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TITLE Masonry Infilling Effect On Seismic Vulnerability and Performance Level of High Ductility RC Frames

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Abstract. In last years researchers preferred behavior-based design of structure to force-based one for designing and construction of the earthquake- resistance structures, this method is named performance based designing. The main goal of this method is designing of structure members for a certain performance or behavior. On the other hand in most of buildings, load bearing frames are infilled with masonry materials which leads to considerable changes in mechanical properties of frames. But usually infilling wall's effect has been ignored in nonlinear analysis of structures because of complication of the problem and lack of simple logical solution. As a result lateral stiffness, strength, ductility and performance of the structure will be computed with less accuracy. In this paper by use of Smooth hysteretic model for masonry infillings, some high ductile RC frames (4, 8 stories including 1, 2 and 3 spans) designed according to Iranian code are considered. They have been analyzed by nonlinear dynamic method in two states, with and without infilling. Then their performance has been determined with criteria of ATC 40 and compared with recommended performance in Iranian seismic code (standard No. 2800).

Keywords: Infilling wall, Performance, Ductility, Vulnerability, Smooth hysteretic model.

INTRODUCTION

One of the resisting systems which is introduced in Iranian Seismic Code (Standard No.2800) [1] is reinforced concrete moment resisting frame with high ductility. With taking structure of these frames in to consideration , inside the frame is infilled by panels of constructional materials but on the other hand the effect of this infilling materials is not considered in analysis of the structure ; it is noted that when inside a frame is infilled, properties like stiffness, strength and ductility of the frame is changed sensibly against the lateral force in which getting to result of the infilled frame by simply adding the bare frame and wall separately is impossible.

In previous earthquakes in Iran, it has been seen that infilling walls may have pleasant or unpleasant effect on the seismic performance of structure , so there are two ways to deal with this issue ; first, to benefit the frame with taking the performance of infilled frames and to prevent unpleasant effects even with the presence of this infilling panel / second, by suitable prediction transferring the load to infill panels be prevented and the frame can be considered a bare frame so that the frame would have the normal performance without the effect of infill walls. According to the two above mentioned solutions , separation of frame and infilling walls would not be easy and considering the separation details would be necessary , and even in case of separation assumption not to transfer the load to infill walls would not be valid due

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to diagonal cracks which are seen in infilling walls , on the other hand , it has been practically proved that infilling walls have got decent structural performance if their problems be solved so it is necessary to research about the seismic performance of infilled frames, in order to benefit from infilling walls as a structural element or at least to prevent the unpleasant effects.

1. Modeling of infill walls in nonlinear analysis

1.1 Compressive strut model

In this model, infilling walls as a two strut member which is placed in the diameters of frame and just considered as compressive elements, due to small tensile strength and the final frame can determined the infilled frame behavior according to diameter element properties. Stress-strain relationship for masonry in compression is considered as a parabolic function till the peak stress f'_m, Then with increasing of strain the amount of stress decreases linearly and after that stress is constant (Fig. 1).

The lateral force-deformation relationship assumed for the system of compression struts is shown in Fig. 2. The analytical formulations for the envelope were developed based on the masonry constitutive model and theoretical model for infill masonry frames suggested by Saneinejad and Hobbs [3]. With taking the infilled frame shown in Fig. 3 in to consideration maximum lateral force V_m and corresponding displacement u_m are calculated as [2]:

$$V_m^+\left(V_m^-\right) \leq A_d f_m{}' \cos\theta \leq \frac{\upsilon . t . l'}{(1-0.45\tan\theta')\cos\theta} \leq \frac{0.83(MPa)tl'}{\cos\theta} \tag{1}$$

$$u_m^+\left(u_m^-\right) = \frac{\varepsilon'_m L_d}{\cos\theta} \tag{2}$$

that t is the thickness of masonry infilling panel; f'_m is the masonry prism strength; ε'_m is the corresponding strain; ν is the Basic shear strength or cohesion of masonry; and A_d , L_d are the area and length of the equivalent diagonal struts respectively, which are calculated as following [4] :

$$A_d = \frac{\left(1-\alpha_c\right)\alpha_c th\dfrac{\sigma_c}{f_c} + \alpha_b tl\dfrac{\tau_b}{f_c}}{\cos\theta} \leq 0.5\frac{th'\dfrac{f_a}{f_c}}{\cos\theta} \tag{3}$$

