

Influence of Masonry Infill Wall Distribution on the Seismic Response of a Reinforced Concrete Building

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Abstract:

This study investigates the effects of masonry infill walls and their distribution on the seismic response of a five-story reinforced concrete (RC) building. Four three-dimensional models were developed in SAP2000: a bare frame, a fully infilled frame, and two partially infilled models with different ground-story infill arrangements. The building was designed in accordance with the Turkish Building Earthquake Code 2018 (TBEC 2018), and the masonry infill walls were represented by equivalent diagonal struts. Linear time-history analyses were performed using eleven ground-motion records. For comparative evaluation, the analysis results were grouped by event moment magnitude as $M_w < 7.0$ and $M_w > 7.0$. Fundamental period, roof displacement, effective interstory drift ratio, soft-story irregularity, torsional irregularity, and base shear were evaluated. The inclusion of masonry infill walls increased the lateral stiffness of the building, with the fully infilled model showing a 56.2% reduction in fundamental period compared with the bare frame. The infilled models also produced lower mean maximum roof displacements and effective interstory drift ratios, with reductions reaching 65.8% and 71.8%, respectively. The distribution of the infill walls had an important influence on the irregularity response. Removing selected ground-story infills did not consistently result in soft-story irregularity, whereas torsional irregularity was more pronounced in the partially infilled models. The infilled models generally developed higher base shear forces than the bare frame. Overall, the results show that masonry infill walls increase structural stiffness and reduce lateral deformation, while their distribution plays an important role in the irregularity response of RC frame buildings.

1. Introduction

Masonry infill walls are widely used in reinforced concrete (RC) frame buildings as interior partitions and exterior enclosures. Although they are generally considered non-structural components in structural analysis, their interaction with the surrounding frame under lateral loading affects the response of the structural system. Masonry infills contribute to the lateral stiffness and strength of RC frames, and neglecting this contribution may lead to differences between the assumed analytical model and the response of the infilled structure [1], [2], [3], [4].

Post-earthquake observations also show different types of infill wall damage resulting from the interaction between the masonry panels and the surrounding RC members [5], [6].

The influence of masonry infill walls depends not only on their presence but also on their location and distribution within the building [7]. Changes in the amount and arrangement of the walls modify the stiffness distribution of the structural system. Numerical studies considering different in-plan infill configurations have shown that irregular wall distributions can change the seismic response and that this effect may also vary with the structural

system and earthquake record [8], [9]. Symmetric and asymmetric arrangements have also been shown to produce different capacity responses [10]. When infill walls are concentrated on one side of the plan or are discontinuous along the building height, torsional and soft-story irregularities can become important in the structural response [11], [12]. Similar studies considering different wall positions and distributions have also reported changes in stiffness, deformation demand and lateral load response [13].

The contribution of infill walls is reflected in several global response parameters. Analyses in which masonry walls were represented by equivalent compression struts have produced shorter vibration periods, smaller roof displacements and lower interstory drift values than corresponding models in which their structural contribution was neglected. Higher base shear forces have also been obtained when the stiffness contribution of the walls was included [14]. Time-history analyses of bare, fully infilled and partially infilled frames have likewise shown differences in story displacement, interstory drift and story shear response, with the results also changing according to the location of the soft story [15]. Analyses performed with different infill ratios have shown that increasing the contribution of masonry walls increases structural stiffness and generally reduces vibration periods and interstory drift ratios [16]. Similar changes in period, interstory drift and base shear have been observed for RC models incorporating different masonry infill materials [17].

The arrangement and characteristics of the infill walls are also important when these effects are evaluated. Increasing the amount of regularly and symmetrically distributed infill has been associated with reductions in fundamental period and target displacement, whereas asymmetric arrangements can alter the capacity response of the building [10]. Large parametric studies have shown that the influence of masonry infills cannot be described by a single trend and depends on the properties of both the structural system and the infill walls [18]. The response may also vary with the characteristics and orientation of the earthquake input [19]. Recent investigations of earthquake-damaged RC buildings have similarly shown that the inclusion of infill walls increases lateral stiffness, while displacement-related response may vary depending on the selected ground-motion record [20]. The effects of masonry infill should therefore be evaluated together with the wall configuration and the characteristics of the seismic input, rather than considering only whether the walls are present or absent.

Different numerical approaches have been developed to represent the interaction between

masonry infill walls and RC frames. Detailed micro-models allow local wall and frame behavior to be represented, but their use in whole-building analyses requires greater modeling effort and computational cost. Macro-models provide a simpler alternative for studies mainly concerned with the global response of the structural system [20], [21], [22]. Among these approaches, the equivalent diagonal strut method is widely used to represent the in-plane action of masonry infill walls [21], [23], [24]. Compression-only diagonal struts have been shown to provide a practical representation of the global seismic response of infilled frames [25]. Studies comparing different equations for equivalent strut width have also shown that the selected formulation can affect structural stiffness, fundamental period and seismic force demands [26].

The Mainstone formulation is one of the established approaches for determining the effective width of an equivalent diagonal strut and has also been adopted in seismic provisions for the modeling of masonry infill walls [26]. More recent studies comparing strut-based numerical models with experimental results have shown that macro-models can represent the global stiffness and strength response of infilled RC frames when appropriate mechanical parameters are assigned [27]. In the present study, the masonry infill panels are represented by single equivalent diagonal struts using the Mainstone-type formulation given in FEMA 356 [28], with a mathematically equivalent form provided in Annex 15C of TBEC 2018 [29]. Previous studies have investigated the effects of masonry infills using bare, fully infilled and partially infilled or soft-story configurations, different wall ratios and arrangements, different masonry materials, in-plan irregular distributions, and changes in wall position and openings [8], [10], [13], [15], [16]. Other investigations have shown that the resulting response may also depend on structural system properties and ground-motion characteristics [18], [20]. These studies provide a broad basis for evaluating the contribution of infill walls, but they also show that the response is closely related to the particular wall configuration considered. In the present study, this effect is examined through a controlled comparison in which the same building geometry, structural properties, and set of earthquake records are maintained while the presence and ground-story distribution of the masonry infill walls are varied.

