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Seismic Vulnerability of Multi-Storey Buildings with Masonry Walls

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***Abstract:** In the seismic codes, lateral rigidity and strength of infill panels are ignored in the design. However recent earthquakes occurred in the world has shown that infill walls change the dynamic behavior of the frame. In this article we propose to investigate the effect of infill wall on the seismic behavior of framed concrete buildings. For this purpose, a framed reinforced concrete building is considered. An equivalent diagonal strut model is used for masonry infill. The strut properties are calculated according to the FEMA306 [7]. Nonlinear pushover analysis is used to assess the seismic behavior. The results show that introduction of the masonry infill wall in the analysis modifies the behavior of bare frame. There is a drastic change in the bending moments and shear forces. The modeling of infill wall transforms the rigid frame into braced frame.*

Keywords: **Building, seismic, infill, strut, stiffness,** ***RPS2000***

I. INTRODUCTION

Frames with masonry infill panels are frequently used for construction of multi storey buildings. Recent earthquakes occurred in the world have shown that infill walls modify the seismic behavior of the buildings. In the Moroccan seismic provisions RPS2000 [1], infill walls are ignored in the seismic analysis and design. The essential role of this study is to analyze the influence of infill walls on the seismic behavior of reinforced concrete buildings. For this purpose a framed reinforced concrete building is considered. The strength and stiffness of the infill wall are considered by modeling the infill wall as a diagonal strut. The strut properties are calculated according to the FEMA306 [7].

II. MATERIALS AND METHODS

A. Nonlinear behavior of reinforced concrete

The columns and beams are analyzed as elastic elements with a plastic hinge at each end [12]. Material nonlinearity is included in the analysis using plastic hinges with a moment rotation relationship as described in the FEMA 356 [9].

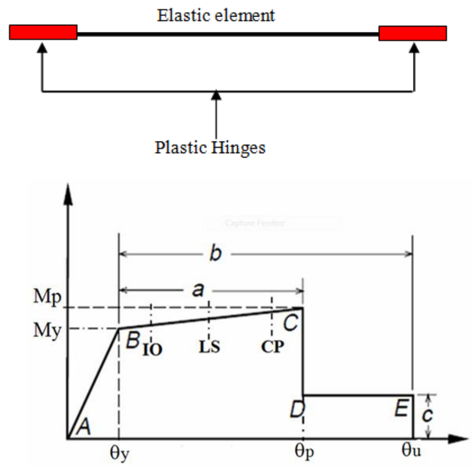

Fig. 1.Moment -rotation relationship of plastic hinge

B. Nonlinear behavior of infill masonry

The lateral rigidity of infill wall is determined by analysing masonry wall as a diagonal strut that carries only compression forces. The strut properties are calculated according to the FEMA report [7].

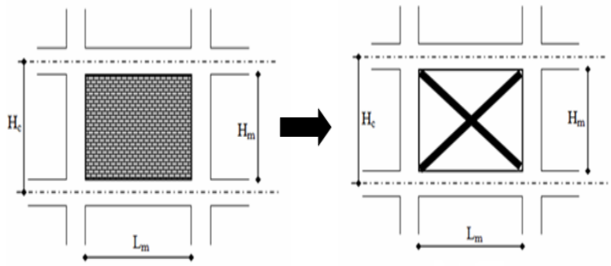

Fig. 2.Equivalent diagonal strut for masonry infill

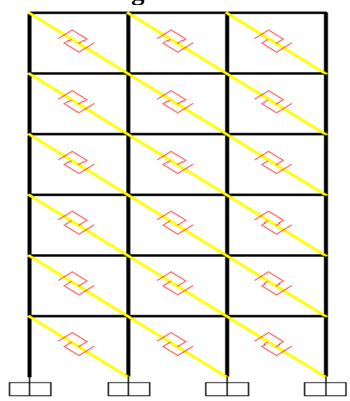

Fig. 3.Link element used for infill wall in the SAP2000

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III. NUMERICAL INVESTIGATIONS

The essential role of this paper is to study the influence of masonry panel on the dynamic behavior of the building. A regular framed reinforced concrete building is considered. The building has six stories, three bays and three spans. The building is situated in moderate seismic region. Two models are analyzed. First model is infill frame in which infill wall is idealized as a diagonal strut .The second model is bare frame in which lateral rigidity of panel is ignored.

