Seismic Evaluation Study of existing reinforced concrete buildings with masonry infill in Jordan

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1. Introduction:

Jordan is located along the seismically active Dead Sea Transform Fault that extends 1000 km from the Red Sea to Turkey. Current estimates predict a major earthquake in the region roughly every 100 years. It is not until 2004 that a seismic code for buildings based on UBC code 1997 was implemented.

Concrete structures are widely used in Jordan. Concrete structures mostly used are structures with masonry infill wall. These masonry walls are sometimes allowed to work as a bearing wall for buildings less than 12 m in height in practice design regulations. This resulted in a large number of low rise buildings with masonry infill are constructed usually as residential and commercial buildings in the main cities.This practice is not based on a structural analysis, but is based on past experiences and practices in surrounding countries. There are no specific limits for length and strength of the masonry wall in the code.

Although seismic hazard in Jordan is identified as being moderate, seismic capacity for existing buildings have not been studied enough. This paper presents the study of eight buildings with different usages, evaluated using the Existing Building Japanese standard[1]

2. Type and characteristics of buildings:

8 buildings are chosen with different usages and floor areas as shown in the table below:

Table 1

Build No.	No. of stories	Floor Area m2	Function of building
1	4+1Basement	150	Residential
2	4 Stories	270	Residential
3	4+1Basement	256	Hotel
4	4 Stories	886	School
5	3 Stories	350	Residential
6	3 Stories	300	Residential
7	1 Story	120	Commercial
8	4+1Basement	420	Residential

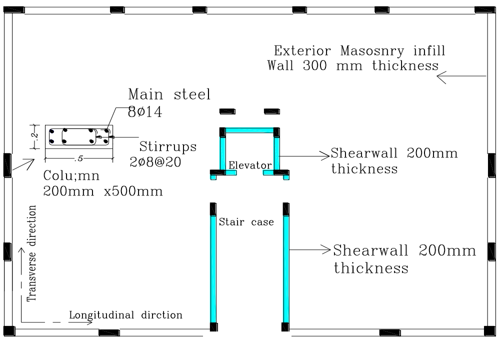

Figure 1

Figure1 show the structural plan for Building No.3. Jordan's typical buildings allocate shearwalls around staircase and elevator case wall, which are usually in the transverse direction as shown in the figure3. Except for buildings No5 and No6 where the staircase shearwalls are located with the longitudinal direction.

Only Building No7 doesn't contain any shear walls, but it is single story building.

The exterior masonry infill used in Jordan buildings is composed of stone facing followed by plain concrete of average compressive strength Fc=15MPa as in figure1, this plain concrete in some cases is followed by hollow concrete blocks as in figure2.

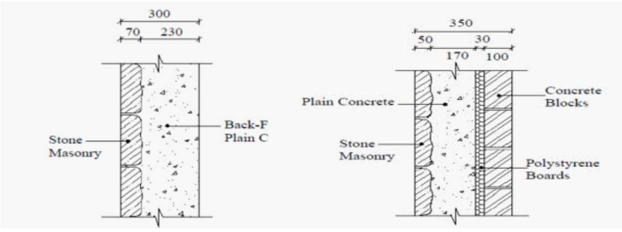

Figure 2

3. Method of Analysis

General concept of the Japanese Seismic Evaluation Standard of Existing Building[1] is as follows. Seismic capacity of a building is expressed by Is-index.:

$I_s = E_o . S_D . T$

I_s=Seismic index representing seismic performance of structure

E_o.=Basic seismic capacity index of structure

S_D= Irregularity index.

T= Time index (Time index in the selected building is 1 since all buildings were built recently)

The strength capacity of masonry infill is not mentioned in the standard. Therefore a capacity using the values proposed by the Chi-Chi Earthquake Report[2] was used.

In that report a value of average shear stress τ = 0.6 N/mm2 for Masonry walls without openings and a value of shear stress τ = 0.2 N/mm2 for walls with openings was employed. Ductility Index F of masonry infill of F=0.8 is assumed. These values are approximate and considerably conservative values judged from previous experiences and experiments.

Second level screening procedures were carried out. Seismic capacity I_s index was calculated for two cases, with and without consideration of contribution of the masonry strength to I_s index. The maximum value from both conditions

ヨルダンの組積造壁を有する鉄筋コンクリート建物の耐震性能の検討

is chosen to be the I_s value of the building in each direction, shown in Table2. The addition of the masonry strength in some cases doesn't give larger I_s value because of lower ductility value F = 0.8.

