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Investigation of Behavior of Steel Bar Joints between Reinforced Masonry Wall and RC Slab

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ABSTRACT

Reinforced masonry buildings are technically and economically suitable options for earthquake-prone countries. Inadequate connections between the components of these structures cause damage and destruction in an earthquake. Percentage and connection type between wall and concrete slab are the most effective parameters on safety of these buildings. In this article a model for the seismic behavior of reinforced masonry (RM) building subjected to push-over analysis has been presented. The modeling of the RM structure with concrete slabs has done in ABAQUS, using explicit finite element model. The proposed finite element model has been verified by comparison with experimental data available in the literature and then five models including one, two and four story buildings in different situations have been modeled. Bending length, distance and diameter of joint bars between the walls and concrete slab have been investigated and some recommendations in this field have been presented.

KEYWORDS:

Reinforced Masonry Structure, Concrete Slab, Push over Analysis, Shear Force, Joint Bar

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1- Introduction

Masonry is the building of structures from individual units laid in and bound together by mortar. Due to the availability and low cost of masonry materials, these types of structures consist of large percentage of existing buildings. Unreinforced masonry (URM) bearing wall buildings have shown poor performance in past earthquakes (Fig. 1) [1].

After the 1933 Long Beach earthquake, building codes changed prohibiting unreinforced masonry buildings and few have been built since then; however, there are URM buildings that remain which fall into three categories: 1) fully retrofitted, 2) partially retrofitted and 3) not retrofitted [2].

Modeling of masonry structures under static and dynamic loads compared with experimental studies has low cost [3], but must be considered that these models provide accurate results when the components and interactions between them and the forces applied to the modeling has done accurately [4]. For accurate modeling of masonry structures finite element (FE) analysis in micro-scale because of comprehensive and coverage of the complexities of modeling is the best choice. Based on these assumptions to analyze the masonry structures, micro and macro modeling methods are examined [5,6].

Fig. 1. URM collapse, Long Beach, California 1933 [1]

Porter and Braun (1997) have studied the strength characteristics of bed joint reinforcement in masonry walls; have concluded that bed joint reinforcement can serve to RM walls as long as sufficiently large areas of horizontal reinforcement as provided [7]. Lourenco (1994) have studied on masonry walls using micro modeling, he suggested using homogenization of masonry by a micromechanical model decreases computational cost [8]. The specimens were modeled at a semi-detailed level (the so-called micro-modeling strategy) using finite element method. This implies that the joint is modeled as an interface with zero thickness (Fig. 2) [9].

2- Methodology

The proposed finite element model has been verified by comparison with experimental data available in the literature [11]. The wall specimen W1 was analyzed and its geometric and mechanic characteristics are given in Fig. 3 and Table 1.

Fig. 4 illustrate the comparison between the load–displacement diagrams of the experimented specimen, and that of the numerical analysis, up to a deformation in which the failure mechanism is formed. The agreement between experimental and numerical responses is satisfactory with a maximum error of 8%.

3- Results and discussion

Five models including one, two and four story buildings in different situations have been modeled. Bend steel bar length, distance and diameter of joint bars between the walls and concrete slabs have been investigated. Table 2 summarizes the characteristics of each specimen.

The models has selected to be in various places with different seismic risk to determine the best percentage of reinforcement steel including bend

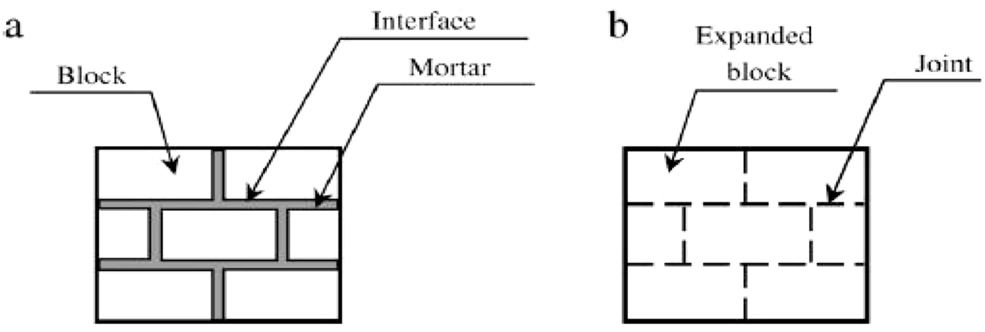
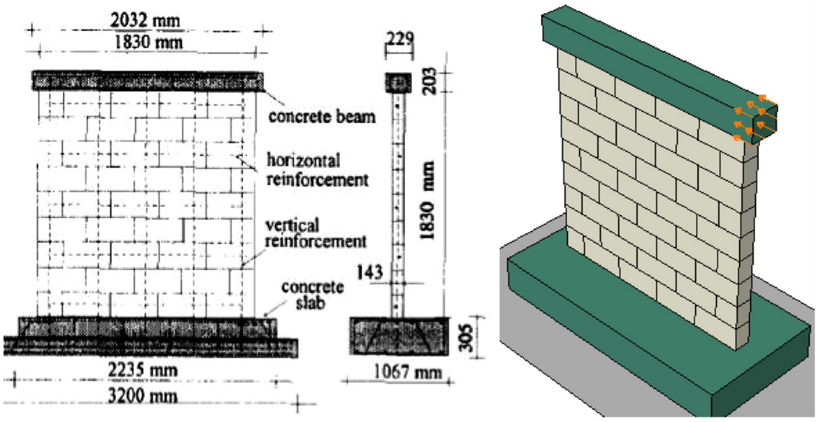


