	V (KN)	d (cm)	S_a(g)	S_d(cm)
Model M_0	2534.08	11.50	0.442	8.28
Model M_1	4155.76	7.31	0.546	5.8
Seismic demand .EQ3=0.35g				
	V (KN)	d (cm)	S_a(g)	S_d(cm)
Model M_0	2985.45	18.5	0.466	14
Model M_1	4865.59	12.74	0.598	9.88

Table 3 Seismic demands for building B2

Seismic demand .EQ1=0.16g				
	V (KN)	d (cm)	S_a(g)	S_d(cm)
Model M_0	2533.54	8.23	0.288	5.49
Model M_1	4136.45	4.70	0.294	3.92
Seismic demand .EQ2=0.24g				
	V (KN)	d (cm)	S_a(g)	S_d(cm)
Model M_0	3251.45	15.14	0.340	10.8
Model M_1	5332.39	8.09	0.448	6.86
Seismic demand .EQ3=0.35g				
	V (KN)	d (cm)	S_a(g)	S_d(cm)
Model M_0	4123.25	21.14	0.356	16.53
Model M_1	6542.48	14.41	0.498	11.27

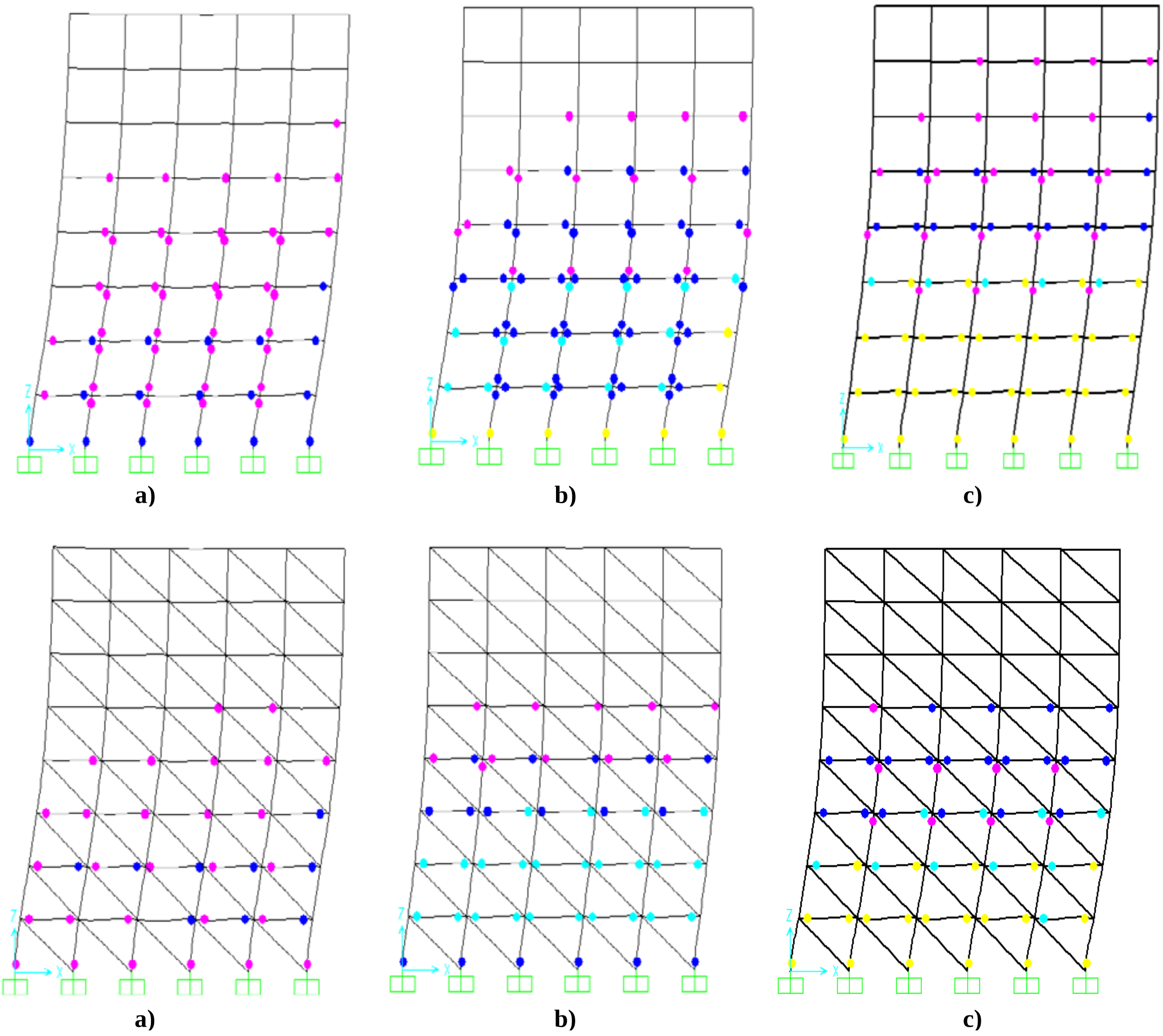

Fig. 14 plastic hinge distribution of building B1 with and without masonry infill, a) under EQ1, b) under EQ2 and c) under EQ3 bare frame was nearly 30% in the case of building