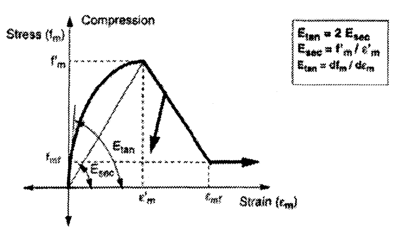


FIGURE 1. Constitutive model for masonry [2]

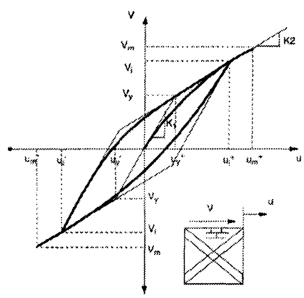


FIGURE 2. Bouc-Wen model for smooth hysteretic response of infill panels [2]

$$l_d = \sqrt{(1-\alpha_c)^2 h'^2 + L'^2} \tag{4}$$

the parameters of $\alpha_c, \alpha_b, \sigma_c, \tau_b, f_a$ and f_c Depends on geometry and properties of frame and infill panel [4].

The initial stiffness K_0 can be estimated using the following relation:

$$K_o = 2(V_m / u_m) \tag{5}$$

The lateral yield force and displacement in the masonry infill are obtained as following ;

$$V_y^+(V_y^-) = \frac{V_m - \alpha K_o u_m}{(1-\alpha)} \tag{6}$$

$$u_y^+(u_y^-) = \frac{V_m - \alpha K_o \mathrm{u_m}}{K_o(1-\alpha)} \tag{7}$$

A value of 0.1 is suggested for the post-yield stiffness ratio α .

1.2 Reinhorn hysteretic model

Smooth hysteretic model which is introduced by Reinhorn and his colleagues is being used to model hysteretic behavior of infilling walls [5]. This model is introduced after development of Wen-Bouc model in which stiffness degradation, strength deterioration and slip effects have been considered. The force displacement relationship for smooth hysteretic model is [5]:

$$V_i = V_y[\alpha\mu_i + (1-\alpha)Z_i] \tag{8}$$

in which V_i , V_y are the instantaneous force and the yield force, respectively; μ_i is normalized displacement calculated as: $\mu_i = \frac{u_i}{u_y}$ where the subscript "i" is used to refer to the instantaneous values, while subscript "y" is used to denote yield values; α defines post yielding stiffness to initial elastic stiffness ratio; and Z_i is hysteretic component that can be obtained from the following differential equation:

$$dZ_i = \left\{A - |Z_i|^n \left[\beta \operatorname{sgn}(d\mu_i Z) + y\right]\right\} d\mu_i \tag{9}$$

$$,\operatorname{sgn}(\,) = \{1 \ \text{if}(\,) > 0\}, \{-1 \ \text{if}(\,) < 0\}$$

that A, β and γ Are constants that control the shape of the generated hysteretic loops, and n control the rate of transition from the elastic to the yield state [6].

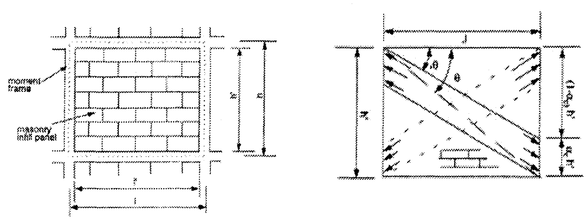


FIGURE 3. Masonry infill panel and compressive struts [2]

With taking stiffness deterioration in to consideration in hysteretic model controlling parameter η is calculated as following [5]:

$$dZ_i = \left\{A - |Z_i|^n \left[\beta \operatorname{sgn}\left(d\mu_i Z\right) + y\right]\right\} d\mu_i / \eta_i \tag{10}$$

Stiffness controlling parameter η_i is defined as:

$$\eta_i = \left[s_k + \alpha(\mu_i - 1) + 1\right] / \left[\mathrm{s_k} + \mu_i\right] \quad , \quad \mu_i > 1.0 \tag{11}$$

S_k is a control parameter used to vary the rate of stiffness decay as a function of the current ductility that amount of 5 percent is suggested [6]. Degrading systems such as masonry infill panels also exhibit a loss of strength when subjected to cyclic loading in the elastic range. The strength deterioration in the smooth hysteretic model was modeled reducing the yield force of panel according to [5]:

$$V_y^k = V_y^{\circ}(1 - DI) \tag{12}$$

Where DI defines cumulative damage index that depends on maximum accessible ductility $(\mu_{\max})$ and maximum absorbed energy which is calculated as following [5]:

$$DI = \frac{\mu_{\max} - 1}{\mu_c - 1}\left[1 - 0.25 S_{p1} \int \left(\frac{V}{V_y}\right) \frac{d\mu}{(\mu_c - 1)}\right]^{-S_{p2}} \tag{13}$$

μ_c is the ductility capacity of the infill panel and the parameters S_{p1} , S_{p2} control the rate of strength deterioration. Pinching are seen in hysterics loops during cyclic loading as a result of opening and closing of cracks of infill panels.

