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Concrete Structural Wall with Cut-Out Openings: A Parametric Study

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Abstract – Concrete structural wall is gaining importance with increase in the construction of reinforced concrete buildings and are considered to be a good axial compressive load carrying member. The advancement in the field of tilt-up construction and pre-stressed construction made the concrete structural member an importance structural element. Many researches are going on concrete structural centrally reinforced wall in single layer. In this paper, the work is done to study the influence of change in the dimensions of opening as openings are source of weakness and depending on its size and orientation influence adversely the load carrying capacity of the member. Parametric study is conducted for this and the results obtained are presented. The study shows that in typical practical wall the incremental increase in deformation when % in opening area cut increased from 15 to 20 is 1.5 times the incremental increase in deformation when % in opening area cut increased from 10 to 15. The study also reveals that side restrain can increase the load carrying capacity considerably.

Index Terms— Concrete structural wall, cut-out opening, OW wall panels, TW wall panels, parametric study, % area of opening, side restraint.

1 Introduction

THE concrete walls reinforced in both direction, horizontal and vertical, in single layer centrally are now a days, accepted as good axial load carrying compressive member. The acceptance of the concrete wall as structural compressive element is increasing due increase in tilt-up constructions and pre-stressed constructions. Understanding this, many researches are done on concrete structural walls and concrete walls are defined as one-way (OW) action walls (panels restrained only along their top and bottom edges than two way (TW) action panels (walls or panels restrained along three or four sides).

Openings need to be cut in old building to meet the need of current living standards or / and legislations. And in newly constructed buildings openings are provided due to a change in purpose of the constructed buildings. These cut outs considerably decease the strength of the member. This make it necessary to understand the influence of opening configuration on the strength of member.

This paper is the result of a continuation of analytical study conducted on concrete structural walls. In this work, a parametric study is carried out to have thorough knowledge of influence of opening. Figure 1 shows the general behaviour expected of OW and TW walls with opening under loading with opening.

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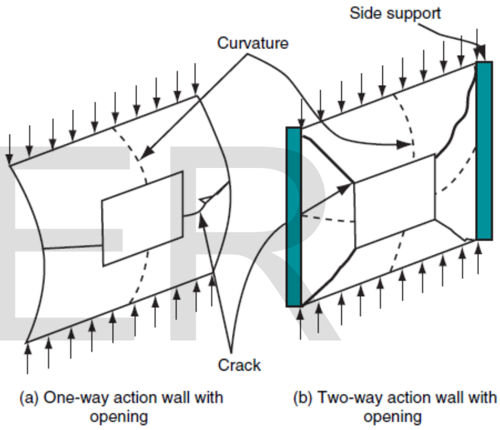

Fig 1. Walls with and without side supports (Doh and Fragomeni 2006)

2. Concrete Structural Wall with Opening: Parameters that Influences the Strength

Openings are source of weakness and depending on their size and orientation, openings influences adversely the load carrying capacity of the member. So before cutting the opening, the influence of increasing the length and height of opening should be thoroughly understood. Following parameters influences the load carrying capacity of concrete structural wall.

2.1 Slenderness Ratio

The load carrying capacity of structural concrete walls depends on its slenderness ratio. Their design is similar to the design of design of masonry walls and is lesser of the following two ratios:

(a) Ratio of effective height along vertical direction and thickness = He/t

(b) Ratio of effective length along the horizontal direction and thickness = Le/t.

Where He is the effective height and t the thickness and

Effective length of plain walls is Le.

As per IS 456, when the slenderness ratio is equal to or more than 12, walls are considered slender. And according to BS 8110, walls are slender when this ratio exceeds 15 for a braced wall and 10 for unbraced wall. Slender walls will have a lower ultimate strength. Influence of slenderness ratio is predominant in case of high strength concrete walls than normal strength concrete walls. Short walls or less slender walls fail by crushing on the compressed face and bending on the tension face, while slender walls may additionally fail through buckling. All experimental studies showed a brittle types of failure.

