Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (43) No. (2) April . 2021

Lateral Stiffness of shear walls with openings

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الملخص العربى :

تعتبر حوائط القص من اكثر الانظمة الانشائية استخداما لمقاومة القوى الجانبية المؤثرة علي المبنى كاحمال الرياح والزلازل، يهتم المهندس الانشائى بدقة النماذج الحسابية الخاصة بحوائط القص نتيجة تاثير الاحمال الديناميكية على المنشئ والصلابة المطلقة من نظام حوائط القص هي المحدد الرئيسى لمقاومة القص فى المنشئ، فى هذا البحث تم دراسة تأثير عمل فتحات بالابعاد مختلفة فى الحوائط الخرسانية وامكان مختلفة للفتحات وتاثريها على معرفة سلوك اجهاد القص فى الحوائط تم عمل اربع نماذج للحوائط بفتحات مختلفه تحت تأثير حمل جانبى اعلي الحوائط . أظهرت النتائج أن تقسيم المساحة المراد عمل فتها بها علي فتحتين مجاورين افضل من عمل فتحة واحدة بمركز الحائط . ينصح بها في الاستخدامات المعمارية.

Abstract:

Shear walls are popular structural systems to resist lateral forces acting on building such as wind and earthquake. structural engineers are interested in the accuracy of computational models for shear walls because for dynamic loading, the absolute stiffness of shear wall systems is the prime determinant for the design base shear of the building. In this research, was studied the effect of making different openings at shear walls to investigate the effectiveness of opening on the stiffness and strength of the reinforced wall, The experimental program consisted of four reinforced concrete walls with different openings supposed to lateral load. The results show that, Usage two vertical openings at center is better than use one central opening has A bad effect on stiffness of wall.it is recommended for the architectural usage.

Key Words —shear walls with openings, stiffness of wall, lateral load

Introduction

Shear walls are vertical elements of the horizontal force resisting system. Shear walls are constructed to counter the effects of lateral load acting on a structure. In residential construction, shear walls are straight external walls that typically form a box which provides all of the lateral support for the building. When shear walls are designed and constructed properly, and they will have the strength and stiffness to resist the horizontal forces.

Shear walls are introduced in modern tall buildings to make the structural systems more efficient in resisting the horizontal loads that arises from the wind and the earthquakes. The introduction of shear wall represents a structurally efficient solution to stiffen a building structural system. The main function of shear wall is to increase the rigidity of lateral load resistance. Shear walls in apartment buildings may have openings that are required for windows in external walls or for doors ways or corridors in internal walls. The size and location of openings may vary from architectural and functional point of views. These openings may have an adverse effect on stiffness of shear wall as well as on the seismic response of frame-shear-wall structures. Relative stiffness of shear walls is important since lateral forces are distributed to an individual shear wall according to their relative stiffness.

Furthermore, the stress concentration may occur around the opening which in turn induces the crack at early stage of loading process and hence reduce the stiffness and strength of the wall, in this study specimens with different size of opening and different location, tested to illustrate the effect of the design parameters on post –cracking behavior.

The main of this study was to investigate the effectiveness of opening on the stiffness and strength of the reinforced wall, the study highlights the need to include the ductility and shear strength of shear walls in the Egyptian Code requirements for shear walls.

I. EXPERMNTAL PROGARAM

A. Matarials

The materials used in this research included a concrete mix was designed to achieve the compressive strength used to cast shear walls. The targeted compressive strength was 32 N/mm2 after 28 days. The properties of the materials used for concrete mix are explained below, coarse aggregate is Crushed dolomite size no.1, no.2 was used as coarse aggregate in this study the nominal maximum size of aggregate was 20 mm. The coarse aggregate was washed using potable water to ensure the removal of dust or impurities that might exist.

Fine aggregates -Sand was used as fine aggregate. It was clean from impurities, silt, loam, and clay or any organic materials, The cement used in this study was ordinary Portland cement, Potable clean water was used in the mixture to allow its full hydration. Concrete mix design and curing The absolute volume method was used to determine the concrete mix proportions Table (1) shows mix proportions by weight of the quantities used for one cubic meter of concrete to achieve the target strength of 32 N/mm^2 after 28 days.

Also Steel Reinforcing Bars High-tensile steel (36/52) of 10mm diameter were used for main longitudinal steel, and stirrups. Test results of steel reinforcement bars are shown in tables (2).

TABLE1. MIX DESIGN OF NORMAL STRENGTH CONCRETE (PER M^3)

	Material	**Weight (Kg/m^3)**
Compressive target strength =32 N/mm^2	Cement	400
	Water	220
	Fine aggregate (sand)	700
	Coarse aggregate (crushed dolomite)	970

TABLE 2. PROPERTIES OF 10MM DIAMETER BARS.