Four three-dimensional structural models are considered: a bare frame (BF), a fully infilled frame (FI), a partially infilled model in which selected ground-story infills are removed along one exterior frame line in the X direction (PI-1D), and a partially infilled model in which selected ground-story infills

are removed along one exterior frame line in both the X and Y directions (PI-2D). Linear time-history analyses are carried out in SAP2000 using eleven scaled ground-motion records. For comparative evaluation, the analysis results are grouped into $M_w < 7.0$ and $M_w > 7.0$ moment-magnitude groups. Fundamental periods, roof displacement, effective interstory drift ratio, B2 soft-story irregularity, A1 torsional irregularity and base shear are evaluated to examine the effects of the presence and ground-story distribution of masonry infill walls on the seismic response of the building.

2. Materials and Methods

A numerical study was carried out to investigate the effect of different masonry infill arrangements on the seismic response of a reinforced concrete building. Four three-dimensional models were developed in SAP2000 [30]. The numerical study included the definition of the reference building and infill configurations, modeling of the masonry infill walls, and selection and scaling of ground-motion records for linear time-history analysis.

2.1. Investigated building and numerical models

A five-story reinforced concrete residential building was considered as the reference structure. The building was assumed to be located in Karabük, Türkiye, and was designed in accordance with the Turkish Building Earthquake Code 2018 (TBEC 2018), TS 500 for reinforced concrete design and TS 498 for structural loads [29], [31], [32]. The building has a square plan of 25 m $\times$ 25 m with five equal bays of 5 m in both the X and Y directions. The ground-story height is 6.0 m, while the height of each of the four upper stories is 3.0 m. The structural system consists of reinforced concrete frames in both principal directions. The column bases were assumed to be fixed, and rigid diaphragm constraints were assigned at each floor level. The structural layout of the reference building is shown in Figure 1 and The main material, section and loading properties adopted in the numerical models are summarized in Table 1.