Fig. 2. Micro-modeling strategies for masonry walls: (a) detailed and (b) semi-detailed [10]



(a) **(b)**

Fig. 3. a) W1 masonry wall [11] and b) ABAQUS model

Table 1. Material parameters of CDP model for masonry

Material's parameter	Masonry	The parameters of CDP	
		β	38
Concrete elasticity		m	1
E [Gpa]	20	$F = f_{b_0}/f_c$	1.12
υ	0.2	γ	0.666
Concrete compression hardening		Concrete compression damage	
5.898	0	0	0
7.941777	7.47307E-05	0	7.47307E-05
11.79624	9.88479E-05	0	9.88479E-05
15.84745	0.000154123	0	0.000154123
19.66302	0.000761538	0	0.000761538
15.82083	0.002557559	0.195402	0.002557559
7.956831	0.005675431	0.596382	0.005675431
2.067271	0.011733119	0.894865	0.011733119
Concrete tension hardening		Concrete tension damage	
Stress [MPa]	Cracking strain [-]	Damage T [-]	Crushing strain [-]
1.99893	0	0	0
2.842	0.00003333	0	0.00003333
1.86981	0.000160427	0.406411	0.000160427
0.862723	0.000279763	0.69638	0.000279763
0.226254	0.000684593	0.920389	0.000684593
0.056576	0.00108673	0.980093	0.00108673

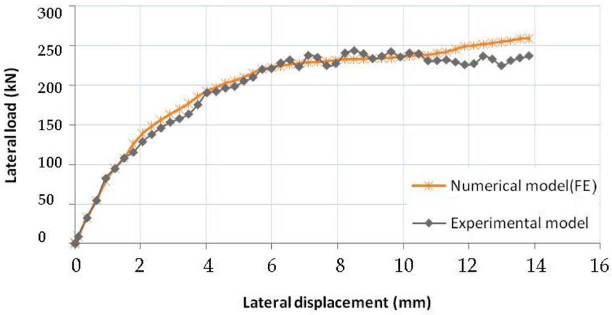


Fig. 4. Comparison between the experimented specimen and the numerical analysis

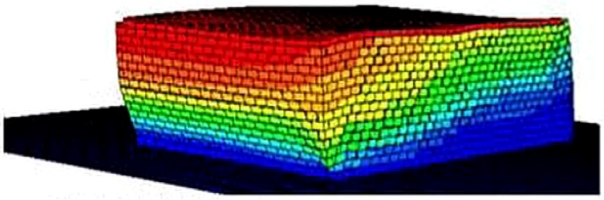


Fig. 5. Deformation form of model No. 3 (The red section of figure shows the most displacement of the wall and the blue section shows the less displacement of it)

steel bar length, distance and diameter of joint bars between the walls and concrete slabs. According to FEMA-302 for masonry structures the design story drift, does not exceed the allowable story drift, 0.7% [12]. As Fig. 5 shows the collapse of RM buildings happens in diagonal direction due to weak shear strength of grout between blocks which in this article modeled as interface. By studying all models for different places, suggested values for ρ and D is shown in Table 3.

4- Conclusions

In the models which are studied in this research, cracking occurred in tensile corner and crack propagation is diagonal. Numerical simulation has proved to be a convenient powerful tool for homogenization of masonry material, and should be regarded as the effective complementary tool to laboratory tests. Bend length and ρ for places with low and normal earthquake factor are less than values said in [12,13]. So for this places it's proper to use values in these references (minimum bend length (D)=36d and ρ=0.0007). For places with normal and high earthquake factor, ρ is more than values said in [12,13], also obtained values for bend length for these places is nearby what've been said in references [12] and [13].

5- References

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Table 2. Description of the selected models to be studied

	Storey	Dimension (m)	Slab thickness (m)	Seismic risk
No. 1	1	6×8×3	0.15	Low, Normal
No. 2	1	12×8×3	0.15	Low, Normal
No. 3	1	12×15×3	0.2	Low, Normal
No. 4	2	12×15×3	0.2	Normal, High
No. 5	4	12×15×3	0.2	Normal, High

Table 3. The proposed model

	Proposed bend length and ρ for different places		
	Low earthquake factor	Normal earthquake factor	High earthquake factor
Bend length	30-36 d	40 d	45 d
ρ	0.07	0.08	0.09

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