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Deformation capacity of RC frames with unreinforced masonry infill

Keyword:
Reinforced concrete　　Masonry infill
Deformation capacity

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1. Introduction:

Many of the reinforced concrete buildings in developing countries use masonry as partition walls. Structural designer usually assume that the walls are non-structural walls. The influence of masonry infill walls and how it greatly changes the behavior of structure has been studied by many researchers in the past studies. However, the deformation capacity of RC frame with masonry infill is not enough focused on. The objective of this study is to find an approximate way to estimate the drift of the backbone curve of RC frames with masonry infill based on the results of different experiments conducted around the world and identifies the main parameters influencing the deformation capacity. The scope of this study is unreinforced masonry infill without opening which is attached to the surrounding RC frame.

2. Outline of the experiments database:

21 specimens consisted of single span and single story of RC frame with masonry infill under static loading from 7 researchers (from 1~7 in reference) are shown in Table .1. The data are chosen for different types of masonry infill to represent a general case for different masonry types used in the world.

Table .1 Test specimens by different researchers

No	Researcher name	Test specimen name	Masonry type	*fm* (MPa)	R-max %	Ru %	α
1	Mehrabi et al 1996	3	solid bricks	15.1	0.4	1.16	0.22
2		4	hollow bricks	10.6	0.63	1.45	0.25
3		5	solid bricks	13.8	0.79	1.42	0.22
4		6	hollow bricks	10.1	0.61	1.78	0.32
5		7	solid bricks	13.6	0.71	1.04	0.28
6		8	hollow bricks	9.5	0.91	1.82	0.26
7		9	solid bricks	14.2	0.48	1.98	0.21
8		10	hollow bricks	10.6	0.4	1.88	0.25
9		11	solid bricks	11.4	0.74	1.5	0.24
10		12	solid bricks	13.6	0.55	1.02	0.22
11	Maidiawati et al 2013	IF-FB	brick with plaster	2.9	0.5	1.6	0.32
12		IF-SBw/FM	brick	16.3	0.5	1	0.24
13		IF_SB	brick with plaster	18.5	0.45	0.5	0.20
14	Jin et al 2012	IFRB	concrete block	6.7	0.4	1.5	0.46
15		IFFB	concrete block	6.7	0.4	1.5	0.46
16	Ho Choi et al 2015 AIJ	1B-1S-H	concrete block	6.7	1	2	0.32
17		1B-1S-v	concrete block	6.7	1.5	2.8	0.32
18	D. Kakaletsis et al	S	hollow bricks	2.6	0.92	2.3	0.54
19	B. Blackard et al	S	brick * double wythe	19.1	0.25	0.55	0.12
20	Hanan AlNimry et al 2014	IF4	stone and concrete	16.6	0.4	1.1	0.12
21		IF5	stone and concrete	16.6	0.4	0.93	0.12
	Average				**0.62**	**1.47**	
	standard deviation σ				**0.29**	**0.56**	

R-crack, R-max and Ru are the drift angle at cracking point, maximum strength and when strength is degraded to 80% of the peak strength respectively as shown in figure 1.

As for the R-crack, the FEMA 306[8] states that diagonal cracking begins with the onset of nonlinear behaviour at inter-story drifts of 0.25%. Mehrabi et al[1] states based on his experimental studies that first major crack in infill occurred at inter-story drift between 0.17%～0.46%. In other experimental references the R-crack was not clearly stated.

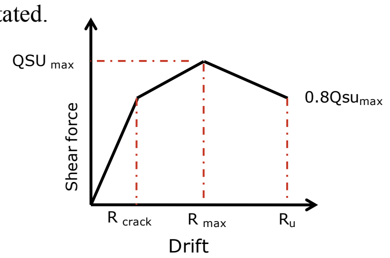

Figure 1. Backbone curve of RC frame with masonry infill

3. Drift (Rmax) at Peak strength

Based on the studied experiments, the Rmax drift has an average of 0.62% and most of values in the range of 0.4%~0.9%. The standard deviation was calculated to be 0.29.

The relationship between the masonry compressive strength fm and Rmax is shown in Figure 2. The weaker the masonry compressive strength, the greater the tendency of having a larger Rmax .

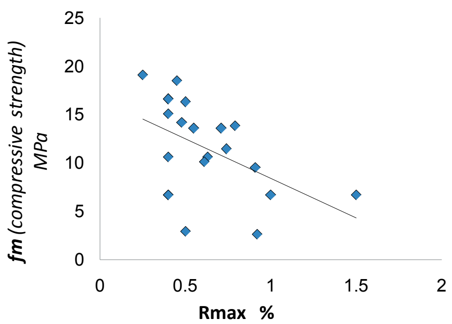

Figure 2 Compressive strength vs. Drift angle Rmax

This is theoretically explainable since the masonry infill forms a compression strut within the RC frame as shown in figure 3. The compression strut depend mainly stress-strain characteristics of masonry infill material. The weaker masonry with low strength mortar has lower elasticity and larger peak strain. However, masonry infill characteristics have large range variations and there are some exceptions as shown in figure 4.