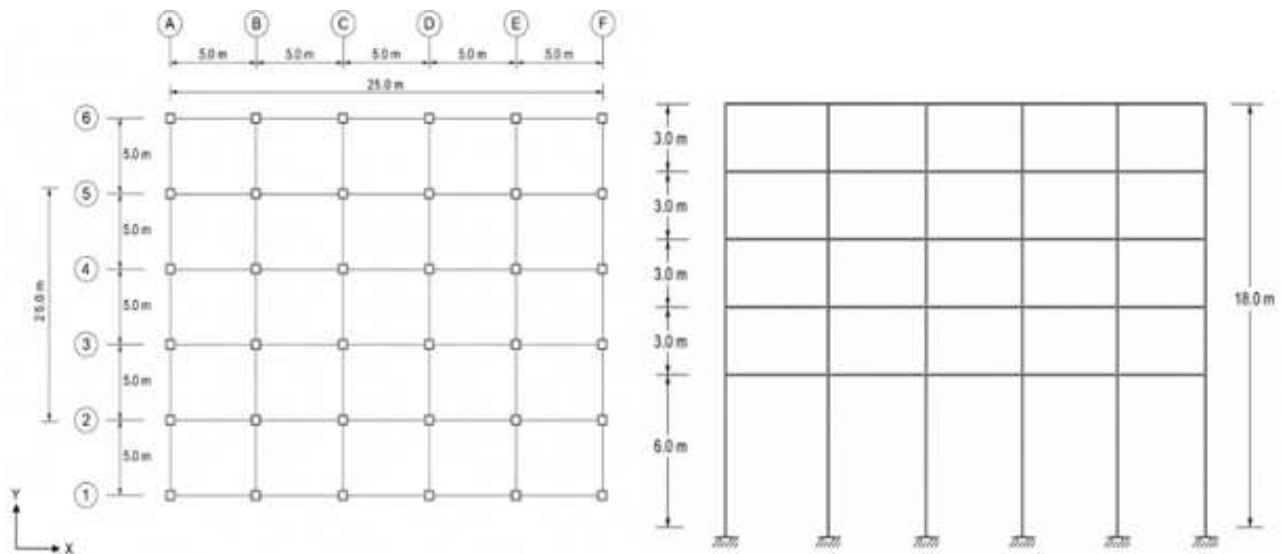


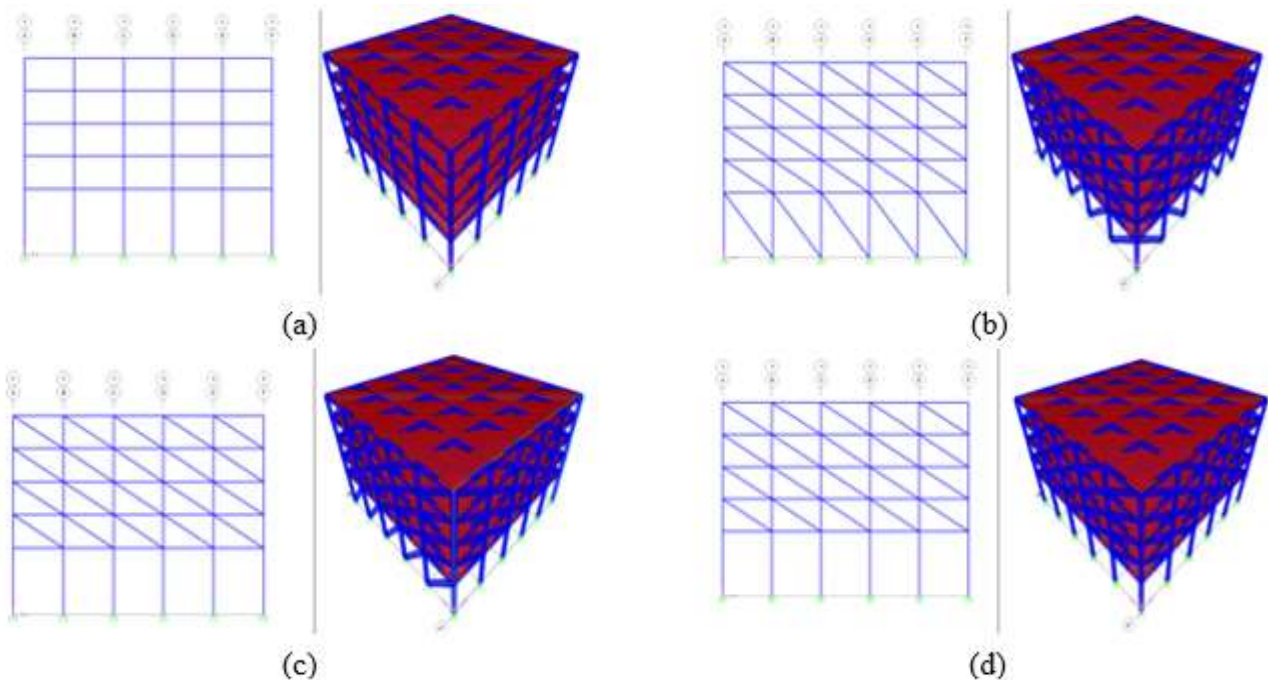
Figure 1. Structural plan and elevation of the reference building

Table 1. Material, section and loading properties of the reference building

Parameter	Value
Concrete class	C25 ($f_{ck}=25$ MPa)
Reinforcing steel class	B420C
Column cross-section	400 × 400 mm
Beam cross-section	300 × 600 mm
Slab thickness	120 mm
Masonry infill thickness	190 mm
Unit weight of concrete	25 kN/m ³
Unit weight of masonry infill	19 kN/m ³
Dead load	2.26 kN/m ²
Live load on typical floors	2.0 kN/m ²
Live load on roof	1.5 kN/m ²

Four different infill configurations were considered, as illustrated in Figure 2. In the bare-frame model (BF), the masonry infill walls were not included as structural elements, while their gravity effect was applied to the supporting beams as a distributed load of 10.85 kN/m. In the fully infilled model (FI), masonry infill walls were included at all stories in both principal directions. In the partially infilled

model in one direction (PI-1D), the ground-story infills along one exterior frame line in the X direction were removed. In the partially infilled model in two directions (PI-2D), the ground-story infills along one exterior frame line in both the X and Y directions were removed. In both partially infilled models, the remaining ground-story infills and all upper-story infills were retained.

**Figure 2.** Numerical models with different masonry infill arrangements. (a) BF, (b) FI, (c) PI-1D, and (d) PI-2D

2.2. Modeling of masonry infill walls

The masonry infill walls were represented by equivalent diagonal struts to account for their in-plane contribution to the reinforced concrete frames. Under lateral loading, the interaction between the masonry wall and the surrounding frame results in a

diagonal compression path. Accordingly, each masonry infill wall included in the numerical model was represented by a single equivalent diagonal strut.

The effective width of the diagonal strut was determined using the Mainstone-type formulation

given in FEMA 356 [29]. A mathematically equivalent form is also provided in Annex 15C of

TBEC 2018 [30], and the effective strut width, α , was calculated as

$$\alpha = 0.175 (\lambda_h \times h_{col})^{-0.4} \times r_{inf} \quad (1)$$

where the relative stiffness parameter λ_h is defined as

$$\lambda_h = \left[\frac{E_m \times t_{inf} \times \sin 2\theta}{4 \times E_{fc} \times I_{col} \times h_{inf}} \right]^{1/4} \quad (2)$$

where α is the effective width of the equivalent diagonal strut, h_{col} is the height of the column between beam center lines, λ_h is the relative stiffness parameter, r_{inf} is the diagonal length of the masonry infill wall, E_m and E_{fc} are the moduli of elasticity of the masonry infill wall and frame material, respectively, t_{inf} is the thickness of the masonry infill wall, I_{col} is the moment of inertia of the column, H_{inf} and L_{inf} are the height and length of the masonry infill wall, respectively, and θ is the angle of the diagonal strut with the horizontal.

The elastic modulus of masonry was taken as $E_m = 1000$ MPa and the wall thickness was 190 mm. For the bays containing masonry infill walls, the corresponding frame bays were assumed to be fully infilled without openings. Since the ground-story height was 6.0 m and the upper-story height was 3.0 m, the strut properties were calculated separately for the two different story heights. The geometric parameters of the adopted strut model are illustrated in Figure 3 and the resulting parameters are summarized in Table 2.