It should be noted here that the equation $E_o = \sqrt{E_1^2 + E_2^2}$ is used. This equation in this study gave greater values for I_s index when the masonry strength capacity is taken into account.

I_s indices for first story of each building are used in the discussions below because I_s index for first story is generally the lowest in a building.

The selected buildings are then compared with damage survey of school buildings in Japan, after 1995 Kobe Earthquake[3].

4.Results:

Second level evaluation results are shown in the table below:

Table 1

Build No.	Second Screening				
		Longitudinal Direction		Transverse direction	
	S_D	E_o	I_s	E_o	I_s
No.1	1.15	0.35	0.41	0.53	0.61
No.2	1.00	0.26	0.26	0.54	0.54
No.3	1.20	0.31	0.37	0.75	0.90
No.4	0.92	0.47	0.43	0.49	0.45
No.5	0.92	0.47	0.43	0.33	0.30
No.6	1.00	0.70	0.70	0.40	0.40
No.7	1.00	0.82	0.82	0.65	0.65
No.8	1.10	0.50	0.55	0.47	0.52

The comparison between I_{s2} values with and without the masonry strength capacity is shown in figure3. The arrow direction is from I_s index of each building without of consideration masonry strength to Is index with masonry strength capacity added.

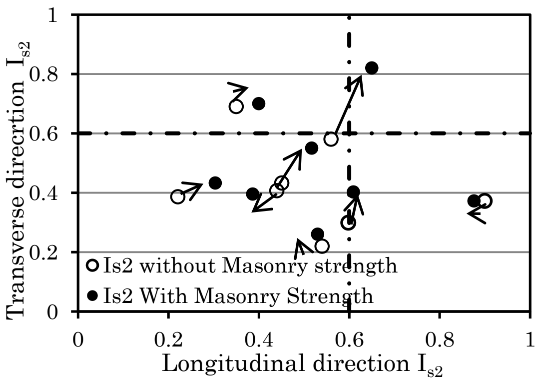

Figure 3

The addition of masonry infill wall capacity increased the strength in most cases especially in the weak direction which doesn't have sufficient shear walls strength capacity. However in some cases the addition of masonry strength has adverse effect and decreased the I_{s2} index as shown in the figure3. This is due to the low ductility value of F =0.8 assumed for the masonry infill wall.

I_s indices in longitudinal and transverse direction is compared in the figure4. In the figure, school buildings damaged due to 1995 Kobe Earthquake, categorized by damage levels, were shown in addition to Jordan buildings.

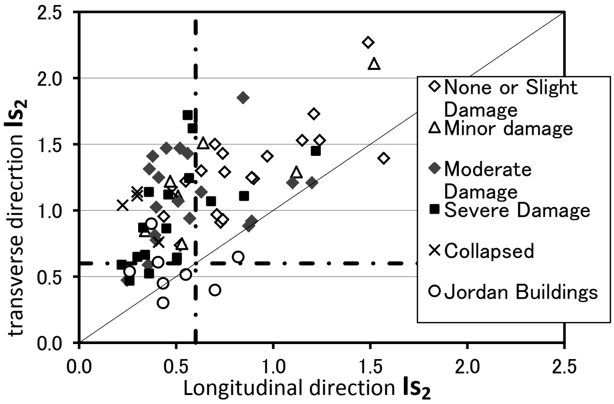

Figure 4

In figure4 I_s index with values of 0.6 or above where considered as a criteria in order to prevent severe damage or collapse. This value is based on past experiences earthquake in Japan.

In the 1995 Kobe Earthquake I_s values of collapsed or severely damaged buildings were lower than 0.6 as shown in Figure4.

5. Discussion and Conclusion:

1. The investigated buildings in Jordan showed low seismic capacity in one direction. This was because shearwalls were usually located only in the staircase or elevator walls as shown in figure1. Staircase is usually positioned with the transverse direction.
2. According to seismic evaluation, almost all the selected building may possibly be severely damaged or collapse if an earthquake similar to 1995 Kobe Earthquake occurred in Jordan.
3. In some cases the addition of masonry strength has adverse effect and decreased the I_{s2} index as shown in the figure because of low ductility of masonry infill wall.

6. References:

1-JBPDA, Standard for Seismic Evaluation of Existing Reinforced concrete Buildings, 2001.
2-AIJ, Report on the Technical Cooperation for Temporary Restoration of Damaged RC School Buildings due to the 1999 Chi-Chi Earthquake.
3- AIJ, Report of damage survey of reinforced concrete buildings due to the 1995 Hyogo-ken Nambu Earthquake.

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