Review on the effect of opening on the structural performance of RC wall based on past experiments

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Abstract— **Reinforced concrete (RC) structures are usually infilled with structural or non-structural walls. Considering the functional requirements of buildings, it is impossible to avoid openings in wall. However, opening leads to uncertainty in the seismic response of the wall. Therefore, given the immediate need to address the opening effect, a review study on the past experiments is required for better understanding the effect of opening on wall. One objective of the study is to investigate the effect of different parameters of opening like opening area, opening size, location of opening on the lateral performance of RC wall. Another purpose is to compare the reduction in lateral strength due to opening obtained from past experiments with analytical models found from previous research and available codes.**

I. Introduction

RC walls feature various types of openings for functional requirements of building in form of door, window and lift shaft etc. The seismic response of a structure infilled with perforated wall panels is influenced by different parameters of openings such as opening area, opening aspect ratio, position of opening. Hence it is of great importance to identify the most influencing parameter of opening for future considerations while inserting opening in wall.

The aim of the study is to investigate the effect of various parameters of opening on RC wall and also to compare the lateral strength reduction factors due to opening obtained from past experiments with the available analytical models in order to understand the effectiveness of those models.

II. Study on Past Experiments

All studied test specimens are under lateral reversed cyclic loading and are mainly of one storied regular shaped RC walls with 1 or 2 openings. The details are given below.

A. *Ono & Tokuhiro, 1992*

The effects of different size and location of opening investigated in this study are illustrated in Fig. 1 & 2 Compression field area (A_e) proposed in this study was based on compression strut formed at 45^0 angle near corner opening due to lateral loading as shown in Fig.1a [1].

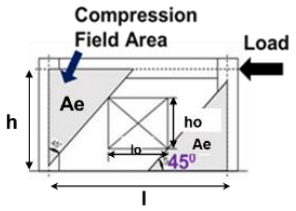

Fig.1(a) Compression field area

*Ae- Compression field area; *h, l* -height, length of wall respectively; *ho, lo* -height, length of opening respectively; **Strength reduction factor,

$$r = \sqrt{\frac{\Sigma A_e}{hl}} \qquad (1)$$

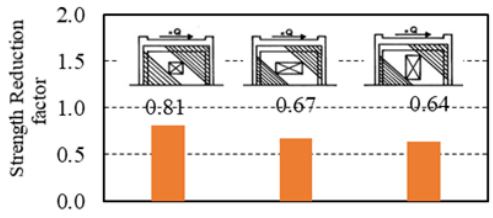

Fig.1(b) Effect of Opening size

[h_o=l_o=370mm (Left), h_o=370mm, l_o=670mm (Middle); h_o=67mm0, l_o=370mm (Right)]

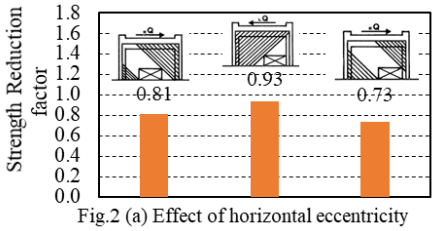

Fig.2 (a) Effect of horizontal eccentricity

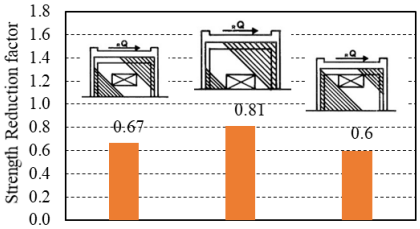

Fig. 2(b) Effect of vertical eccentricity of opening (ho=370mm, lo=670mm)

It is noticed from Fig.1b, lateral strength varied much with opening area than aspect ratio. According to this study, when opening goes near the loading edge of the wall, the strength increases as compared to center location as shown in Fig.2b. In contrast, the strength decreases when the opening goes toward the opposite wall edge of loading. It is also observed from Fig.2b that lateral strength of wall tends to decrease when the opening goes toward the top edge of wall while compared with center opening. In contrast, this strength increases when the opening goes toward the bottom location of the wall. The reason behind this might be the variation in the compression field area (see Fig.1a).

B. *Massone et al, 2019*

Massone et al [2] performed tests on RC slender walls with the variation in width and length of door opening. The variation in lateral strength and stiffness was found very small compared to solid specimen. That is because the test specimens failed in flexure and thus only the bars in tension edge and concrete in compression edge governed the strength.

C. *Hosseini et al, 2019*

In this study [5], a cut out door opening with different horizontal eccentricity of opening had been investigated. For 6% and 12.5% horizontal eccentricity of opening, lateral strength varied a little for both push & pull load (see Fig.3).

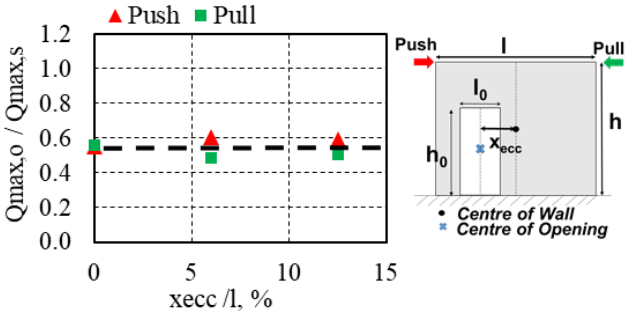

Fig. 3- Effect of horizontal eccentricity of door opening on push-pull load (***xecc***-Horizontal distance of opening centre to wall centre; ***Qmax,s, Qmax,o*** -lateral strength of solid wall & wall with opening respectively)

D. *Lin & Kuo, 1988*

In the study [3] the effect of additional reinforcement around opening was investigated on specimens with same opening size but different reinforcing pattern around opening. Specimen with vertical & horizontal reinforcement had a 15% reduction in lateral strength while a 25% reduction in strength was observed for specimen with diagonal reinforcement when compared to solid wall.