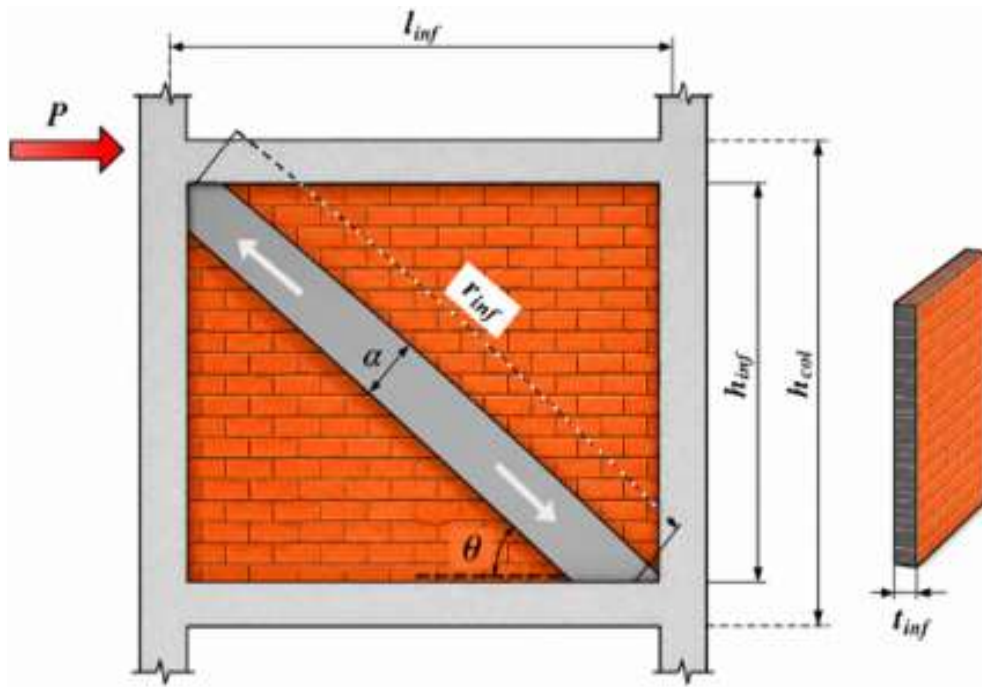


Figure 3. Geometric parameters of the equivalent diagonal strut model for a masonry infill wall

Table 2. Parameters of the equivalent diagonal strut model

h_{col} (mm)	L_{inf} (mm)	h_{inf} (mm)	r_{inf} (mm)	$\theta(^{\circ})$	λ_h	α (mm)	t_{inf} (mm)
3000	4600	2400	5188.45	27.553	0.0007097	671	190
6000	4600	5400	7093.66	49.57	0.0006062	740	190

2.3. Ground motion selection, scaling, and dynamic analysis

The seismic hazard parameters for the building site were obtained from the Türkiye Earthquake Hazard Maps Interactive Web Application of AFAD [33]. The site was defined at 41.221056° N latitude and 32.663513° E longitude with a local soil class of ZC.

The DD-2 earthquake ground motion level specified in TBEC 2018 was adopted for the seismic analysis. The corresponding horizontal elastic design spectrum is presented in Figure 4, and the associated seismic hazard parameters are summarized in Table 3 [29].

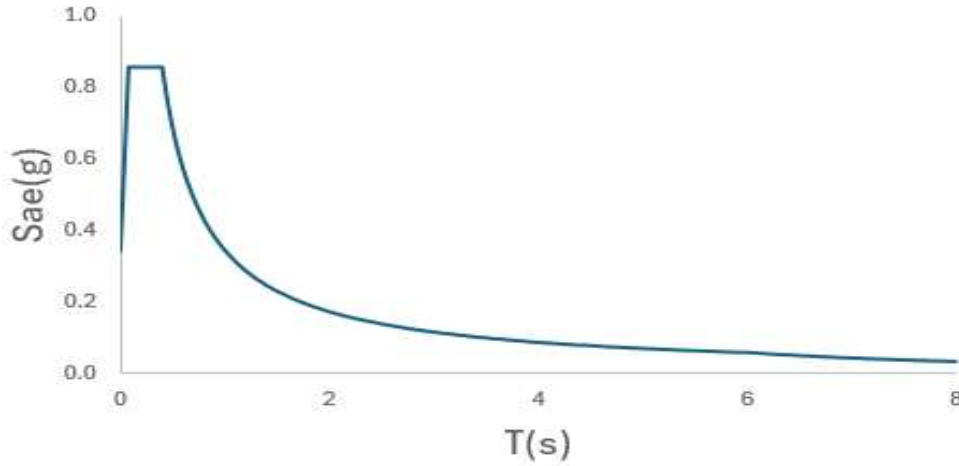


Figure 4. Horizontal elastic design spectrum for the DD-2 earthquake ground motion level

Table 3. Seismic hazard parameters adopted for the DD-2 earthquake ground motion level

Parameter	Value	Description
Local soil class	ZC	Local soil class according to TBEC 2018
S_s	0.705	Short-period map spectral acceleration coefficient
S_1	0.230	Map spectral acceleration coefficient at 1.0 s
F_1	1.500	Site coefficient at 1.0 s
S_{DS}	0.859	Short-period design spectral acceleration coefficient
S_{D1}	0.345	Design spectral acceleration coefficient at 1.0 s
PGA	0.297 g	Peak ground acceleration
PGV	20.063 cm/s	Peak ground velocity

Eleven ground-motion records were selected from the PEER NGA-West2 database based on predefined magnitude, source-to-site distance, and site-condition criteria [35]. The selection was limited to records with moment magnitudes of $6.5 \leq M_w \leq 8.0$,

Joyner-Boore distances (R_{JB}) of 0–20 km, and V_{S30} values between 360 and 760 m/s. Records from strike-slip and normal faulting events were considered. The main characteristics of the selected ground motions are presented in Table 4.