2.2 Aspect ratio

For OW walls the ultimate strength tends to decrease with an increase in aspect ratio, while for TW walls the opposite trend is found. Aspect ratio is the height to length ratio.

2.3 Openings

Openings are required to be provided in the reinforced concrete wall panel for functional requirements of newly constructed structures or functional modifications to the existing structures. These openings are essential in order to design the building for space efficiency and reuse for long-term conditions. The openings are a source of weakness and can size-dependently reduce the structures' stiffness and load-bearing capacity. The presence of openings in a wall considerably reduces its ultimate load capacity relative to the equivalent solid wall. here the influences of opening is studied in detail.

3. Analysis and Modelling

Static structural linear analysis using ANSYS17.0 software and element SOLID186 is done to find the influence of opening is cut in OW and TW wall panels. For this a model with small door opening, same as the one in reference 2, is modelled and validated. Changing the type and dimension of opening and having constant material property and loading condition different models are created and analysed.

3.1 Material Properties

The material properties assigned to steel and concrete in workbench is as shown in table 1. The property of the specimen is kept constant throughout this work.

TABLE 1
MATERIAL PROPERTIES OF CONCRETE AND STEEL.

Material No.	Material	Material Property
1	Concrete	Density = 2300kg/m^3
		Young's modulus, E = 35355 MPa
		Poison's ratio = 0.18
		Tensile ultimate strength = 5 MPa
		Compressive ultimate stress = 50 MPa
2	Structural Steel	Density = 7850 kg/m^3
		Young's modulus, E = 2 x 10^5 MPa
		Poison's ratio = 0.3

The reinforcement bars are placed centrally in both horizontal and vertical directions at a spacing of 200 mm centre to centre. The rebars used are deformed bars of tensile yield strength of 500 MPa. The diameter of the bars is 10mm. the permissible stress for

- Concrete, M50=12
- Reinforcement, Fe500= 275MPa

The original wall model has a dimension of 3600mm X 2700mm X 120mm. And for analysis half scale model is adopted here.

3.2 Model Geometry

For various study in this work a model, wall specimen, of same outer dimension of 3600 mm X 2700 mm X 120 mm is used. Here the properties of opening are varied. Figure 2 shows general geometry of the specimen models that are analysed in this work. Depending on the study the dimension and the position of opening from the wall edge varies.

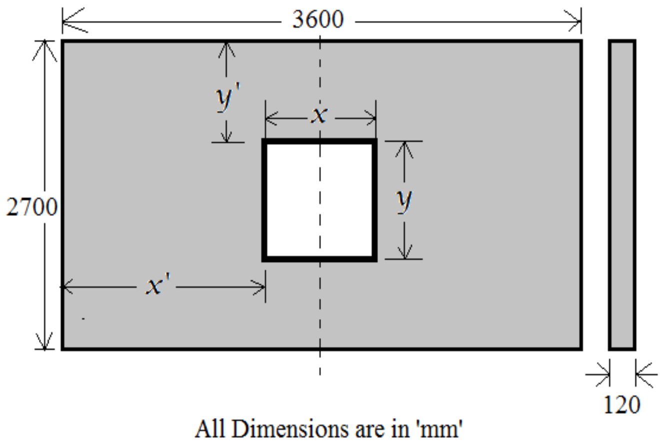

Fig 2: Geometry of specimen under study

3.3 Modelling and Meshing

The wall having dimensions 3600mm X 2700mm X 120mm is the actual specimen taken for study. The analysis is done on the half scale of this specimen. That is the study is done on structural concrete specimen having dimension 1800mm X 1350mm X 60mm with reinforcement bar of 5mm diameter at 100mm centre to centre spacing. This wall is modelled in ANSYS Workbench using various tools. The rebars used are deformed bars of tensile yield strength of 500 MPa. The above said material properties are then assigned to corresponding model.

