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Effect of Size and Location of Openings on the Structural Behavior of Walls of Reinforced Self-Compacting Concrete Incorporating Attapulgite as a Partial Replacement of Cement

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Abstract

This experimental investigation is about the structural performance of sustainable self-compacting concrete walls exposed to eccentric axial regularly dispersed loading, including the effect of openings (location and dimensions) by one-way and two-way action. The experimental program includes testing twelve wall panels, the eccentricity of the loading system equivalent to one-sixth of depth. These wall panels are separated into four groups, each one of them consisting of three specimens in addition to two reference solid samples, all specimens with dimensions (80×50×5) cm. First and second groups clarify the opening's effect by one and two-way action with various dimensions (15×25, 20×30 and 20×40) cm. The results indicated a decrease in failure load of about 10.52 %, 14.7%, and 23.68% for one way and 12.195 %, 13.88%, and 24.39% for two way as dimensions of openings increased from (15×25 to 20×30), (20×30 to 20×40) and (15×25 to 20×40) respectively. In the third and fourth groups for the effect of opening's locations by one and two-way action, failure load decreased as they approached the edges 11.76%, 10% for one way, and 13.88 %, 3.2% for two way decreasing for (center to centerline near edge, and from the last to corner) respectively.

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Abbreviations

ATP:	attapulgite
BC:	boundary condition
C.L:	centerline
OW:	One-way action
RCW:	Reinforced concrete wall
SCC:	Self-compacting concrete
SSCC:	sustainable Self-compacting concrete

TW:	Two-way action
fcu:	Compressive Strength on cube
fr:	Modulus of Rupture
fct:	Splitting Tensile Strength
EC:	Modulus of elasticity
HRA:	High reactivity attapulgite

1. Introduction

Concrete is one of the most widely used and durable building materials. It provides sufficient strength to bear loads and is resistant to external conditions. It comprises different constituent materials with significantly different properties that complement each other. One type of concrete is self-compacting concrete (SCC), which is defined as concrete that must meet the requirements of passing and flow ability, segregation resistance, and attaining complete compaction with the weight of one's own body alone, independent of external compaction. Moreover, it can be filled in small places with reinforcement steel, eliminating the need for external compaction equipment [1-4].

Concrete, in general, has unique and qualitative properties, and the presence of cement as its main component is considered one of its most important properties. So, large quantities of tons of cement are produced annually, and in addition to being expensive, cement also pollutes the environment by emitting a lot of carbon dioxide during production; for this reason, there are many research directions on the production of concrete using sustainable alternatives that limited the use of cement.

The first part of this research is about the production of sustainable self-compacting concrete SSCC, which includes the properties of SCC in addition to containing a sustainable material with a partial or complete replacement of one of its components.

The second part of this work study the structural behavior of 12 reinforced concrete wall panels contains openings of different dimensions and different locations. The walls restricted from two directions (one-way action) or all sides (two-way action).

2. Related Research

There is a group of research on the production of this type of SSCC, Ofuyatan et.al, study about SCC with silica fumes as a cement substitute by the extents of 0%, 15%, 25%, and 35% of volume. Results for compressive strength at 21 Days (kN/mm^2) were 39.24, 34.42, 25.10, and 20.60, respectively. This study's evaluation of a variety of qualities relevant to concrete production employing silica fumes as a substitute for cement proved successful [1].

Hilal, et.al, investigate the initial and final performance of SCC prepared by coal ash besides fly ash (CA&FA), each one alone a fractional exchange of cement, mixtures done with 0%, 10%, 20% and 30% (by weight) of cement. The findings indicated that the CA had detrimental effects on the fresh characteristics of SCC. However, the outcomes still align with the fresh SCC's requirements, also has significantly increased SCC's durability and water absorption versus the addition of FA [2].

Younis et.al, used recycled glass powder (RGP) as a partial alternative to cement, the test findings showed that increasing the amount of cement replaced with RGP generated a modest reduction in passing ability while maintaining flow ability and improving segregation resistance. The resulting mixes' mechanical characteristics improved up to a 30% replacement level [3].

Kumar, et.al, substitute Metakaolin and plastic fiber by the cement in the SCC mixture; metakaolin with 20% constant replacement and plastic fiber ratio are 0%, 0.25%, 0.5%, 0.75%, and 1%, respectively with metakaolin. The research result demonstrated that with the inclusion of plastic fiber, SCC's ability to fill and pass is reduced, but the characteristics are not significantly altered. The parameters of hardened SCC demonstrate that both substances have an effective role in the strength of SCC [4].