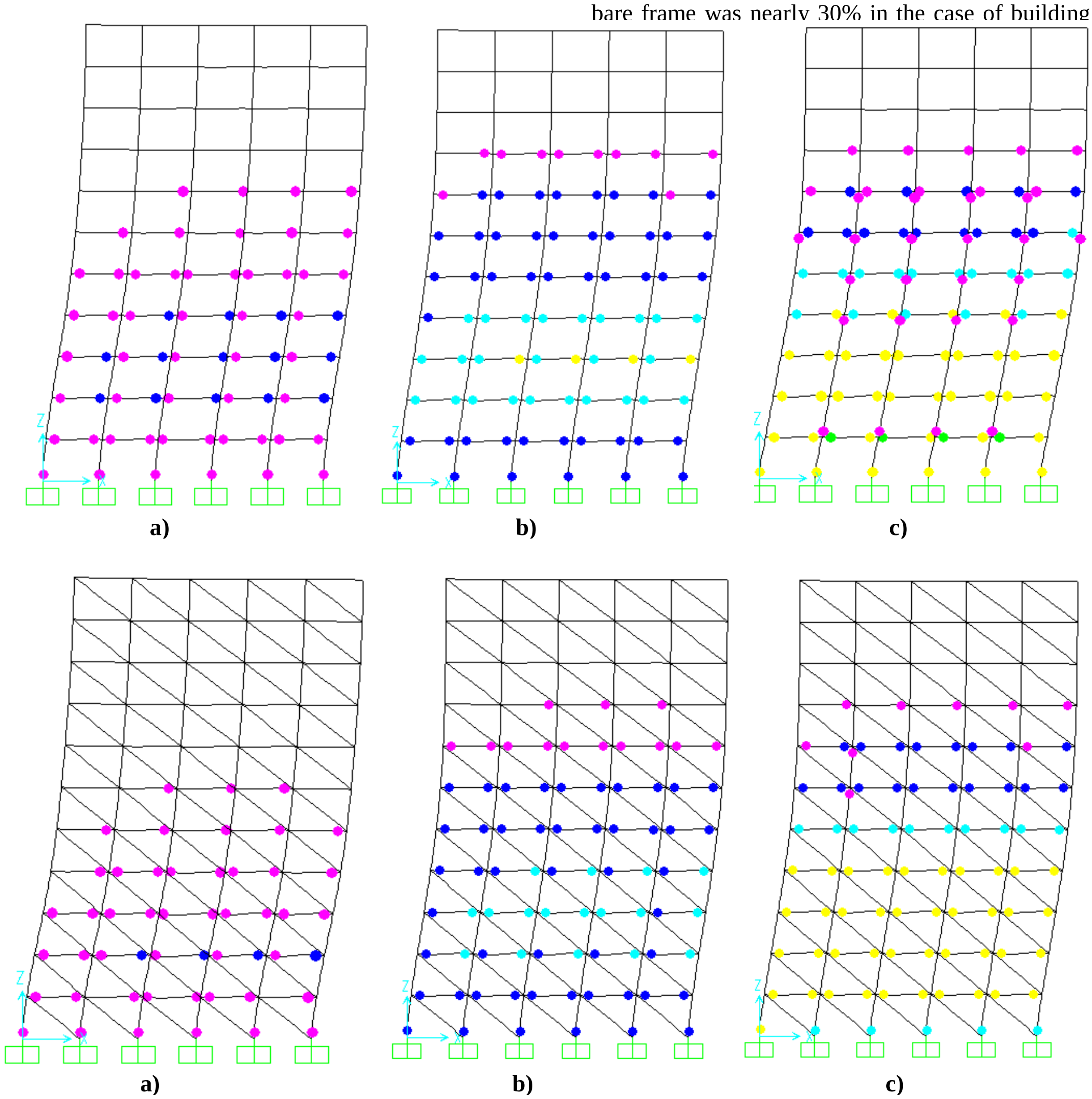

Fig. 15 plastic hinge distribution of building B2 with and without masonry infill, a) under EQ1, b) under EQ2 and c) under EQ3

5. DISCUSSION OF RESULTS

Results of pushover analysis (figures 8 and 9) show an increase in initial stiffness, strength, and energy dissipation of the infilled frame compared to the bare frame.

From Table 2 and Table 3 it was observed that the increase in the base shear in infill frame model M1 compared to bare frame model M0 was nearly 63% for both buildings B1 and B2. The decrease in the top displacement in infill frame compared to the

considerably the roof displacement under various seismic intensities.

Figures 10 to 13 show that the introduction of infill walls in the reinforced concrete frame reduces considerably the roof displacement under various seismic intensities.

Figures 14 and 15 show that the introduction of infill walls in the reinforced concrete frame changes the distribution of plastic hinges. It is observed that the performance of fully masonry infill panels was significantly superior to that of the bare frame under various seismic intensities. The numerical results presented in this study agree with the experimental studies conducted by Fardis, M.N [8], George C et al [9]. The experimental studies indicate that the inclusion of masonry infill increases the lateral stiffness and strength of the bare frame. The initial stiffness is higher than that of the bare frame. The inclusion of masonry infill in the model improves the seismic response.

6. CONCLUSION

In this paper, the seismic response of reinforced concrete buildings including a set of 8 and 11-story buildings with masonry infill was studied. The main conclusions that can be drawn from this study are:

The introduction of infill panels in the reinforced concrete frame reduces the time period of bare frames. Bare frame idealization leads to an overestimation of natural periods and under estimation of the design lateral forces.

Results of pushover analysis show an increase in initial stiffness, strength, and energy dissipation of the infilled frame, compared to the bare frame.

The presence o infill walls in the reinforced concrete frame change the distribution of plastic hinges. It is observed that the performance of fully masonry infill panels was significantly superior to that of the bare frame under various seismic intensities.

Finally, masonry infill has a strong influence on the seismic response and ignoring their effects is not on the safe side. They should be considered in the seismic design of buildings with masonry infill.

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