The main concept for slip-lock element according to Baber and Nouri (1985) received acclaim and considered in hysteretic model [6]. The normalized displacement of the pinching smooth hysteretic element μ is the sum of the normalized displacement of the smooth degrading element μ_1 and the slip-lock element μ_2 ($\mu = \mu_1 + \mu_2$), which are calculated from the following differential equation as following [5];

$$d\mu_2 = a\, f(Z) dZ \tag{14}$$

Where a is the constant related to slip length and the function f(Z) is as following [5];

$$f(Z) = \exp\left(\frac{-\{Z - \overline{Z}\}^2}{Z_s^2}\right) \quad ; \; -1 \le \mathrm{Z}, \overline{\mathrm{Z}} \le 1 \tag{15}$$

that $\overline{Z}$ Is equal to amount of Z when f(Z) is in the maximum level , or when the slip is maximum and Z_s Is around Z = $\overline{Z}$ at the time slip happening. Now, according to equations 10, 14, 15 the hysteretic component Z is obtained from the following differential equation [5];

$$\frac{dZ}{d\mu} = \frac{\left[A - |Z|^n \{\beta \operatorname{sgn}(d\mu.Z) + \gamma\}\right]}{\eta\left[1 + a\ \exp\left(\frac{-\{Z - \overline{Z}\}^2}{Z_s^2}\right)(A - |Z|^n \{\beta \operatorname{sgn}\left(d\mu\ Z\right) + \gamma\right]} \tag{16}$$

a is slip length in equation 14 is considered as ductility function ;

$$\mathrm{a} = \mathrm{A_s}\left(\mu^r - 1\right) \tag{17}$$

Where A_s is a control parameter to vary slip length which may be linked to the size of crack openings (Lobo 1994) and μ^r is the normalized displacement attained at the load reversal prior to the current loading or reloading cycle. Numerical Runge Kutta method has been used to solve hysteretic pinching component (Eq. 16) [6]. Reinhorn model in IDARC [7] software which has the capability to analyze non linear RC frames is being used in this research.

2. Considered frames

Seismic behavior of infilled frames is different from bare frames that this issue is important in structures which their lateral resisting system is moment resisting frame because ductility of these frames is far more than frames with shear wall and it seems that the effect of infill panels on the performance of these kinds of frames is considerable, so 4 storey frames (1, 2 and 3 spans) and 8 storey frame (1, 2 and 3 spans) are being studied in two states of infilled and bare. 4 meters Frame span averagely, 3.4 meters height of ground floor and 3 meters for the height of other floors have been considered. Regarding to characteristics of construction materials for moment resisting frame with high ductility, It is said in Iranian concrete code that for concrete compressive strength (f_c) must not be less than 20 (N/mm^2) and reinforcing steel yield strength (f_y) must not be more than 400 (N/mm^2) [8], that according to the code 30 (N/mm^2) for concrete compressive strength and 400 (N/mm^2) for reinforcing steel yield strength has been considered. Gravity loads according to Iranian loading code [9] and lateral loading according to introduced method in Iranian Seismic Code (Standard No.2800) [1] have been done. In seismic loading, it is assumed that frames are located inside a residential building with one way slab ceiling and 4 meters load bearing width and it is noted that the building is located high risk earthquake area on the land type 3(the land is considered type 3 in many urban areas in Iran). It is noted to mention that the effect of masonry infill walls have been considered according to Iranian Seismic Code (Standard No.2800). Analysis and designing is according to SAP 2000 [10] software. All criteria mentioned in Iranian concrete code for moment resisting frame with high ductility have been taken in notice in designing the frames. The summary of designing results is listed in Table 1 to 3.