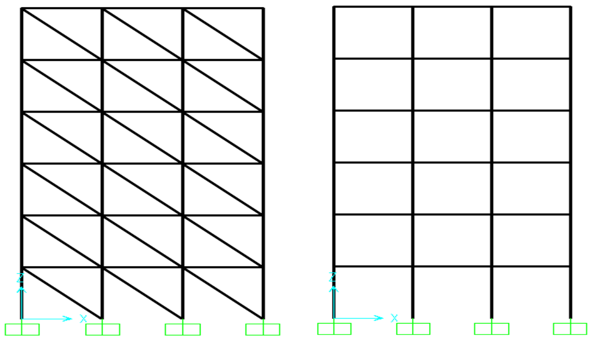

Fig. 4.frame with and without infill wall

IV. RESULTS AND DISCUSSION

A. Natural periods of vibration

Table 1 presents the results of fundamental periods of vibration of the building. Introduction of lateral rigidity of masonry infill in the analysis modifies the fundamental periods. Masonry infill increases the lateral rigidity of the frame and consequently reduces the fundamental period. Frame without considering the lateral rigidity of infill wall leads to an under estimation of the base shear design.

Table- I: Natural periods of vibration

mode number	with infill	without infill
mode 1	0,251	0,419
mode 2	0,083	0,136
mode 3	0,049	0,078
mode 4	0,036	0,054
mode 5	0,029	0,042
mode 6	0,027	0,036

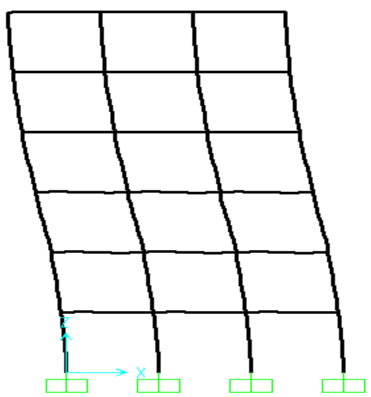

Fig. 5.First mode of vibration, T=0.42s

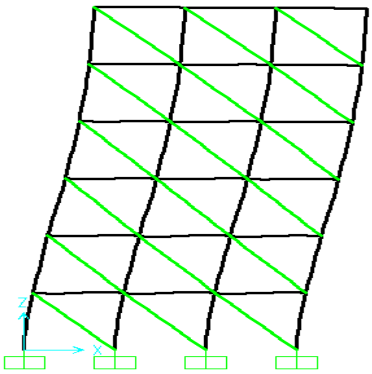

Fig. 6.First mode of vibration, T=0.25s

B. Bending moments and shear forces

In the figures 7, 8, 9 and 10, the results of shear forces and bending moments obtained when the lateral rigidity of masonry wall is introduced in the frame or when it is ignored are presented. There is a drastic change in the internal forces when masonry infill is taken into account in the analysis.