Liauw et al[9] proposed different failure mechanism for masonry infill, In this study only 2 of the mechanisms are presented. Failure Mechanism no.1 is shown in figure 3 where the plastic hinges are developed at both ends of the columns. As for mechanism no.2 hinges are developed near beam to column joints. Mechanism failure no.2 is considered a low ductile failure mode because of corner crushing failure of masonry infill and short column behavior. Taking the summation of moments at point A (figure 3) gives the contact length α as shown in Eq1.

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$$\alpha = \sqrt{\frac{4Mu}{fm.t.h^2}} \qquad \text{Eq.1}$$

in which Mu is the plastic moment of columns, *fm* is compression strength of masonry prism, *t* is the thickness of masonry infill and *h* is height of infill.

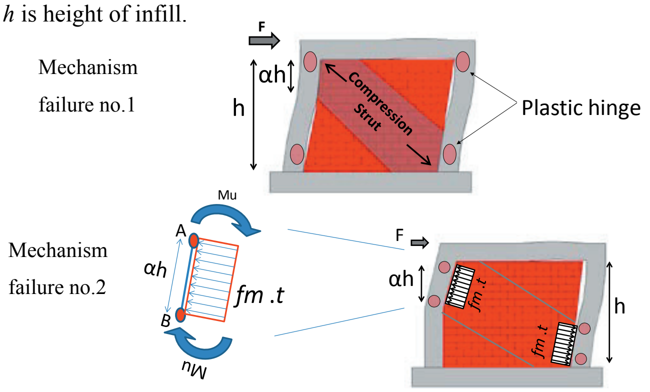

Figure 3 Failure mechanism by Liauw et al

α index also can be used to represent the ratio of frame to infill strength. Based on Liauw et al[9] study, the smaller the α which is the case when we have strong infill and weak frame, the greater the probability of having mechanism failure no.2. In other words, the greater α index represents a stronger frame relative to infill strength which is considered a more ductile failure mode.

The relation between Rmax and α index has large variation.. However, the greater α index the greater the possibility of having higher ductility as shown in figure 4. Even though experiment data are few for α≤ 0.2 , the Rmax is in this case is less than 0.4%. Based on this results, the Rmax can be assumed to be taken as 0.5% or more if α>0.2 .

4. **Deformation (Ru) at 80% of peak strength;**

The Ru (see figure 1) has an average of 1.47% , but a standard deviation of 0.56 which means that values are of a wide range. The relation between Ru and *fm* (compression strength) is shown in figure 5. It is clear the Ru drift is inversely proportional to *fm,* the greater the compression strength the steeper is the degradation slope of the backbone curve.

The relation between α index and Ru are shown in figure 6. The greater α index the greater is Ru drift. This is explainable since larger α index indicates stronger frame which offer more confinement to the infill because inelastic deformations of frame members are reduced.

5. Discussion and Conclusion:

1- It is concluded that *fm* and α index (used in this study to represent the frame to masonry infill strength) are two of the important parameters to estimate the drift angles of backbone curve.

2- Lower *fm* compression strength of masonry infill has greater tendency of increasing the ductility. However, it should be noted that low *fm* compression strength has many negative aspects because it greatly reduces the shear strength, energy dissipation capacity and out of plane strength capacity.

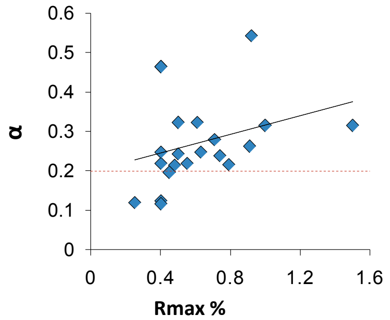

Figure 4. α index vs. Drift angle Rmax.

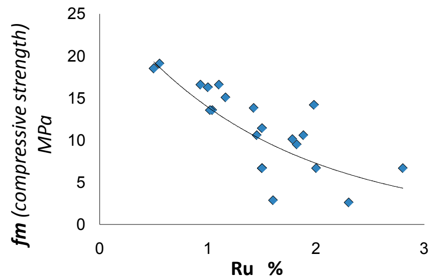

Figure 5. Compressive strength vs. Drift angle Rmax

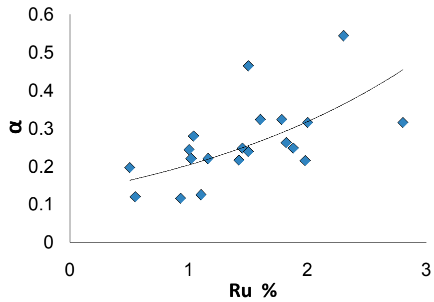

Figure 6. α index vs. Drift angle Ru.

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