TABLE 1. One span frames designing results

Frame		Cross Dimensions(mm)	Longitudinal Reinforcements	Transverse Reinforcements
14	1St, 2St Columns	350 × 350	8 Φ 20	Φ 12@100 mm
	3St, 4St Columns	300 × 300	8 Φ 16	Φ 12@100 mm
	Beams	300 × 400	Top:4Φ22 Bot : 4Φ20	Φ 10@100 mm
18	1St, 2St Columns	550 × 550	12 Φ 22	Φ 12@100 mm
	3St, 4St Columns	500 × 500	8 Φ 22	Φ 12@100 mm
	5St, 6St Columns	400 × 400	8 Φ 22	Φ 12@100 mm
	7St, 8St Columns	350 × 350	8 Φ 16	Φ 12@100 mm
	1St to 4St Beams	400 × 500	Top:4Φ22 Bot :5Φ22	Φ 12@100 mm
	5St to 8St Beams	400 × 400	Top : 4Φ22 Bot : 4Φ22	Φ 12@100 mm

TABLE 2. Two spans frames designing results

Frame		Cross Dimensions(mm)	Longitudinal Reinforcements	Transverse Reinforcements
24	1St, 2St Columns	400 × 400	8 Φ 20	Φ 12@100 mm
	3St, 4St Columns	350 × 350	8 Φ 16	Φ 12@100 mm
	Beams	300 × 400	Top : 4Φ16 Bot : 4Φ22	Φ 12@100 mm
28	1St to 4St Border Columns	450 × 450	8 Φ 28	Φ 12@100 mm
	1St to 4St Middle Columns	500 × 500	8 Φ 28	Φ 12@100 mm
	5St to 8St Columns	400 × 400	8 Φ 22	Φ 12@100 mm
	1St to 4St Beams	400 × 400	Top : 4Φ22 Bot : 5Φ20	Φ 12@100 mm
	5St to 8St Beams	400 × 400	Top : 4Φ22 Bot : 4Φ22	Φ 12@100 mm

TABLE 3. Three spans frames designing results

Frame		Cross Dimensions (mm)	Longitudinal Reinforcements	Transverse Reinforcements
34	1St, 2St Columns	400 × 400	8 Φ 20	Φ 12@100 mm
	3St, 4St Columns	350 × 350	8 Φ 16	Φ 12@100 mm
	Beams	300 × 400	Top : 4Φ18 Bot : 5Φ18	Φ 10@100 mm
38	1St to 4St Border Columns	500 × 500	12 Φ 20	Φ 10@100 mm
	1St to 4St Middle Columns	550 × 550	12 Φ 22	Φ 12@100 mm
	5St, 6St Columns	450 × 450	12 Φ 20	Φ 10@100 mm
	7St, 8St Columns	400 × 400	8 Φ 16	Φ 12@100 mm
	1St to 4St Beams	400 × 400	Top : 4Φ22 Bot : 5Φ22	Φ 10@100 mm
	5St to 8St Beams	400 × 400	Top : 4Φ20 Bot : 5Φ20	Φ 10@100 mm

Infilled frames with the symbol of IFxy (Infilled Frame) and bare frames with symbol of BFxy (Bare Frame) have been illustrated, where x is to define number of frame span and y is to define number of floors. Such as IF38 defines infilled frame 3 spans and 8 floors.

2.1 Masonry infill walls

Most of bricks are made of clay and made in the type of solid, ceramic, hollow bricks in Iran, where usually solid brick is used for infill frames. Approximate size of solid bricks is 220 * 110 * 55 mm and thickness of infill walls is considered 220 mm in considered frames. Paulay and Priestley (1992) equation has been used to calculate prism strength of masonry as following [11];

$$f'_m = \frac{f'_{cb}(f'_{tb} + \alpha f'_j)}{U_u(f'_{tb} + \alpha f'_{cb})} \; ; \alpha = \frac{j}{4.1h_b} \; ; \; U_u = 1.5 \tag{18}$$

where f'_{tb} defines tension strength of the brick, f'_{cb} Defines compressive strength of the brick, f'_j defines mortar compression strength, h_b defines height of masonry unit (50 to 60 mm is considered for the height of a solid brick), j is the mortar joint thickness and U_u is the stress non uniformity coefficient equal to 1.5 . Compressive strength of the solid brick is 75 (Kg/cm^2) according to suggested number from Building and Housing Research Center of Iran [12]. The tension strength of the solid bricks may be determined as, (T. Paulay, M.J.N Priestly 1992) [11]: $f'_{tb} = 0.1f'_{cb}$, therefore, $f'_{tb} = 7.5$ (Kg/cm^2).
In addition, the corresponding compression strength of the mortar is considered to be 50 (Kg/cm^2) which is derived from experimental results carried out by Moghaddam (for the cement-sand ratio of the mortar is 1:5) [13]. So regarding to mentioned numbers, and 15 mm for the mortar joint thickness and 60 mm for height of masonry unit; compression strength of a masonry prism is calculated as following;

$$\alpha = 0.061 \; ; \; U_u = 1.5 \; ; \; f'_m = 44\frac{kg}{cm^2} = 0.0043164 \; \frac{KN}{mm^2}$$