III. Effect of Different Parameters of Opening

A. *Effect of Opening Length, Width*

Fig.4 presents the effect of maximum value between opening length and opening height ratio on the lateral capacity of RC wall from past research studies. It is also observed from Fig.4. that the influence of opening length or height alone is not well correlated to the reduction for wall capacity.

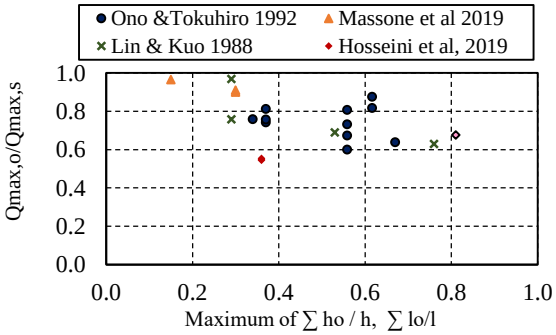

Fig.4- Effect of opening length & opening width

B. *Effect of Opening area*

Fig.5 illustrates the effect of opening area ratio (A_o/A_w) on the strength reduction factor. A_o, A_w indicate opening area and wall area respectively.

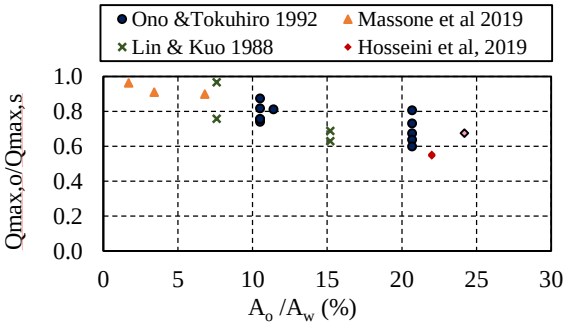

Fig.5- Effect of opening area on lateral strength of wall

From Fig.5, it can be said that opening area considering both opening length and height has more significant influence on the strength reduction factor.

IV. Verification of Experimental Results

Shear strength reduction factor of RC wall due to opening was developed by AIJ (2010) which is shown in Eq (2) [6].

$$r = minimum\ of\ \{r_1, r_2, r_3\} \qquad (2)$$

$$r_1 = 1\text{-}1.1\left(\frac{\sum l_o}{l}\right);\ r_2 = 1\text{-}1.1\sqrt{\frac{\sum h_0\, l_o}{h\, l}};\ r3 = 1\text{-}0.5\left(1+\frac{l_o}{l}\right)\frac{h_0}{h}$$

Fig.6 illustrates the comparison of lateral strength reduction factors obtained from past experimental results with those calculated from analytical formulas using Eq. 1 & 2 (Ono & Tokuhiro and AIJ respectively). From Fig.6, it is observed that Ono and Tokuhiro method showed a better correlation in these investigated tests.

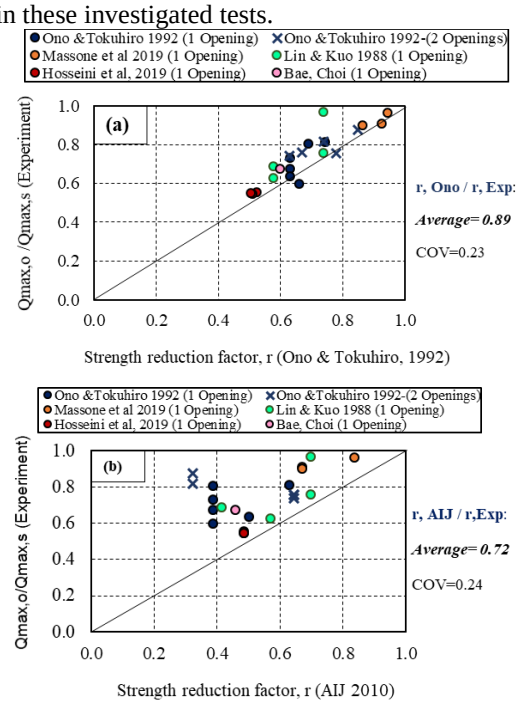

Fig.6- Comparison of reduction factor between experiment and analytical formulas by (a) Ono &Tokuhiro [1] (b) AIJ [6]

V. CONCLUSION

The observations from the review study are given below-

- Opening area has great influence on the lateral strength. of RC wall. A decreasing trend of lateral strength was observed with increase in opening area.
- Small eccentricity of opening (12%) studied by Hosseini *et al.* effects less on the lateral strength whereas large eccentricity (22%) significantly effects the strength from Ono & Tokuhiro's study.
- Lateral strength reduction method by Ono & Tokuhiro exhibits close values to the experimental results when compared to AIJ guideline.

References

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