Meshing is done by using generate mesh tool in ANSYS Workbench. Different kinds of meshing can be done in ANSYS. In normal meshing option we can't control minimum edge length of meshing but have a control on meshing element size. Which may affect the results of analysis and subsequently the conclusion derived.

3.4 BOUNDARY CONDITION AND LOADING

Boundary condition is also called support conditions. Here the study is done for both OW and TW wall panels. For one-way wall panels, the constraint is applied at top and bottom. At top displacement is arrested in Z direction and bottom displacement is arrested in all direction X, Y and Z. In TW wall panels in addition to these constraints the sides are restrained in both X and Z directions. Here Z indicate the direction perpendicular to the plane of the paper and along the direction of thickness of the wall. The XY plane is the plane of the paper and X and Y directions corresponds to the direction along length and height of wall respectively.

A uniformly distributed load is applied as a line pressure in ANSYS at an eccentricity of 1/6 of thickness from the centre of wall. The eccentricity allowed by the various codes are within the central middle third of thickness. And the 1/6 of the thickness from the centre line of thickness is the maximum eccentricity allowed. This eccentricity in applied load will make the wall to undergo the out of plane displacement which the parameter employed to study the behaviour of the wall with cut out openings. The loads are applied in such a magnitude the study is constrained to the linear analysis making use of the linear portion of stress and strain. To maintain linear analysis a load of 50N/mm is applied as line pressure in the half scale plan model for all the analysis hereafter.

4. PARAMETRIC STUDY

The parametric study is done to study the influences of various opening parameters on the behaviour of structural concrete wall. Here parametric study is done by varying length alone, breadth alone and varying both for OW and TW wall panels. For this study wall panel model and properties employed are same as general model. But the opening size is varied.

4.1 OW concrete wall

Under this section the parametric study is done on OW structural concrete wall in three following sections. Parametric study is done by varying length, varying breadth and varying both of dimension of the opening.

4.1.1 Varying length of opening

First parametric study is done by varying the length of the opening. The opening is placed concentric with the centre of wall specimen as shown in Figure 3 for this parametric study. The length(l) of the opening is varied by keeping the height(h) constant. Figure 4 shows variation in the out of plane deformation with varying length of the opening. From the graph it can be seen that the deformation increases with increase in the length of the opening in OW wall panels. And it can also be stated that increasing length has critical influence on the strength behaviour of wall. Or the opening with small length is most suited in OW wall panels.