Where this value have been used in this study. All other needed parameters in software for masonry infill walls are listed in Table 4.

2.2 Nonlinear dynamic analysis of frames

E-W record of Bam (2004) is used to analyze nonlinear dynamic analysis which is shown in Fig. 4. Mentioned accelerogragh is calibrated by design base acceleration of relative high risk area (PGA=0.35g) and then has been used to analyze the frames. Damping is 5 percent of critical damping according to Iranian seismic code (Standard No. 2800) [1] for different kinds of structures despite higher damping values are reported where damping is considered up to 7 percent of critical damping for structures with have got infilled frame in all floors [14]. So averagely, damping is used as 6 percent of critical damping.

TABLE 4. Masonry materials properties

Parameter	Description	Amount
FM	Prism strength of masonry	0.00432
FMCR	Cracking modulus of masonry	0.0002158
EPSM	Strain corresponding to prism strength	0.002
VM	Basic shear strength of masonry bed joints	0.000176
SIGMM	Maximum allowable shear strength	0.0002158
CFM	Coefficient of friction of frame-infill interface	0.3

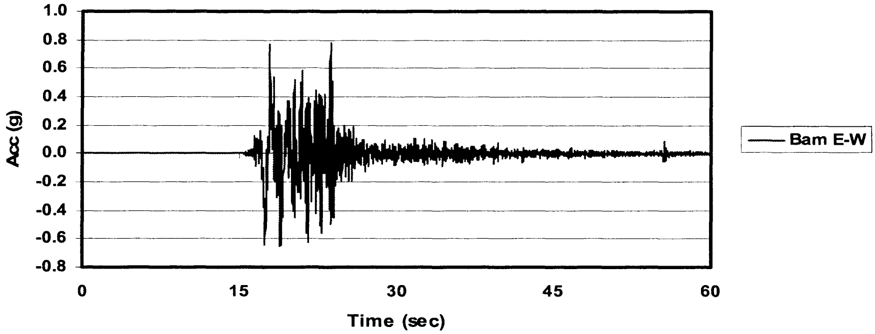
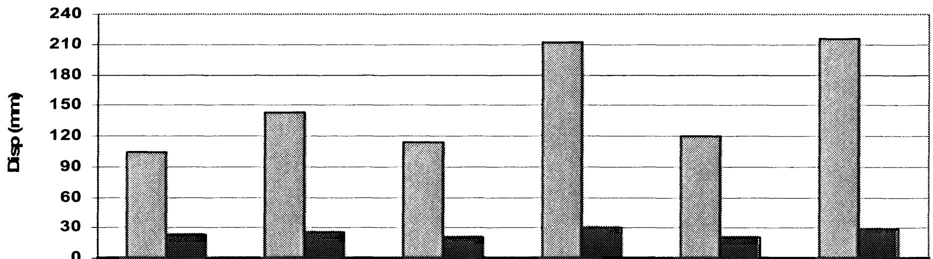


FIGURE 4. Bam Earthquake E-W Component [12]



	14	18	24	28	34	38
BF	104.56	142.97	113.95	211.56	120.3	215.3
IF	22.45	25.65	20.43	30.57	20.31	29.25

FIGURE 5. Comparison of maximum displacement response of frames in nonlinear dynamic analysis

2.2.1 Maximum displacement response of frames

Maximum displacement response of frames in BF and IF cases are shown in column diagram to compare the maximum displacement response of frames obtained from nonlinear dynamic analysis both of bare and infilled cases (Fig. 5).

It has been seen that the role of infill walls is noticeable in decrease of maximum displacement of frames, after considering maximum displacement in two cases of IF and BF, where averagely, 81 percent in 4 floors frames and 84 percent in 8 floors frames of maximum displacement of frame in IF than BF cases has decreased that illustrates the effect of infill walls to increase the stiffness of IF frames.