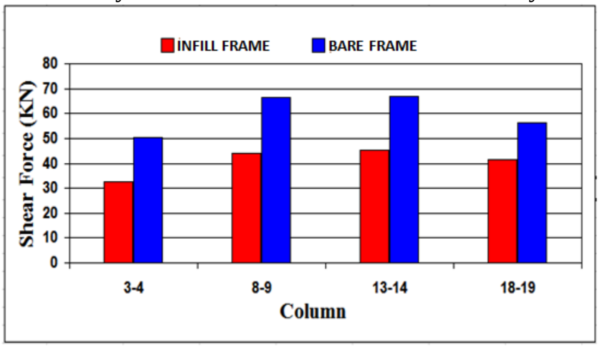

Fig. 7.Shear forces in the columns

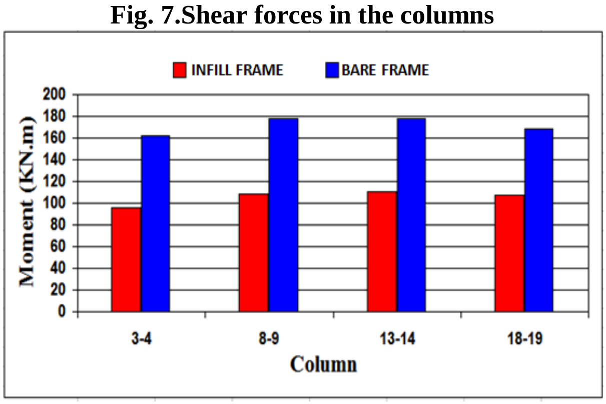

Fig. 8.Bending moments in the columns

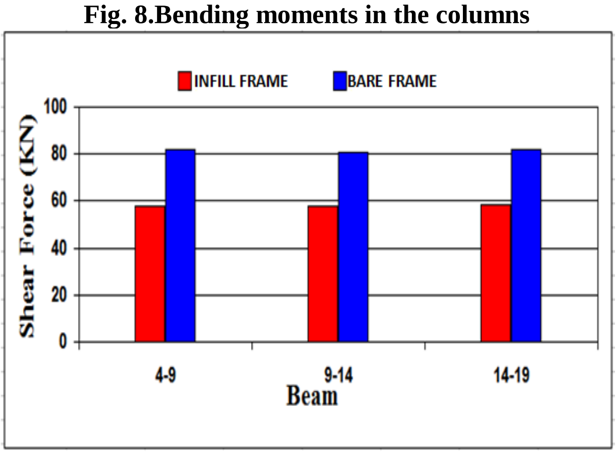

Fig. 9.Shear forces in the beams

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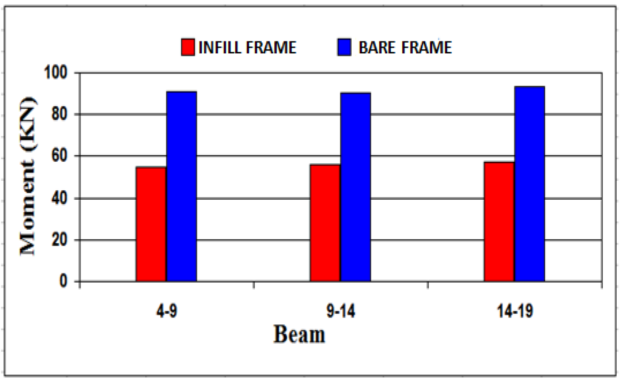

Fig. 10.Bending moments in the beams

C. Lateral storey displacement and inter storey drift

The damage limitation of RPS2000 [1] is satisfied by meeting the maximum storey drifts. Lateral storey displacements and storey drift are presented in the table 2 and 3. In the Figures 11, 12, 13, 14, 15 and 16, the story displacement versus total shear force is presented. The lateral displacements decrease when the masonry wall is taken into account in the analysis. There is a major reduction in the lateral displacements and storey drifts when the lateral rigidity of infill is taken into account in the analysis.

Table- II: Lateral storey displacement

Storey	displacement (cm) Without infill M1	displacement (cm) With infill M2	Ratio (M1-M2) /M1
6° storey	5,02	2,14	57%
5° storey	4,48	1,94	56%
4° storey	3,54	1,61	54%
3° storey	2,52	1,21	52%
2° storey	1,36	0,72	47%
1° storey	0,47	0,28	40%

Table- III: Interstorey drift

Storey	Interstorey drift (%) Without infill M1	Interstorey drift (%) With infill M2
6° storey	0.18	0.06
5° storey	0.31	0.11
4° storey	0.34	0.13
3° storey	0.38	0.16
2° storey	0.29	0.14
1° storey	0.15	0.09