Table 4. Characteristics of the selected ground-motion records

No.	Earthquake	Year	M_w	Station	$R_{jb}(\text{km})$	$R_{rup}(\text{km})$	$V_{S30}(\text{m/s})$	RSN
1	Imperial Valley-06	1979	6.53	Cerro Prieto	15.19	15.19	471.53	RSN164
2	Irpinia, Italy-01	1980	6.90	Bagnoli Irpinio	8.14	8.18	649.67	RSN285
3	Irpinia, Italy-01	1980	6.90	Bisaccia	17.51	21.26	496.46	RSN286
4	Irpinia, Italy-01	1980	6.90	Calitri	13.34	17.64	455.93	RSN289
5	New Zealand-02	1987	6.60	Matahina Dam	10.27	10.27	361.40	RSN587
6	Landers	1992	7.28	Morongo Valley Fire	16.09	16.09	551.30	RSN881
7	Kocaeli, Turkey	1999	7.51	Arcelik	17.36	17.36	396.41	RSN1148
8	Duzce, Turkey	1999	7.14	Lamont 1061	10.56	13.49	523.00	RSN1614
9	Duzce, Turkey	1999	7.14	Lamont 531	11.46	11.46	481.00	RSN1618
10	Tottori, Japan	2000	6.61	SMN015	8.03	8.03	638.39	RSN3943
11	Duzce, Turkey	1999	7.14	IRIGM 498	19.72	19.72	475.80	RSN8166

The selected ground-motion records were scaled according to the simple scaling procedure specified in TBEC 2018 [29]. The scaling was performed using the PEER NGA-West2 database [34] over the $0.2T_1 - 1.5T_1$ period range defined for each structural model based on its fundamental period. In

accordance with TBEC 2018, the ratio of the mean resultant response spectrum of the scaled ground-motion set to the horizontal elastic design spectrum was not less than 1.3 within this period range. The resulting scale factors used in the linear time-history analyses are presented in Table 5.

Table 5. Scale factors of the selected ground-motion records for the structural models

RSN Code	BF	FI	PI-1D	PI-2D
RSN164	1.5609	1.4502	1.4314	1.4314
RSN285	1.3509	2.0486	1.9825	1.9825
RSN286	2.1493	3.3930	3.2867	3.2867
RSN289	1.3157	1.6646	1.6097	1.6097
RSN587	1.1971	1.1215	1.1271	1.1271
RSN881	1.0488	1.4719	1.4362	1.4362
RSN1148	2.6258	2.5263	2.5584	2.5584
RSN1614	3.1477	2.5141	2.5194	2.5194
RSN1618	2.6472	1.9494	1.9639	1.9639
RSN3943	1.9182	1.6496	1.6508	1.6508
RSN8166	1.5027	1.0554	1.0663	1.0663

Linear time-history analyses were carried out in SAP2000 using the scaled ground-motion records. A damping ratio of 5% was adopted for the analyses. The same set of 11 ground-motion records was applied to all structural models, and the seismic responses were obtained for each model separately.

3. Results and Discussion

The seismic responses of the BF, FI, PI-1D, and PI-2D models were evaluated in terms of fundamental periods, roof displacement, effective interstory drift ratio, soft-story irregularity, torsional irregularity, and base shear. The results are discussed to assess the effects of the presence and distribution of masonry infill walls on the structural response.

3.1. Fundamental periods

The fundamental periods obtained from the modal analysis are presented in Table 6. Compared with the BF model, the fundamental period decreased by 56.2% for FI, 53.5% for PI-1D, and 51.5% for PI-2D. The largest reduction was obtained for the FI model, while the partially infilled models exhibited slightly longer periods. These results indicate that masonry infill walls increase the lateral stiffness of the structural system and that their distribution influences the global dynamic response of the building.

Table 6. Fundamental periods of the structural models

Model	T_1 (s)
BF	1.737
FI	0.761
PI-1D	0.808
PI-2D	0.842

3.2. Roof displacement

The maximum absolute roof displacement was determined for each ground-motion record, and the mean values were calculated separately for the $M_w < 7.0$ and $M_w > 7.0$ groups. Figure 5 compares the

mean maximum roof displacement of the four structural models in the X and Y directions.

The BF model exhibited the largest mean maximum roof displacements, whereas the FI model produced the lowest values in both directions. Compared with

BF, the FI model reduced the mean maximum roof displacement by 63.1% and 53.3% in the X direction for the $M_w < 7.0$ and $M_w > 7.0$ groups, respectively. The corresponding reductions in the Y direction were 56.9% and 65.8%. The PI-1D and PI-2D

models generally showed intermediate responses. These results indicate that the presence and distribution of masonry infill walls influence the lateral displacement response of the building.