2.2.2 Drifts of floors

Drift of floors is a useful factor to analyze the seismic behavior of structure which identify the performance level of whole structure. Maximum drifts of floors in nonlinear dynamic analysis for considered frames are shown in Fig. 6.

It is obtained from maximum drifts of floors of frames that along increase of frame height effect of infill walls in controlling displacements of lower floors is decreased where the main cause is fracture of infill walls in these floors due to great shear force during lateral loading but on the other hand it is seen that in upper floors infill walls are able to control the displacements of floors that defines the pleasant effect of infill walls in upper floors.

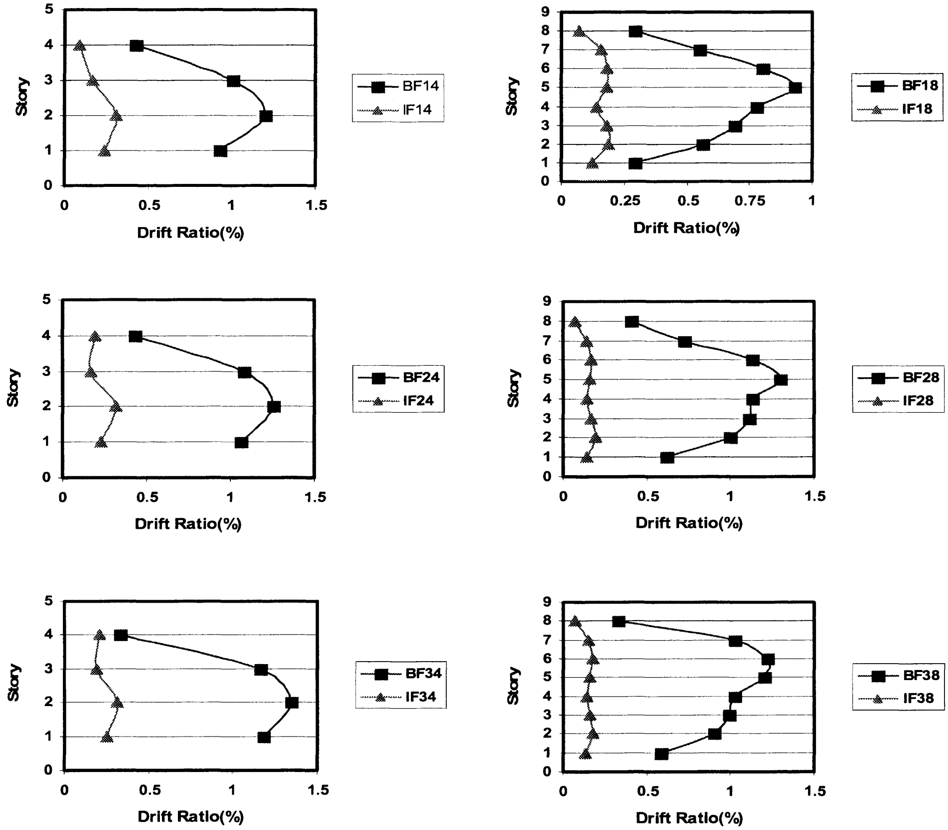


FIGURE 6. Comparison of maximum drifts of floors in nonlinear dynamic analysis

3. Performance level of frames

The main goal of this study it to research about the effect of non connected masonry infill walls in seismic performance of RC moment resisting frames with high ductility, there fore performance level for each frame is defined regarding to nonlinear dynamic analysis . First step to define the performance level of structure is to choose suitable factor to evaluate the performance. One of the commonplace factors to define performance level of structures is drift of floors which is used to evaluate the performance level of whole structure. To reach this goal ATC 40 [15] criteria has been used. It is said in ATC 40 that if the maximum drift of structure is less than 1 percent performance level will be immediate occupancy (IO), if the drift is between 1 to 2 percent it will be damage control (DC), if the factor is 2 percent it will be Life safety (LS), and if the factor is 2 percent to 0.33 V_i/P_i (V_i = calculated shear force for storey i, P_i = gravity load (including dead load and 20% of live load) in storey i) it will be structural stability (SS) [15]. The result of performance level of considered frames of IF and BF cases is shown in Table 5.