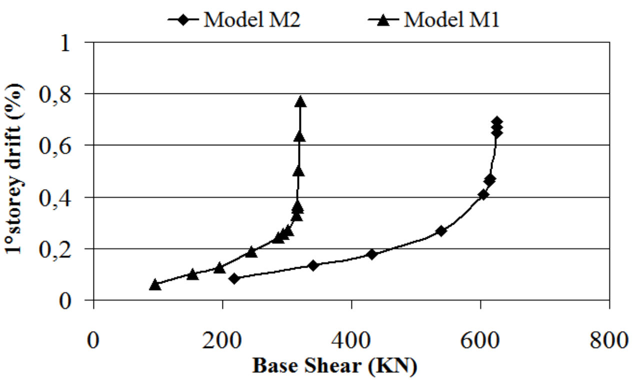

Fig. 11.Base shear vs storey drift.1° story

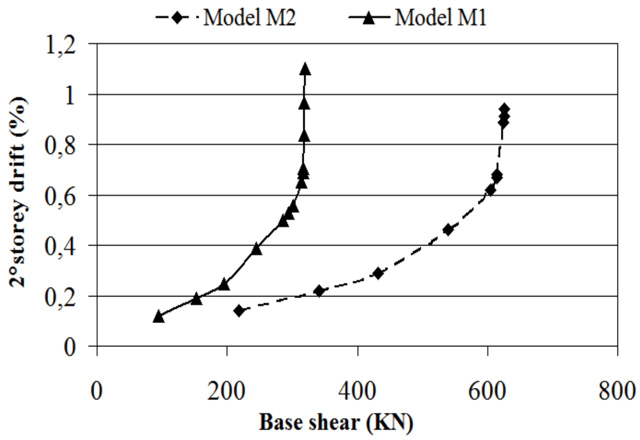

Fig. 12.Base shear vs storey drift.2° story

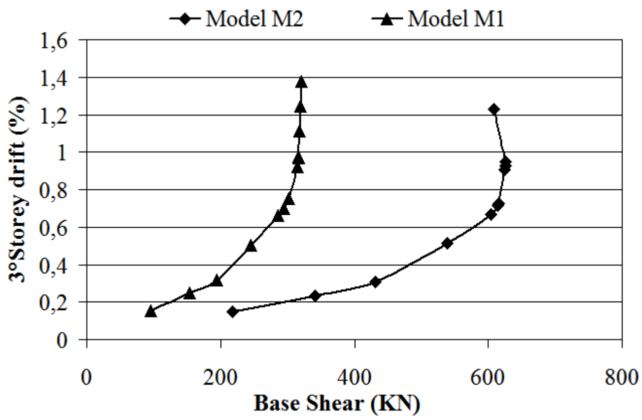

Fig. 13.Base shear vs storey drift.3° story

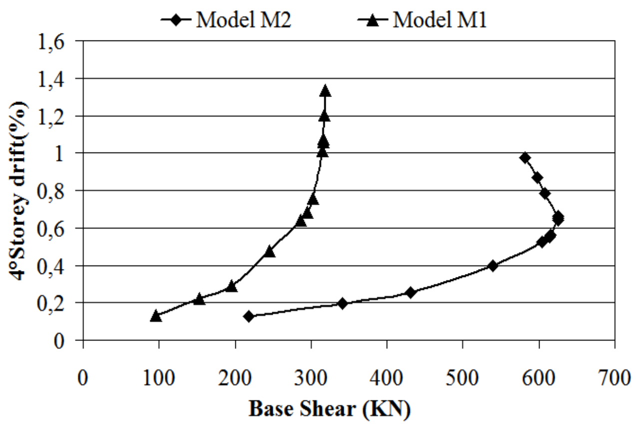

Fig. 14.Base shear vs storey drift.4° story

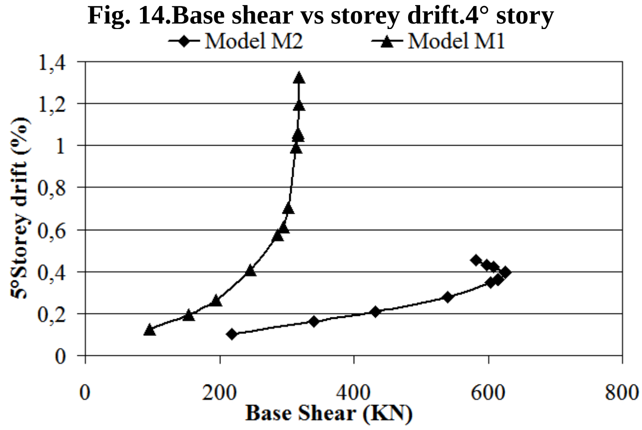

Fig. 15.Base shear vs storey drift.5° story

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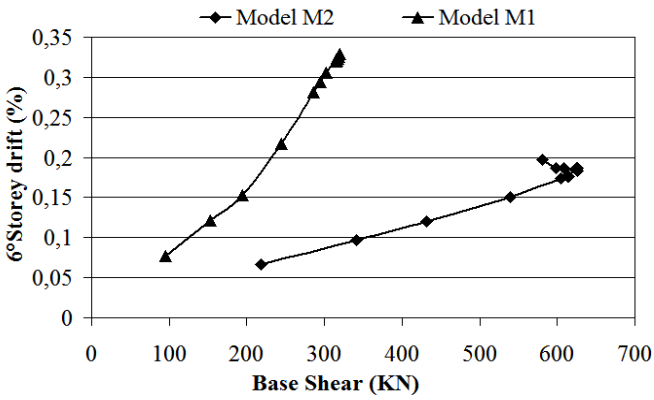

Fig. 16.Base shear vs storey drift.6° story

V. CONCLUSION

In this study the effect of infill panels on the dynamic behavior of reinforced buildings is investigated. The principal conclusions of this study are:

The numerical investigations show that the introduction of the masonry walls reduces the fundamental period of vibration. Seismic analysis without considering the lateral rigidity of the wall leads to an under estimation of the base shear design.

The introduction of lateral rigidity of masonry wall in the model reduces essentially the lateral displacements and storey drifts, then the seismic vulnerability of building will decrease essentially.

The results of this study show also that modeling infill wall as an equivalent diagonal strut transforms the rigid frame into braced frame. The bending moments and shear forces will decrease.

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