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Effect of infill walls on limit states in reinforced-concrete frames

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ABSTRACT

In this study, the infill wall effect was investigated for a reinforced-concrete frame consisting of three different openings. Five different structural models have been created such as completely filled, gap in the corner, double gap and completely bare on the ground floor. The results of static pushover analysis and eigenvalue analysis, which were made by considering only the absence of infill wall as a variable, were compared. The target displacement for performance levels, period, base shear force, elastic and effective section stiffness's were obtained separately for each structural model. The study revealed once again that the amount of infill wall contributes significantly to the seismic capacity of the building.

Introduction

Infill walls are widely used in buildings to fill frame gaps or to separate residences [1]. In the current design of such structures, in most cases only the weight of the infill walls is taken into account and other strength parameters are ignored. The structural behavior of such frames is highly dependent on the dynamic properties of the respective laterally and vertically loaded infill walls, such as stiffness, bearing capacity, period and damping level [2-3]. It has been determined by experimental studies that the values obtained as a result of the calculations will not reflect the truth in cases where the infill walls are not placed appropriately and consciously and are not taken into account [4]. In the literature, the effect of the infill wall was investigated on different parameters by both experimental and numerical modeling. The capacity curves of infill walls, floor horizontal displacements, relative floor offsets, maximum plastic rotations in floors and the distribution of plasticized sections in the system in regular reinforced concrete structures were compared by [5]. In the study conducted by [6], the effects of the infill wall change on the capacity curve of the building, the first natural period, the target displacement request, the damage distribution of the first-floor columns, and the building performance level in residential type reinforced concrete buildings with different openings and number of floors were investigated. In a study by Paripour et al. [7] investigated the effect of infill walls on the risk of progressive collapse in reinforced-concrete (RC) frames. In this and similar studies, the positive contributions of the infill walls used in reinforced concrete structures to the earthquake behavior of the building have been revealed.

Within the scope of this study, the infill wall effect for a reinforced-concrete frame consisting of three different openings was tried to be revealed by static pushover and eigenvalue analysis on five different structural models. For each structural model, period, seismic capacity, elastic stiffness value and target displacement values for structural performance were obtained separately.

Material and Method

The limit states that given in Eurocode-8 (Part 3) (EN 1998-3) [8] were taken into consideration for damage estimation used worldwide in the structural analysis. These are near collapse (NC), significant damage (SD) and damage limitation (DL). These damage limit states were calculated for all the structural models, respectively. These limit states were given in Table 1.

Table 7. Limit states in Eurocode 8 (Part 3) (EN 1998-3) [8]

Limit State	Description	Return Period (year)	Probability of exceedance (in 50 years)
Limit state of damage limitation (DL)	Only lightly damaged, damage to non-structural components economically repairable	225	0.20
Limit state of significant damage (SD)	Significantly damaged, some residual strength and stiffness, non-structural components damaged, uneconomic to repair	475	0.10
Limit state of near collapse (NC)	Heavily damaged, very low residual strength & stiffness, large permanent drift but still standing	2475	0.02

The reference structural model and applied loads are shown in Figure 1. C25-S420 was taken into consideration for all RC buildings model. While the columns were chosen as 40*40 cm, the beams were taken into account as 25*50 cm.

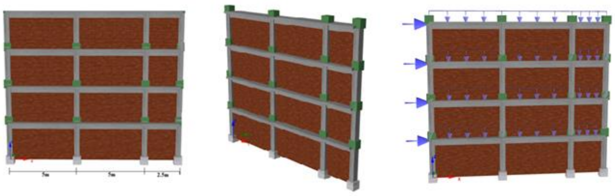

Figure 1. The reference structural model and applied loads

Other structural models considered in this study are shown in Figure 2. The reference building was rated as Model 1. Structural models are shown in Figure 2. The target displacement was chosen as 0.10 m for comparison in all structural models.

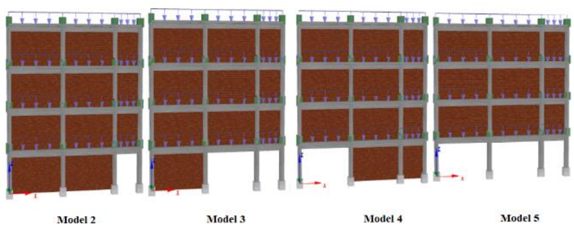

Figure 2. The structural models that used in this study

Results

The natural vibration period of buildings is an important parameter under seismic evaluation. The equivalent seismic lateral force is determined from a design spectrum which is a function of the fundamental vibration period of a building in the static design method [9-10]. The comparison of periods was given in Table 2 for all structural models. The comparison of base shear, elastic/effective stiffness's and target displacements for limit states for all structural models were given in Table 3.

Table 2. Comparison of periods for all structural models

Mode	Model 1	Model 2	Model 3	Model 4	Model 5
1	0.199634	0.208785	0.225426	0.228301	0.308856
2	0.069151	0.071214	0.074129	0.074455	0.08129
3	0.06244	0.062441	0.062452	0.062463	0.062476
4	0.05144	0.051469	0.051482	0.051442	0.051485
5	0.047596	0.047619	0.047668	0.047647	0.047815
6	0.044667	0.045209	0.045829	0.045872	0.046776
7	0.036328	0.036436	0.036547	0.036534	0.036694
8	0.033518	0.033533	0.033536	0.033521	0.033539
9	0.022823	0.022823	0.022827	0.02283	0.022834
10	0.022244	0.022293	0.022336	0.022369	0.022555

Table 3. Comparison of structural analysis

Model	Base Shear (kN)	Kelas (kN/m)	Keff (kN/m)	DL (m)	SD (m)	NC (m)
Model 1	913.61	193954.2	130170.6	0.003017	0.00387	0.009665
Model 2	881.71	173653.5	117333.4	0.003435	0.004406	0.010996
Model 3	554.87	145838.0	88925.6	0.004605	0.007061	0.015233
Model 4	524.43	143538.4	87404.39	0.007618	0.01079	0.021345
Model 5	396.36	62842.24	44267.62	0.014845	0.019238	0.033857

As the amount of infill wall decreased, the period value became higher. The lowest seismic capacity was obtained for the bare frame model. While the smallest values were obtained for Model 1 with a fully infill wall, the largest values were obtained for Model 5, which is a bare frame model.

Discussion

In most cases, only the weight of the infill walls is taken into account and other strength parameters are ignored. The investigation of the effect of type of infill wall material, the use of infill walls at different openings and heights, or the examination of the effects of door and window gaps will also be beneficial.

Conclusion

The results show once again that infill walls make very important contributions to the seismic behavior of reinforced concrete frames. Therefore, it is clear that considering the effect of infill walls in the calculations will allow the structural analyzes to be more realistic.

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Author contributions:

Ercan Işık: Conceptualization, Methodology, Software **Mehmet Cihan Aydın:** Data curation, Writing-Original draft preparation, Validation. **Ali Emre Ulu:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest:

The authors declare no conflicts of interest.

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