After defining performance level in IF and BF cases, it is resulted that when infill walls are not considered in nonlinear dynamic analysis (BF), performance level will be DC, but if infill walls are considered (IF) performance level will be IO, it could be said infill walls in

TABLE 5. Performance level of frames

Frame	14	18	24	28	34	38
Maximum drift of BF (%)	1.2	0.93	1.25	1.3	1.34	1.22
Performance level of frame	DC	IO	DC	DC	DC	DC
Maximum drift of IF (%)	0.31	0.19	0.32	0.19	0.31	0.18
Performance level of frame	IO	IO	IO	IO	IO	IO

performance level of RC moment resisting frame have positive effect and cause the performance level of frames improved to IO.

Results

The goal of this study was to evaluate the effect of non connected masonry infill walls on seismic performance of RC moment resisting frames with high ductility where some moment resisting frames with high ductility in two cases of IF and BF were considered that the main results are as following ;

1. In all considered frames, the role of infill walls to control the displacement in lower floors is small that the main reason is fracture of infill walls in these floors due to great shear force as a result of lateral loading but on the other hand, infill walls in upper floors have been able to decrease the displacements of floors noticeably which illustrate the suitable performance of infill walls in upper floors.
2. In general study of performance level of frames with taking of maximum drift factor of floors in to consideration, it was understood that the performance level of frames in BF case is DC, but in IF case maximum drift in all frames is less than 1 percent which illustrate that performance level of frames in IF case is IO. So it could be said masonry infill walls play a noticeable role to optimize the performance level of RC moment resisting frames with high ductility.
3. By consideration of whole performance level of RC moment resisting frames with high ductility determined that in BF case whole performance level of the frame is DC and in IF case it is IO. On the other hand it is resulted that BF RC moment resisting frames with high ductility can satisfy Iranian seismic code (Standard No. 2800) which recommends that residential buildings should be life safe designed. Further more infilling the frames improve their performance level to IO.

REFERENCES

[1] Iranian code of practice for seismic resistant design of buildings (Standard No. 2800), 3rd edition, Building & Housing Research Center of Iran, 2004.

[2] Reinhorn, A. M., Kunnath S. K., and Valles-Mattox R., (2004), IDARC 2D Version 6.0: users manual. Department of Civil Engineering, State University of New York at Buffalo.

[3] Saneinejad, A., and Hobbs, B., 1995 "Inelastic Design of Infilled Frames", ASCE, Vol. 121, ST. 4, April, pp 634-649.

[4] Baber, T. T., and Noori, M. N., "Random Vibration of Degrading Pinching Systems", Journal of Engineering Mechanics, Vol. 111, No. 8, 1985, pp. 1010-1026.

[5] Reinhorn, A. M., Madam, A., Valles, R. E., Reichman, Y., Mander, J. B., 1995, Modeling of masonry infill panels for analysis of frame structures, Report NO. NCEER-95-018, National center for Earthquake Engineering Research, State

University of New York at Buffalo.

[6] Riddington, J. R., 1984, The influence of initial gaps on infilled frame behavior, Proc. ICE, Part 2, 77, Sept, pp 295-310.

[7] Reinhorn AM et al. IDARC2D Version 6.0 - A computer program for the inelastic damage analysis of reinforced concrete buildings, State University of New York at Buffalo (2004).

[8] Iranian Concrete Code, 3rd Edition, Management and Planning Organization of Iran, 2001.

[9] Iranian Loading Code, Applied load to Structure, National collection of building codes bureau, 2002.

[10] SAP2000, Linear and nonlinear static and dynamic analysis and design of structures. Ver.8.0, Computers and Structures, Inc., Berkeley (CA, USA) (2002).

[11] Paulay, T., Priestley M.J.N.,1992, Seismic Design of Reinforced Concrete and Masonry Buildings, JOHN WILEY & SONS, INC .

[12] BHRC, 2004, Building and Housing Research Center, http : // www.bhrc.gov.ir/.

[13] Moghaddam, H. A, 2004, Lateral Load Behavior of Masonry Infilled Steel Frames with Repair and Retrofit, Journal of Structural Engineering, ASCE, Vol. 130, NO 1, pp 56-63.

[14] Moghaddam, H. A, Dowling . P. J. , 1987, The state of the Art in infiiled frames, ESEE report NO. 87-2, Civil Eng Dept, Imperial College, London.

[15] ATC-40, 1996, Seismic Evaluation and Retrofit of concrete Buildings, prepared by the Applied Technology Council, Redwood City, California 94065, Seismic Safety Commission State of California (Report NO. SSC 96-01).