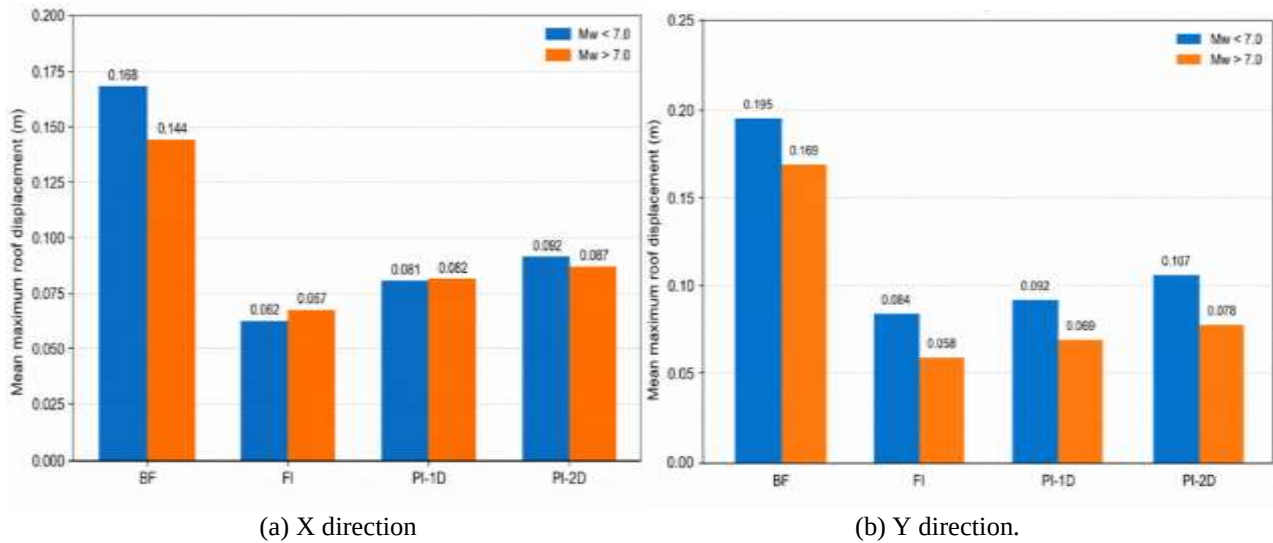


Figure 5. Mean maximum roof displacements for the two moment-magnitude groups: (a) X direction, (b) Y direction

3.3. Effective interstory drift ratios

The maximum effective interstory drift ratio was determined for each ground-motion record, and the mean values were calculated separately for the $M_w < 7.0$ and $M_w > 7.0$ groups. The comparisons for the X and Y directions are presented in Figure 6.

BF had the highest mean maximum drift ratios in both directions. Relative to BF, the FI model reduced the mean maximum drift ratio by 69.5% and 62.5% in the X direction for the $M_w < 7.0$ and $M_w > 7.0$

groups, respectively. The corresponding reductions in the Y direction were 63.7% and 71.8%. PI-1D and PI-2D remained between the BF and FI responses. In all records and for all four structural models, the maximum effective interstory drift ratio occurred at the first story. The lower drift ratios obtained for the infilled models are consistent with the increase in lateral stiffness produced by masonry infill walls. Since the maximum drift was consistently concentrated at the first story, the response of this level becomes particularly important when evaluating the effect of infill distribution.

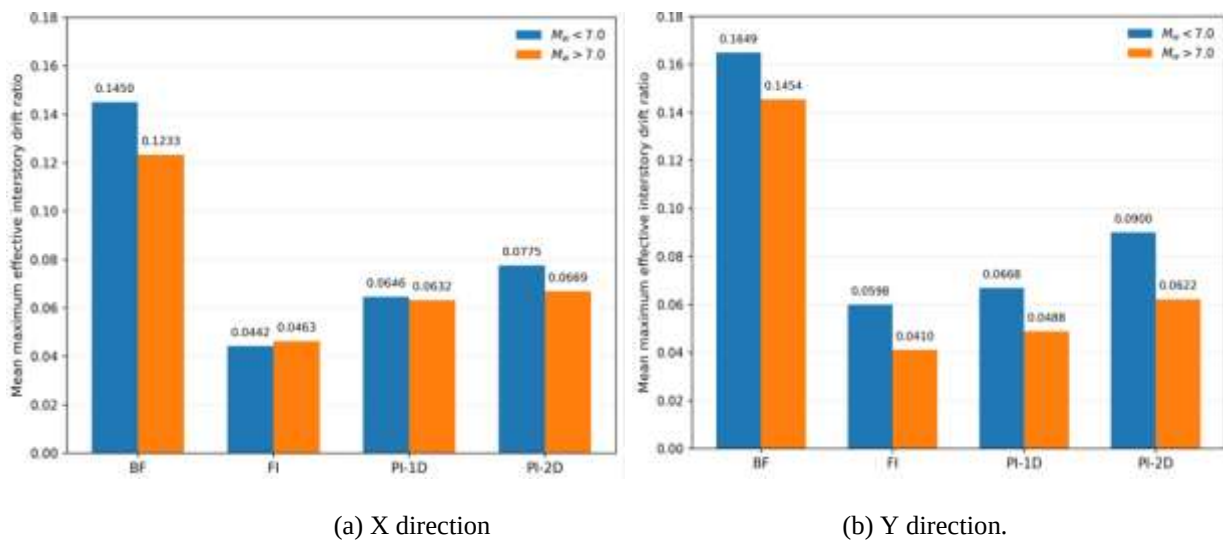


Figure 6. Mean maximum effective interstory drift ratios for the two moment-magnitude groups: (a) X direction, (b) Y direction

3.4. Soft-story irregularity

The soft-story response was evaluated using the stiffness irregularity coefficient η_{ki} . According to TBEC 2018, B2 soft-story irregularity occurs when η_{ki} exceeds 2.0. The maximum coefficient was determined along the building height for each ground-motion record, and the group means are presented in Figure 7.

BF had the highest mean maximum coefficients in both directions, with the group means exceeding the B2 limit. The mean values of FI, PI-1D and PI-2D remained below 2.0. However, the mean response alone does not fully represent the irregularity check, since the limit must be evaluated for each ground-motion record. BF exceeded the limit under all 11 records in both directions. FI exceeded it in only one

record in the X direction, while PI-1D remained below the limit for every record. PI-2D exceeded the limit under three records in the X direction, with no exceedance in the Y direction.

Although some ground-story infills were removed in the partially infilled models, this did not consistently result in B2 irregularity. PI-1D showed no exceedance, while PI-2D exceeded the limit only in three X-direction records. The critical coefficient was most often obtained at story 4, although story 1 governed some cases. This variation shows that the soft-story response depends on the stiffness distribution of the entire structural system rather than only on the removal of infills at one story.