Characteristic	Bar (1)	Bar (2)	Bar (3)
Nominal Diameter (mm)	10	10	10
Nominal area of section (mm2)	78.57	78.57	78.57
Length of sample (mm)	510.4	507.4	508.1
The weight of the sample (kg)	319	317	317
Weight per linear meter (kg/m)	0.625	0.625	0.624
Actual area (mm2)	79.62	79.58	79.48
Length of measurement before tensile (mm)	50	50	50
Length of measurement after tensile (mm)	61.1	62.66	60.77
The highest yield (kN)	36.5	36	36.5
Maximum load (kN)	56.5	56	56.5
High yield stress Reh (N/nm2)	464.55	458.18	464.55
Tensile Strength Rm (N/nm2)	719.09	712.73	719.09
RM/Reh	1.55	1.56	1.55
Elongation %	22.2	25.3	21.5

TABLE 3. RESULTS OF CUBES FOR NORMAL STRENGTH CONCRETE SPECIMENS.

Specimen	Cube Strength (N/mm2) When the specimen was tested (after 7 days)	Cube Strength (N/mm2) When the specimen was tested (after 28days)
Wall 1	269.46	400
Wall 2	269.46	309
Wall 3	269.46	277.282
Wall 4	269.46	291,340

Figure1. Standard cube testing.

Figure 2. Concrete mixer

Figure 3. Freshly cast concrete for the tested specimens

B. **Expermanital programe**

Experimental program consisted of four reinforced concrete walls with same dimensions and reinforcing details. They were 1000mm×2000mm with thickness 150mm figure (3-1) shows the dimensions of the tested walls, they were centered in strip footing with dimensions (300mm×300mm×2500mm). The four walls had the same reinforcement, 6 Ø10 as the flexural main reinforcement and 13Ø10 as the secondary reinforcement. All footings have the same reinforcement (3Ø12Top and 3Ø12 Bottom) and stirrups reinforcement was 12 Ø12.

The program was designed to investigate the different sizes of openings, different reinforcement arrangement around the openings, and the effect of different location of openings. the lateral stiffness of shear walls with openings and their horizontal displacements were studied. Specimens were designed to fail in flexural and not in shear. Table (4) illustrates the tested specimens.

. TESTED SPECIMENS.4TABLE

Specimens	openings	Position of opening	Dimension of opening
Wall 1	solid	--	--
Wall 2	One opening	Centre of wall	500mm×500mm
Wall 3	Two openings	Centre of wall	250mm×500mm
Wall 4	Two openings	Centre of wall	250mm×500mm

C. Specimen preparation and test methods

Metal The specimens were placed in front of the jack head and the steel frame and supported on two hinged supports, then strain gauges were connected to the data acquisition system attached to the computer. Before loading, zero readings of stirrup strains and displacements (LVDTs) were recorded and checked using the testing software of the data acquisition system. All walls were tested up to failure under incremental monotonic static loading, lateral concentered load. The load was applied at top of the wall, as shown in Figure (4).

The load was monitored by a load cell and transmitted to the reinforced concrete wall through transversal steel cylinder beam resting on steel pads to provide uniform bearing surfaces. The testing software of the data acquisition system recorded the readings of the five LVDTS, and the three strain gauges at each load increment. Surface cracks were detected, marked, and photographed, at each load increment.

Figure 4. Test Setup

D. Results and Discussion

Table 5, The tension failure took place, this could be defined by the initiation of cracks along the openings and the diagonals of the tested walls. Table 5 shows results summary of all tested specimens. The table gives displacement, the mode of failure for each specimen, the maximum and cracking loads. In addition, figures (5), (6), and (7) gives a comparison between of the walls, cracking loads, maximum loads and maximum deflection values.

"Fig. 5," shows the first cracking load appear on the walls after spouse to lateral load , we found that wall 3 was the earlier cracking one .

"Fig. 6," shows the maximum load each wall reached to it before failure, The walls failed due to the propagation of cracks in two defined phases. The first phase included the initiation of the early cracks. The second phase were the cracks stabilized; they widened and started to connect forming a cracks network till reaching the flexural failure.

"Fig. 7," shows a comparison was made between the four tested walls top deflection and the results are shown in figure.

TABLE 5. SUMMARY OF THE TEST RESULTS.