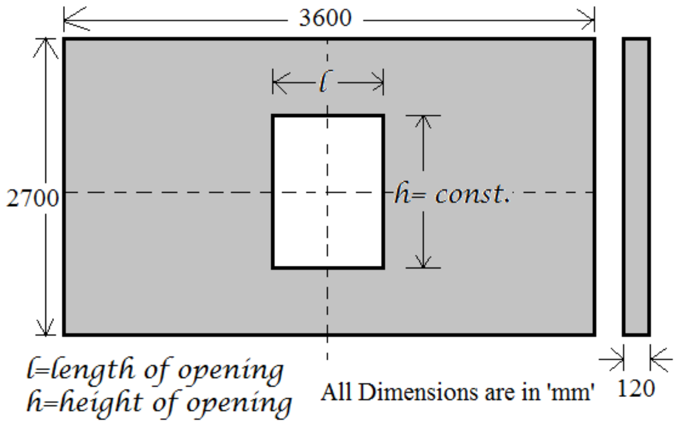

Fig 3: Wall with opening of varying length

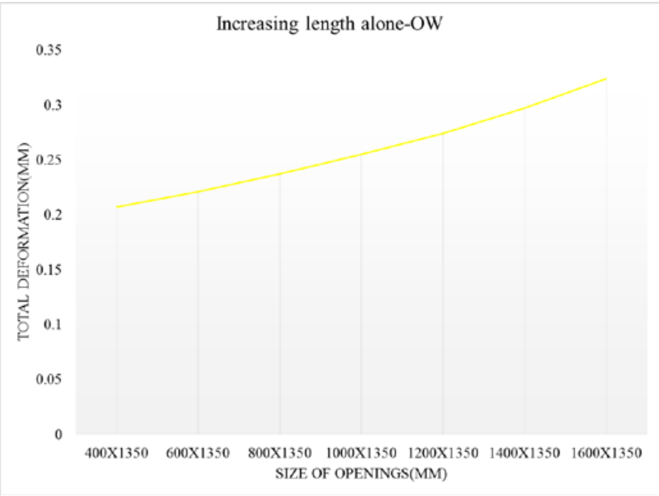

Fig 4: Deformation of wall for varying length of the opening

4.1.2 Varying height of opening

Second parametric study is conducted by varying the height (h) of the opening and keeping length (l) of the opening constant. As shown in Figure 5, opening is placed concentric with the wall specimen. In OW wall panels the deformation of wall increases with increase in the height of the opening as shown in Figure 6. Even though there is an increase in the deformation with height of the opening, compared to the increasing length of opening these variations are less. That means varying height of opening has least effect on the OW wall strength value.

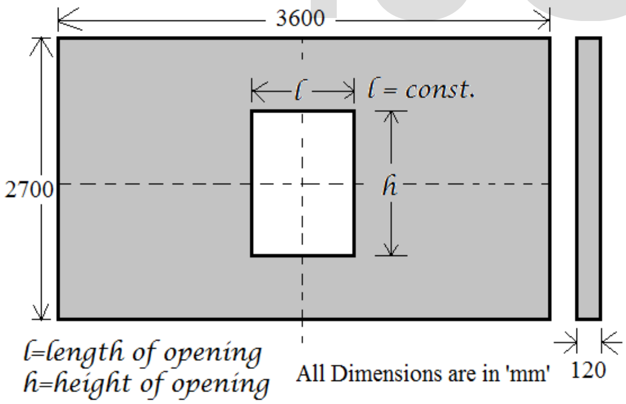

Fig 5: Wall with opening of varying height

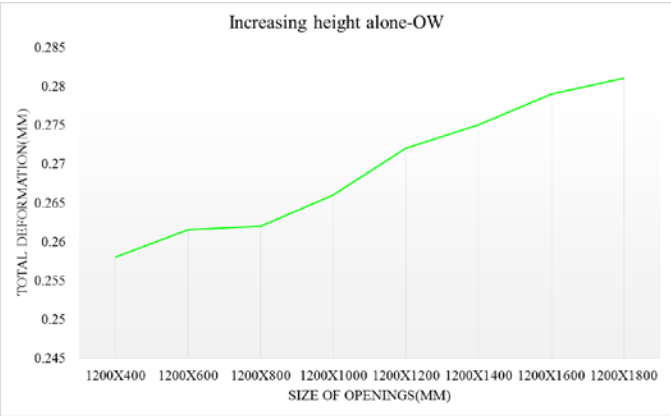

Fig 6: Deformation of wall for varying height of the opening

4.1.3 Varying both length and height of opening

Parametric study is done by varying both length and height of the opening and the opening is placed concentric with wall specimen as shown in Figure 7. The graph 8 shows the deformation variation of OW wall panels with varying both length and height of the opening. The graph shows that the deformation increases with increase in both in length and height. The values show that the influence of increasing/decreasing both length and height has most significant on walls.

