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EFFECT OF INFILLS ON TORSION AND SOFT STOREY IN A CONVENTIONAL RESIDENTIAL BUILDING IN TEHRAN-IRAN

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Nowadays structural engineers usually consider masonry infill walls as non-structural elements during analysis and design process of buildings (Rodrigues et al., 2010; Noorifard et al., 2014) and only calculate their weight. Consequently, analysis and design of the structures is based on the bare frames (Noorifardet al., 2014), But experiences of past earthquakes show that some designed and constructed buildings by engineers have been damaged during earthquakes because of disregarding the negative effects of walls (Rodrigues et al., 2010). Structures with simple and regular geometry performwell during earthquakes, while in many cases, despite designing regular structure, asymmetrical infill walls cause irregularity in plan and discontinuous infill walls in elevation cause irregularity in height (Tabeshpour et al., 2012). Unfortunately these irregular buildings constitute a large portion of the modern urban buildings (Dubey and Sangamnerkar, 2011). The main goal of this paper is to evaluate the amount of detrimental effects of infill walls in conventional buildings. Since theprobability of torsion in the buildings located in corner or northern urban lots due to urban regulation, natural light, solid and perforated walls layout are high, a 5-storey residential building in a south lot in Tehran has been selected as a case study (Figure 1).

For studying the effects of infill walls in seismic behaviour of structures, simulations were performed by a structural analysis and design software for two cases, with and without walls to compare construction condition with design condition. In order to adapt to the characteristics of conventional buildings, structural system is reinforced concrete intermediate moment resisting frame, peripheral walls are hollow block with a thickness of 20 cm and interior walls are hollow block with a thickness of 10 cm. Analysis has been done by linear static method. As it is tried to study detrimental overall effects of walls such as torsion and soft storey, so simulation is based on macro model. In this method infill walls are modelled with an equivalent compression diagonal strut.Yung's modulus assumed 800 times of compressive strength of wall, the effective width of equivalent strut assumed 0.2 times of wall diameter (Tabeshpour et al., 2012) and strut assumed the same thickness as wall. Based on performed experiences, the compressive strength of wall with hollow block and cement mortar is 39 kg/cm^2 (Shahnazari, 1998). For considering the effect of opening on strength and stiffness of walls, equation recommended by the New Zealand Society for Earthquake Engineering, has been used (NZSEE, 2006).

Three criteria included occurrence of torsion in first or second mode of modal analysis, the distance between center of mass and center of rigidity greater than 10% of building length at the same direction (NBC 1994) and the ratio of the maximum relative storey drift at any storey to the average relative storey drift at the same storey in the same direction greater than 1.2 (ASCE 7-02, 2003; Standard No. 2800-05, 2005) are used to evaluate torsion. Two criteria included the lateral stiffness of each story less than 70% of that in the storey above or 80% of the average stiffness of the three stories above are used to evaluate soft storey (ASCE 7-02, 2003; Standard No 2800-05, 2005).

According to the results of simulation, building in construction condition contrary of design condition has a risk of torsion because torsion occurs at second mode of modal analysis (Table 1, Figure 2) and the distance between CM and CR along Y axis is greater than 10% of building length. The results of calculations presented in Table 2 shows there is no soft storey neither in construction condition nor in design condition. Thus, contrary to the initial impression that there is a soft storey in urban buildings because of parking and open spaces on ground floor, in buildings with architectural design similar to the analyzed sample, due to the high stiffness ratioof the structure on ground floor to the upper floors, soft storey would not happen with a high safety factor.

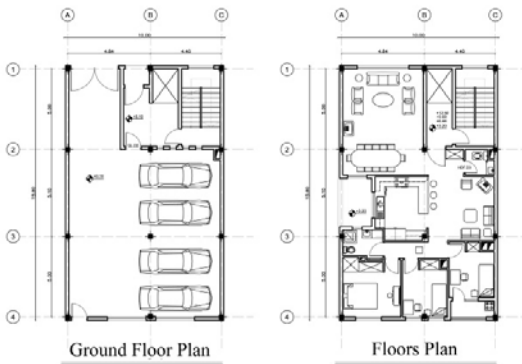

Figure 1. Architectural Plans

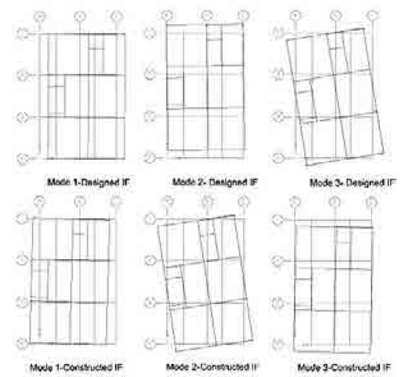

Figure 2. The first three modes of modal analysis

Table 1. The fundamental vibration periods of building in first three modes of modal analysis

	Mode 1				**Mode 2**				**Mode 3**			
	Period	Dir.	UX	UY	Period	Dir.	UX	UY	Period	Dir.	UX	UY
Designed IF	1.015	X	73.75	0.002	0.965	Y	0.008	73.43	0.823	T	0.188	1.044
Constructed IF	0.890	X	74.93	0.000	0.620	T	1.360	3.372	0.589	Y	0.049	77.04

Table 2. The ratio of storey stiffness at two directions for controlling soft storey

Unit: kgf, m	STOREY 1					
	K_X	K_{x1}/K_{x2}	$K_{x1}/((K_{x2}+K_{x3}+K_{x4})/3)$	K_y	K_{y1}/K_{y2}	$K_{y1}/((K_{y2}+K_{y3}+K_{y4})/3)$
Designed IF	122951	1.76	2.41	126404	1.76	2.34
Constructed IF	151515	1.62	2.07	312500	1.34	1.56
Unit: kgf, m	STOREY 2					
	K_X	K_{x2}/K_{x3}	$K_{x2}/((K_{x3}+K_{x4}+K_{x5})/3)$	K_y	K_{y2}/K_{y3}	$K_{y2}/((K_{y3}+K_{y4}+K_{y5})/3)$
Designed IF	69876	1.54	1.84	71885	1.47	1.72
Constructed IF	93555	1.40	1.58	233161	1.23	1.30

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