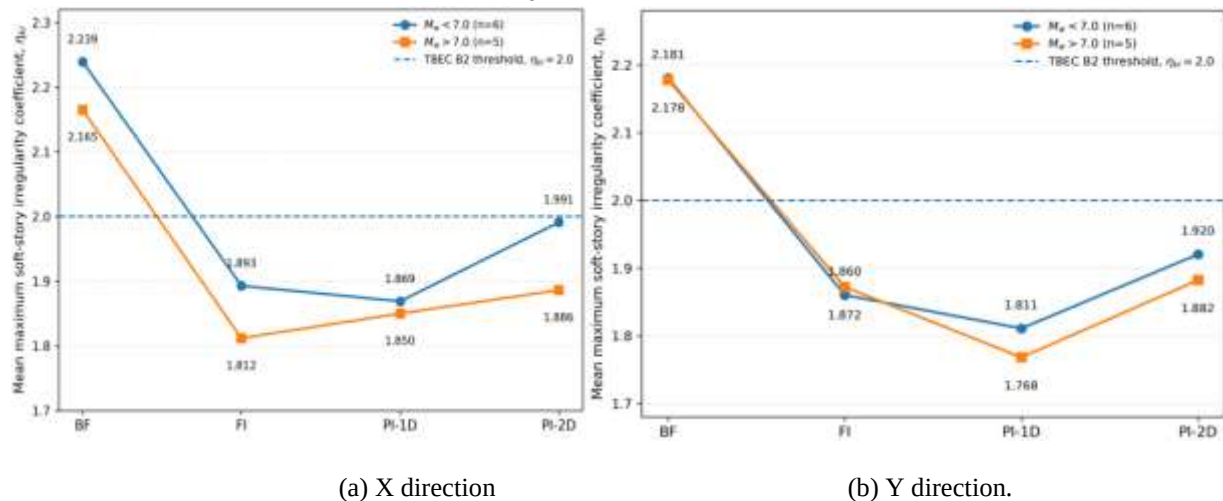


Figure 7. Mean maximum soft-story irregularity coefficients for the two moment-magnitude groups: (a) X direction, (b) Y direction

3.5. Torsional irregularity

The torsional response was evaluated using the torsional irregularity coefficient, η_{bi} . According to TBEC 2018, A1 torsional irregularity occurs when $\eta_{bi} > 1.20$. The mean maximum coefficients obtained for the $M_w < 7.0$ and $M_w > 7.0$ groups are presented in Figure 8.

BF and FI generally had lower torsional irregularity coefficients than the partially infilled models. The mean values of BF and FI remained below the 1.20 limit in both directions, whereas PI-1D and PI-2D exceeded the limit for both moment-magnitude groups. A record-by-record evaluation showed the same general tendency. In the X direction, the limit

was exceeded under 2, 1, 10, and 7 records for BF, FI, PI-1D and PI-2D, respectively. The corresponding numbers in the Y direction were 1, 1, 7, and 7. In the partially infilled models, the maximum torsional irregularity coefficient occurred predominantly at story 1.

The higher torsional response of PI-1D and PI-2D is associated with their non-uniform infill arrangement at the ground story. In these models, infills were removed only along selected exterior frame lines, changing the stiffness distribution compared with the fully infilled configuration. Similar observations have been reported for RC buildings in which the representation and arrangement of infill walls affected torsional irregularity [11].

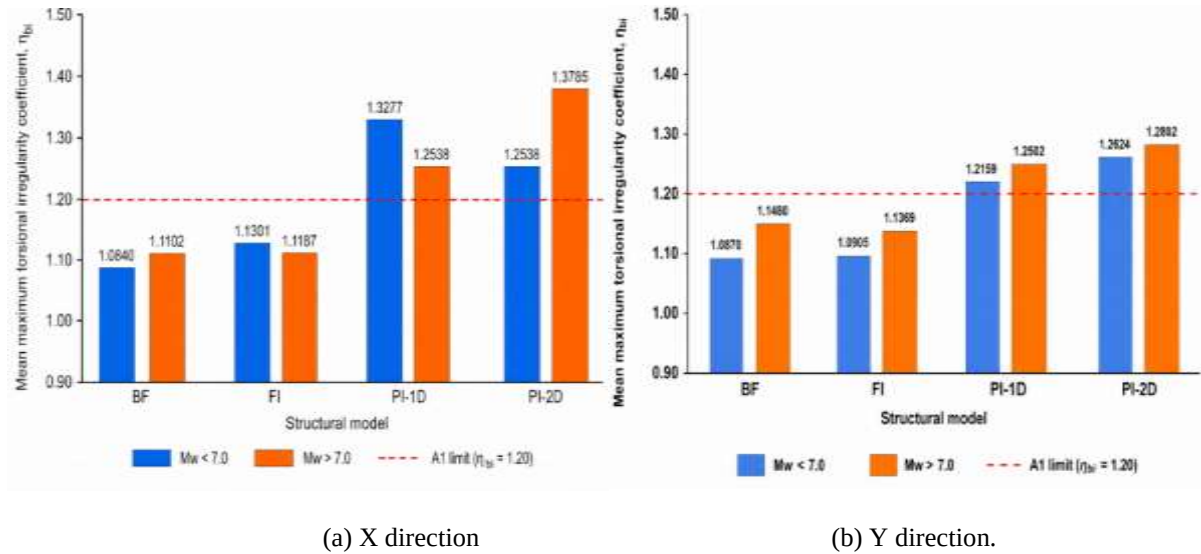


Figure 8. Mean maximum torsional irregularity coefficients for the two moment-magnitude groups: (a) X direction, (b) Y direction

3.6. Base shear forces

The maximum absolute base shear was determined for each ground-motion record, and the mean values were calculated separately for the $M_w < 7.0$ and $M_w > 7.0$ groups. The comparisons in the X and Y directions are presented in Figure 9.

