THE EFFECT OF MASONRY INFILLS ON SEISMIC RESPONSE OF RC STRUCTURES

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In recent years, a couple of studies have been conducted in the field of seismic rehabilitation and strengthening of buildings (Ozden et al., 2011; Akın and Ozcebe, 2013; Akın et al., 2014). The results prove that masonry infill panels alter the response of reinforced concrete frame structures in terms of stiffness, strength and ductility (Cavaleri et al., 2014). Moreover, infill panels can cause significant changes in dynamic properties of the structure such as period, ductility, and seismic performance factor. The question of whether or not these changes are considered as beneficial is usually dependent on the distribution of infill panels in plan and elevation. A regular distribution of infill panels generally indicates, especially for non-seismic designed buildings, a beneficial effect, increasing global bearing capacity and stiffness under lateral actions. On the other hand, irregular distributions of panels may be dangerous, often being the cause of additional torsional effects, in the case of planar irregularities, and of soft-story mechanisms in the case of elevation irregularities (Cavaleri and Trapani, 2014). Various methods have been developed for finite element modeling of infill panels, in order to determine the actual strength and stiffness of the structures. A particularly effective and widespread approach for representing the combined response of the frame and the masonry infill panels under the seismic actions is the use of equivalent diagonal struts (Saneinejad and Hobbs, 1995). According to previous studies, the initial stiffness of frames can be calculated by using this methodology with reasonable accuracy.

The present study examines the impact of infill panels on seismic response of RC frame structures. For this purpose, several low- and mid-rise RC frames (two-, four-, seven-, and ten-story) were numerically investigated. The models consist of four reinforced concrete frames with two, four, seven, and ten stories, and with the average story height of 3.2 meters. Gravity and seismic loads were assigned to the frames according to the criteria in the 6th section of the Iranian National Building Code and the Iranian Code of Practice for Seismic Resistant Design of Buildings. Moreover, the buildings were considered as ordinary buildings with residential occupancy, and are supposed to be built in a site with conditions matching ground type II. The construction site is also located in a region of high seismicity (Design Base Acceleration Ratio=0.35). In order to include the effect of infill panels' stiffness in the structural model, an equivalent compressive strut according to the Iranian Guideline for Seismic Rehabilitation of Existing Structures was used. Besides, the modulus of elasticity and thicknesses for the equivalent strut and the infill panel were considered identical. The inplane stiffness of the uncracked masonry infill panel was estimated through equation (1), by the use of equivalent compressive diagonal strut model. It should be noted that in current study the effective width of equivalent struts was calculated considering the changes in the infill panel material strength, bay length, and stiffness of columns adjacent to the infill panels. The models were then subjected to several nonlinear incremental static as well as dynamic analyses for a range of earthquakes. As indicated in Table 1, the results of analyses showed that the use of reinforced masonry infill panels in RC frame structures can have beneficial effects on structural performance. It was confirmed that the use of masonry infill panels results in an increment in strength and stiffness of the framed buildings, followed by a reduction in displacement demand for the structural systems.

$$W = 0.254[\lambda h]^{-0.4} d,\ \lambda = \left[10 E_i t \sin 2\theta / E_f I_{col} h\right] \quad (1)$$

It should be noted that in the equation (1), "h" represents the height of the infill panel, "d" is the length of the equivalent strut, "I_{col}" is the moment of inertia for the column, and "t" represents the thickness of the infill panel and the equivalent diagonal strut. Moreover, "E_f" and "E_i" stand for the modulus of elasticity for the frame and infill panel materials, respectively.

Table 1. Capacity and displacement ratios of the infilled frames to corresponding bare frames

incremental dynamic analysis:	capacity ratio		relative displacement ratio
	linear range	nonlinear range	
two-story frames	1.7	1.4	0.6
four-story frames	1.5	1.3	0.5
seven-story frames	1.7	1.25	0.65
ten-story frames	1.5	1.2	0.8
nonlinear static analyses:	capacity ratio		relative displacement ratio
	linear range	nonlinear range	
two-story frames	1.6	1.4	0.9
four-story frames	1.4	1.3	0.5
seven-story frames	1.5	1.35	0.45
ten-story frames	1.5	1.3	0.3

It is also worth mentioning that infill panels have a more positive influence on strength and stiffness of the structures in two, four, and seven-story frames compared to the ten story frame. This shows that the use of infill panels in low-rise RC frame structures is an effective way of improving structural performance during earthquakes, because of the fact that stiffness is a crucially important characteristic of low-rise earthquake resistant buildings.

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