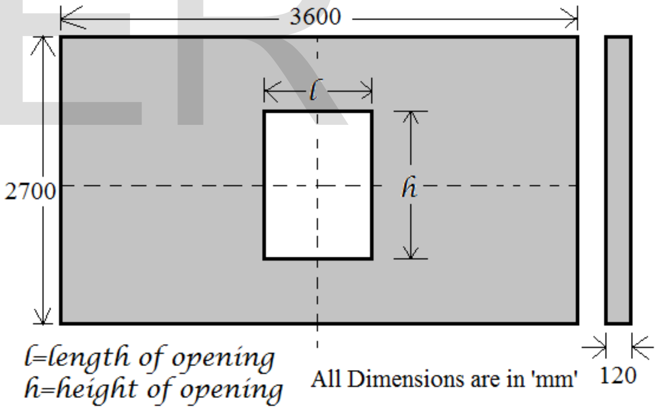

Fig 7: Wall with opening of varying both length and height

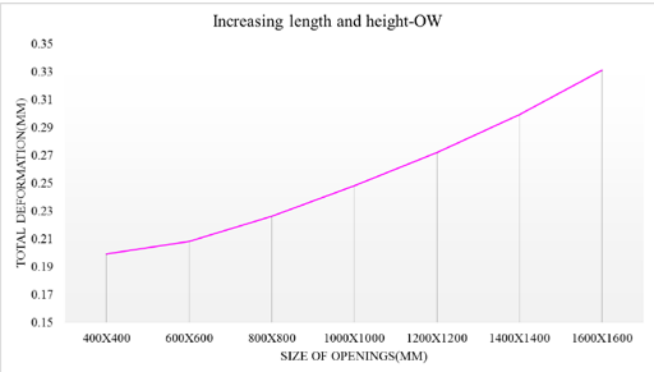

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Figure 8: Deformation of wall for varying both length and height of the opening

4.2 TW concrete wall

Under this section the parametric study is done on TW structural concrete wall in three following sections. Parametric study is done by varying length, varying breadth and varying both of dimension of the opening.

4.2.1 Varying length of opening

In this parametric study, done by varying the length of the opening, the graph shows an increase with increase in length of opening. Less length of opening implies more area of wall to act as column. Therefore, more stability can be attained with side restraint. The effect of side restraint can also be seen while comparing the deformation of OW and TW wall panel for same opening configuration.

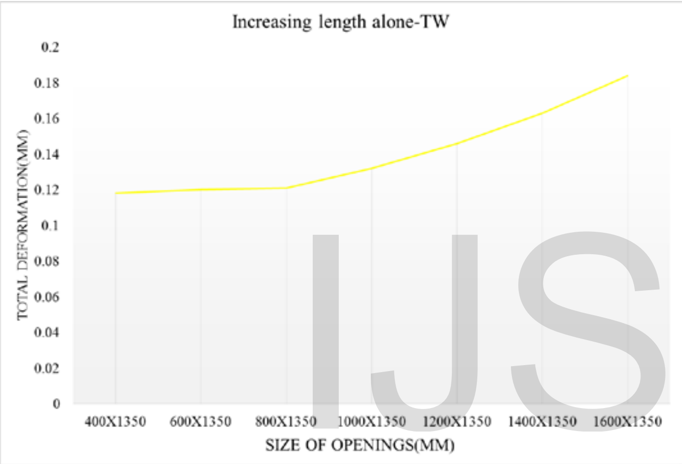

Figure 9: Deformation of wall for varying length of the opening

4.2.2 Varying height of opening

The parametric study done on TW structural concrete wall shows that increasing or decreasing the height of the opening does not have much significance on the strength characteristic of wall. The parametric study is done by varying the height of the opening keeping the length constant.

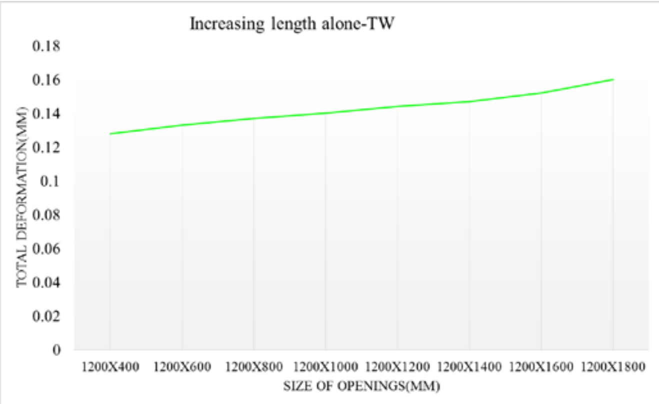

Figure 10: Deformation of wall for varying height of the opening

4.2.3 Varying both length and height of opening

The following figure 11 shows the deformation variation with the opening size. The study is done by varying the length and height simultaneously. And the influence of varying the length and height simultaneously has most significant effect on the strength characteristics of wall.