Specimen	Cracking Load	Maximum Load	Maximum Displacement
Wall1	20	120	130
Wall2	10	119	55.746
Wall3	8	108	112.81
Wall4	15	128	68.675

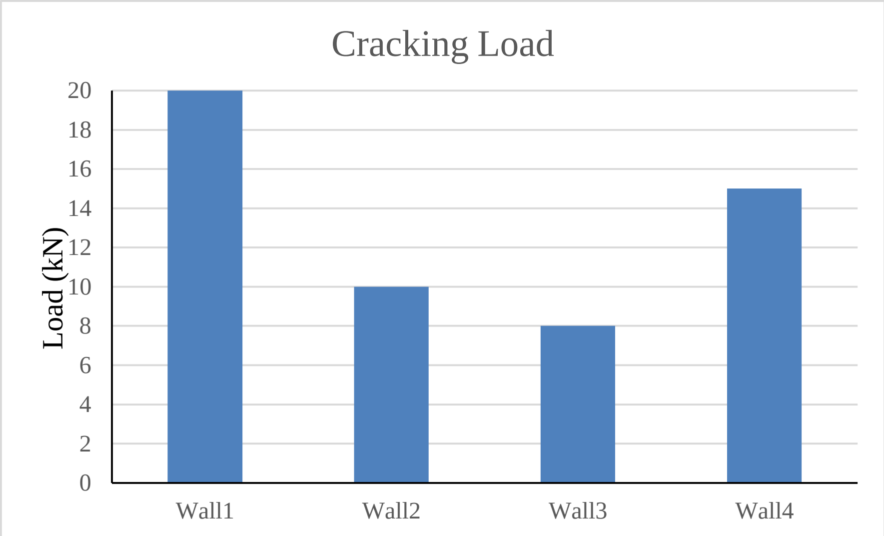

Figure 5. Experimental Cracking loads.

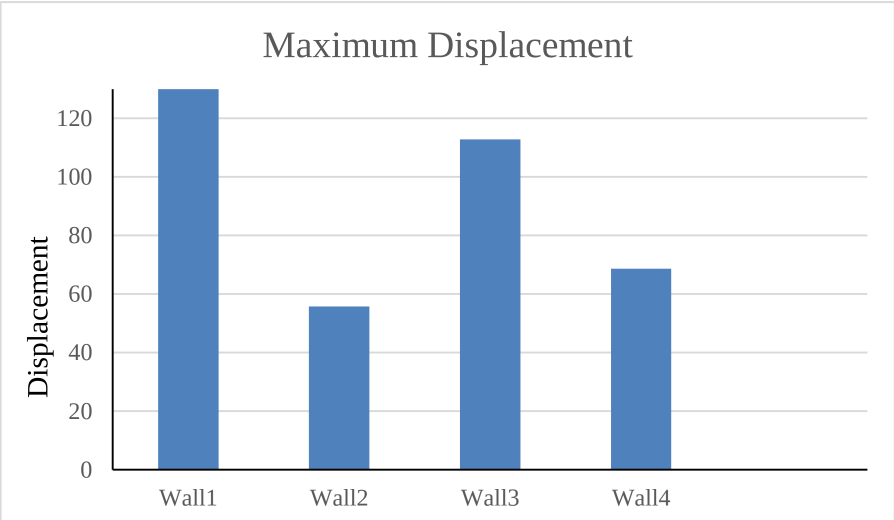

Figure 6. Experimental maximum displacement.

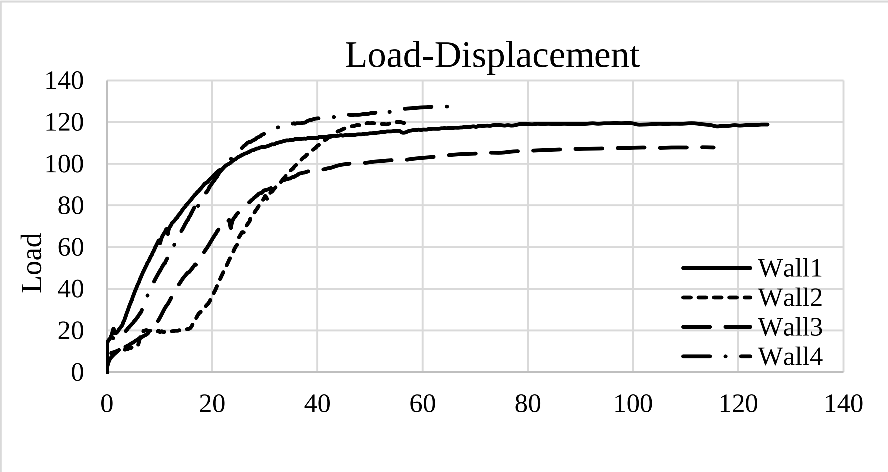

Figure 7. Experimental maximum displacement.

E. **conclusion**

From the results you can conclusion that

- for opening area < 20% of shear wall area the stiffness of shear- wall structure is more affected by the size of openings than their arrangement . However, for opening area>20% of shear wall area, the stiffness of the system is significantly affected by the openings arrangement in shear walls. However, vertical location of window opening significantly affects the stiffness of the system..
- Small openings yield minor effects on the load.

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