RELIABILITY ANALYSIS ON REINFORCED MASONRY BUILDING AGAINST EARTHQUAKE HAZARD WITH SHAKING TABLE TESTS

Vahid RAHIMI
M.Sc. Student of Earthquake Engineering, Civil Engineering Faculty, Semnan University, Semnan, Iran
v.rahimi@students.semnan.ac.ir

Mohammad Iman KHODAKARAMI
Assistant Professor of Earthquake Engineering, Civil Engineering Faculty, Semnan University, Semnan, Iran
Khodakarami@profs.semnan.ac.ir

Keywords: Reliability Analysis, Event Tree, Masonry Building, Fraction Mode, Risk Combination

It is clear unreinforced masonry construction is vulnerable to earthquake hazards. These types of buildings are constructed just for gravitational forces with no consideration of the lateral seismic loads. So, it seems these buildings needs reinforcement to remain in safe mode against lateral loads.

In this paper, a new approach on assessment of the retrofitting methods for the masonry buildings is presented in order to provide an evaluation of the effects of the seismic performance improvement methods on these building performances. For this aim, the results of experimental research used to present a reliability analysis for evaluating the effects of reinforcement methods on the damage state in structure. Experimental tests were done on 9 masonry buildings samples with 1/10 scale (Ersubasi and Korkmaz, 2010). Samples were tested on the shaking table instrument. Affected by dynamic loads on shaking table, fraction mode of samples categorized in to 6 type of damage that is presented in Table 1.

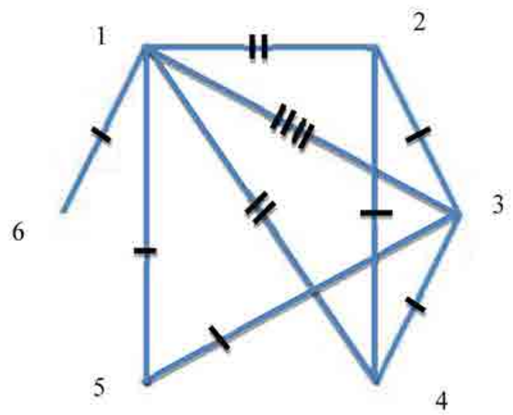
Table 1. Classification of Fraction Mode

Type of Crack	Allotted code
Crack in openings	**1**
Diagonal cracks	**2**
X type cracks	**3**
V type cracks	**4**
Horizontal shear crack	**5**
Separation of roof from structure	**6**

Table 2. Observed cracks in each of reinforced samples

Sample	Reinforcement detail	Observed cracks
Ref Sample	Without reinforcement	**1-2-3-4**
CF1	CFRP strips above the openings	**1-4**
CF2	CFRP horizontal strip above the ground level	**1-3**
CF3	Corner of the structure was covered with strengthening material	**1-3-5**
SWSP	Steel strip on the inner and outer surfaces of the walls	**1-6**
SM	Mesh reinforcement and plaster application over the masonry walls	**1-3**
P1	Horizontal post tensioning was applied and wooden logs were used on the corners of the structure	**5**
P2	Similar to P1 but wooden logs were replaced with shorter wooden pieces	**1**
P3	Horizontal wrapping was applied only at the roof level. The structure was wrapped by steel rods and a box type behavior was obtained	**1-2**

Table 2 introduces the samples reinforced with different techniques has been presented in; in this table, the observed cracks also mentioned in each of samples. As it mentioned in Table 2, various kind of cracks observed in each of the samples. With a focus on crack distribution method in samples, event tree of these tests are defined in Figure 1. The event tree shows combining risk in each of states. Combining risk also shows the average means of damage for each of the samples in given acceleration a_1. In this Figure, the numbers on the apex of sides shows allotted code related to the type of cracks. Each side shows feasibility of synchronism occurrence for two kinds of cracks. Each side demarcate for demonstration the number of synchronism occurrence.



Type of Crack	Occurrence Probability (Damage Pi)		Proportion of Damage (Ci)		Component of risk (Ri)
Crack in openings	$\frac{8}{9}$	×	16.66%	=	14.8%
Diagonal cracks	$\frac{2}{9}$	×	16.66%	=	3.7%
X type cracks	$\frac{4}{9}$	×	16.66%	=	7.4%
V type cracks	$\frac{2}{9}$	×	16.66%	=	3.7%
Horizontal shear crack	$\frac{2}{9}$	×	16.66%	=	3.7%
Separation of roof from structure	$\frac{1}{9}$	×	16.66%	=	1.85%
Mean value of Damage	demonstrate ⟵		Combining risk $\sum R_i$		35.05%

Figure 1. The event tree of this test

With consideration of Table 3 and event tree (Figure1), the effect of reinforcement on damage state of samples was investigated. As it shows in Table 3, P1 and P2 reinforced samples has priority to use because it has a maximum probability of non-occurrence due to lateral seismic loads. This study indicates that post tensioning of masonry walls (P1 and P2) increases the shear and bending capacity providing ductility and also, the cracks at the openings are high-risk component rather than other type of cracks; so, it needs more retrofitting to resist against lateral loads. It seems retrofitting method that used in sample P2, as it shows in Table 3 with priority 1, can resist against cracks at openings and this method has a priority to use for reinforcement. This method is very simple and useful for fast and economic decision making in rural areas against disasters like earthquake and can guide designers to choose an effective method for reinforcement of masonry buildings.

Table 3. Effect of reinforcement on damage state

Sample	Observed cracks	Non-observed cracks	Probability of non-occurrence	Priority
Ref. Sample	1-2-3-4	5-6	0.33	**4**
CF1	1-4	2-3-5-6	0.67	**2**
CF2	1-3	2-4-5-6	0.67	**2**
CF3	1-3-5	2-4-6	0.50	**3**
SWSP	1-6	2-3-4-5	0.67	**2**
SM	1-3	2-4-5-6	0.67	**2**
P1	5	1-2-3-4-6	0.83	**1**
P2	1	2-3-4-5-6	0.83	**1**
P3	1-2	3-4-5-6	0.67	**2**

REFERENCES

Ersubasi F and Korkmaz HH (2010) Shaking Table tests on strengthening of masonry structures against earthquake hazard, *Nat. Hazards Earth Syst. Sci.*, 10, 1209–1220

Kalantari A (2012) Seismic risk management structures, how to calculate risk and damage (In Persian), Publications of International Institute of Earthquake and Engineering Seismology, Tehran, Iran