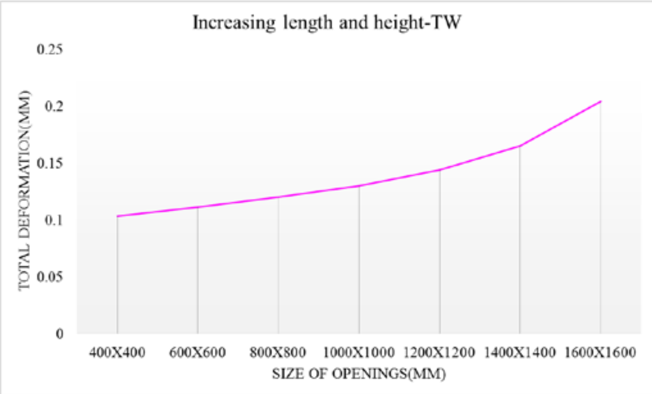

Figure 11: Deformation of wall for varying both length and height of the opening

5. Comparative Study

Based on the above parametric study, varying both length and height of the opening, a comparative study is done. And the values of OW and TW wall also compared.

5.1 Influence of area of opening

The deformation variation with the percentage of area of opening is plotted in graph 12 and the variation shows that as the % of area of opening provided increases the deformation increases and hence weakens the member structural concrete wall. And the study shows that the increment in deformation when the % area of opening increases from 15 to 20 is 1.5 times the deformation increment when the % area of opening increases from 10 to 15.

Figure 12: Variation of deformation with % area of opening

5.2 Influence of side restraint

The influence of side restraint is understood by comparing the results of OW and TW wall panels.

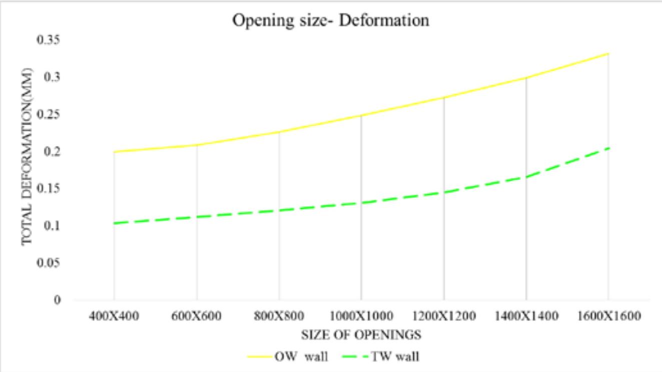

Figure13: Influence of side restrain

For the comparison of OW and TW wall panel the parametric study done by varying the size of opening, i.e. by varying both length and height is employed. The graph shown figure 13 shows that for same size of opening the TW wall gives much less deformation than OW wall panels. Which means that the side restrain applied in TW wall panels increase the strength characteristics of the wall.

6. Conclusion

This study briefly explains the influence of changing the dimensions of opening on the structural wall. Parametric study is done on OW and TW walls by varying length, height and both. Following points can be concluded from this study:

- In both OW and TW walls the increasing the length alone of openings is more significant than increasing height alone on reducing the strength of wall.
- In both OW and TW walls the reduction in strength of wall is more significant when both the length and height of the wall is changed simultaneously.
- In a typical practical wall the incremental increase in deformation when % in opening area cut increased from deformation when % in opening area cut increased from 15 to 20 is 1.5 times the incremental increase in deformation when % in opening area cut increased from 10 to 15.
- The study also reveals that side restrain can increase the load carrying capacity considerably.

More studies are conducted on concrete structural wall the result will be published soon. The work to study the influence of number of openings and the eccentricity in opening position is on progress.

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