The infilled models generally developed higher mean base shear forces than BF. In the X direction, the mean base shear increased by 22.2%, 21.0%, and 24.2% for FI, PI-1D and PI-2D, respectively, for the $M_w < 7.0$ group. For the $M_w > 7.0$ group, the corresponding increases were 50.4%, 41.9% and 43.4%.

In the Y direction, the increases relative to BF were 46.1%, 42.6%, and 36.9% for FI, PI-1D, and PI-2D, respectively, for $M_w < 7.0$. For $M_w > 7.0$, the increases were 12.3%, 12.5% and 4.4%. The comparison also shows that the difference between the two magnitude groups was not uniform in the X and Y directions, reflecting the variability of the structural response among the selected ground-motion records.

The higher base shear forces obtained for the infilled models are consistent with their greater lateral stiffness. Similar increases in ground-floor and overall base shear have been reported when masonry infill walls were included in RC frame models [17].

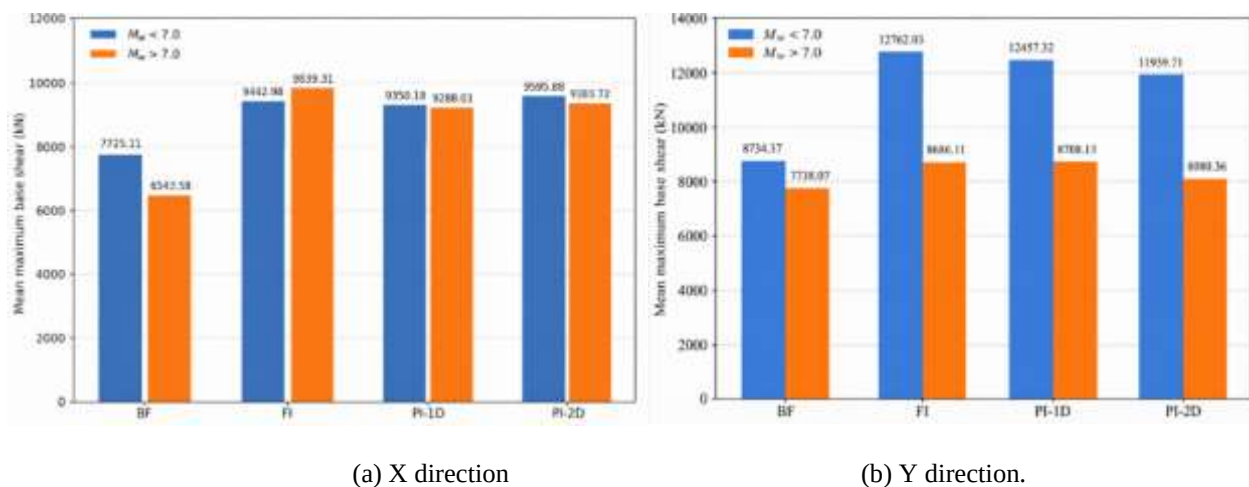


Figure 9. Mean maximum base shear forces for the two moment-magnitude groups: (a) X direction, (b) Y direction

4. Conclusions

This study investigated how the presence and distribution of masonry infill walls affect the seismic response of a five-story RC building. Four structural

models with different infill configurations were evaluated using linear time-history analysis. The main findings are summarized as follows:

- Masonry infill walls increased the lateral stiffness of the building and decreased the fundamental period. The largest reduction was obtained for the FI model, with a 56.2% decrease compared with BF. The partially infilled models also had shorter periods than BF, but slightly longer periods than FI.
- The presence of infill walls reduced roof displacement. BF consistently produced the largest displacement, while FI generally gave the lowest values. The reduction for FI reached 65.8%, and the partially infilled models remained between the BF and FI responses. This shows that roof displacement is affected not only by the presence of infills, but also by their distribution.
- A similar behavior was observed for interstory drift. FI produced the lowest mean maximum drift ratio, with reductions reaching 71.8% relative to BF. For every structural model and ground-motion record, the maximum effective interstory drift ratio occurred at Story 1.
- The soft-story irregularity results did not follow the same pattern as displacement and drift. BF exceeded the B2 limit under all 11 records in both directions, whereas FI exceeded the limit in only one X-direction record. No exceedance was observed for PI-1D, while PI-2D exceeded the limit under 3 records in the X direction. Therefore, removing selected infill walls at the ground-story did not automatically lead to B2 irregularity. The response depended on the stiffness distribution of the complete structural model.
- Torsional irregularity was more pronounced in the partially infilled models. PI-1D exceeded the A1 limit under 10 records in the X direction and 7 records in the Y direction, while PI-2D exceeded the limit under 7 records in both directions. BF and FI exceeded the limit only in a few cases. This difference shows that an uneven infill arrangement can increase torsional response even when it reduces overall displacement and drift.
- The infilled models generally developed higher base shear forces than BF. The increase varied with the model, direction, and moment-magnitude group and reached

50.4% in the examined cases. Thus, the reduction in lateral deformation associated with the added infill stiffness was accompanied by an increase in base shear demand.

Overall, masonry infill walls affected several aspects of the structural response. Their presence increased stiffness and reduced lateral deformation, whereas their distribution played an important role in the development of irregularities, particularly torsional irregularity. For this reason, masonry infills should not be represented only as additional gravity loads when their influence on the seismic response of RC frame buildings is being evaluated.

The conclusions presented here are limited to the structural configurations and ground-motion records considered in this study.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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