Abbas, et.al, used high reactivity attapulgite (HRA) to produce lightweight self-compacting concrete (LWSCC), optimum content of HRA used 10%, causing growth in compression load also splitting tensile value as compared with the original mixture (10.0%, 12.1%, 11.1%, and 12.4%) and (12.0%, 18.2 %,16.6%, and 16.2%) respectively with 7, 28, 56 and 90 days. for this, the attapulgite is appropriate to contribute to the production of LWSCC [5].

Qassim, et.al, investigate that HRA with silica fume has a significant improvement in the properties of concrete and its resistance to shear stresses, as the axial load improves the shear capacity and reduces the shear failure in (LWSCC) [6].

Zghair, et.al, study how the Iraqi clay (Attapulgite) has been processed to pozzolanic material HRA. The possibility of replacing the Iraqi clays with cement can reduce the cost and the impact of cement manufacturing on the environment. In this study, three percentages of HRA were used as a replacement: 0, 10, and 20 % by weight of cement. The test result shows that the10% of HRA is an optimum ratio, which increases the compressive strength compressive strength [7].

Abdulrasool, et.al, used different percentages of attapulgite were used, including 0%, 4%, 8%, 12%, and 16%, in replacement of cement. The findings indicate that using attapulgite enhanced the compressive strength by 9% and 8% for flexural strength. In general, all concrete mortar mixes that were prepared with different attapulgite percentages result in acceptable mechanical properties [8].

Abdulrasool, et.al, used Attapulgite fine aggregates (AFA) in place of two different amounts of normal sand. To examine the effectiveness of internal wet curing, AFA has been proven to be beneficial for internal treatment. It has been discovered that enhancing the properties of high-performance concrete properties with 20% AFA results in low internal stress and a noticeably higher compressive strength [9]. Research is ongoing in this field, as industrial and plastic wastes, and even natural plant wastes, are used as sustainable materials. In any case, concrete gains strength over time and has a long service life. So, it is considered the most suitable material to be the basic component in building structural elements; one of the most important elements is walls. Reinforced concrete walls (RCW) were previously utilized to guard against the outside environment. They were regarded as non-load-bearing walls, without taking into account the wall's strength as a structural component, this is because the early published concrete codes had very low operating design stresses, and little study of these components was conducted. Concrete load-bearing walls that principally sustain vertical loads that operate downward on the upper region of the wall may experience weak-axis bending due to the eccentric behavior of the applying axial vertical load [10]. The wall is defined as a vertical load-bearing element with a length greater than four times its depth in clause 1.3.4.1 of BS 8110: Part 1:1997, which differentiates walls from columns [11].

3. Experimental Program

3.1. Material Properties

In this investigation, the materials used are:

3.1.1. Cement

In this investigation, Ordinary Portland Cement (OPC) type (I) is utilized which conforms to IQS No.5/1984 [12]

3.1.2. Fine Aggregate (sand)

Natural sand was utilized as a fine aggregate for SCC mixtures with specific gravity (2.56) and modulus of fineness (2.6). By the requirements of Iraqi standard (IQS) No.45/1984 zone (2) [13].

3.1.3. Rough Aggregate (gravel)

The largest size of gravel is (12 mm) with specific gravity (2.7), which is used in the SCC mix. Accordance with Iraqi Specification (IQS) No. 45/1984 [13].

3.1.4. High Reactive Attapulgite:

This particular clay, which appears as bluish-green and grey claystone in the Al-Najaf and Karbala districts, after breaking up the large stones into smaller pieces with a hammer, attapulgite can be made by burning it for half an hour at 750°C in an electric oven after grind it into tiny bits to become a fine powder. The properties of attapulgite powder comply with ASTM-C618 [14]

Table 1: Chemical analysis of Attapulgite

Oxide Composition	Oxide content (%)
SiO_2	50.82
Al_2O_3	11
Fe_2O_3	6.455
TiO_2	1.019
CaO	22.78

Oxide Composition	Oxide content (%)
MgO	6.942
SO_3	1.211
Na_2O	2.531
K_2O	2.302

3.1.5. Superplasticizer S.P.

Water Reducing Admixture of superbly Water Reducing, Layda's superplasticizer is designed for the production of an SCC mix.

3.1.6. Limestone Powder

Limestone was used during this work, and it is a common addition to self-compacting concrete. Limestone, a white powder, is locally called (Ghubra). Limestone is used as a filler material to improve certain properties, as compared to cement.

3.1.7. Water

The water used in the concrete mix design is drinking water from the water supply network system.

3.2. Steel reinforcement properties

Steel bars, welded with each other to become a mesh located by the center of the specimen's width with a 15mm concrete cover (use one layer of reinforcement due to limited thickness). The bar's diameter (6mm) was designed with (100mm) c/c spacing in both directions. also, an (8mm) steel reinforcement is positioned around the mesh to brace or guard the wall's edges and (4mm) around openings for strengthening, as shown in Figure (1) and Table (2)

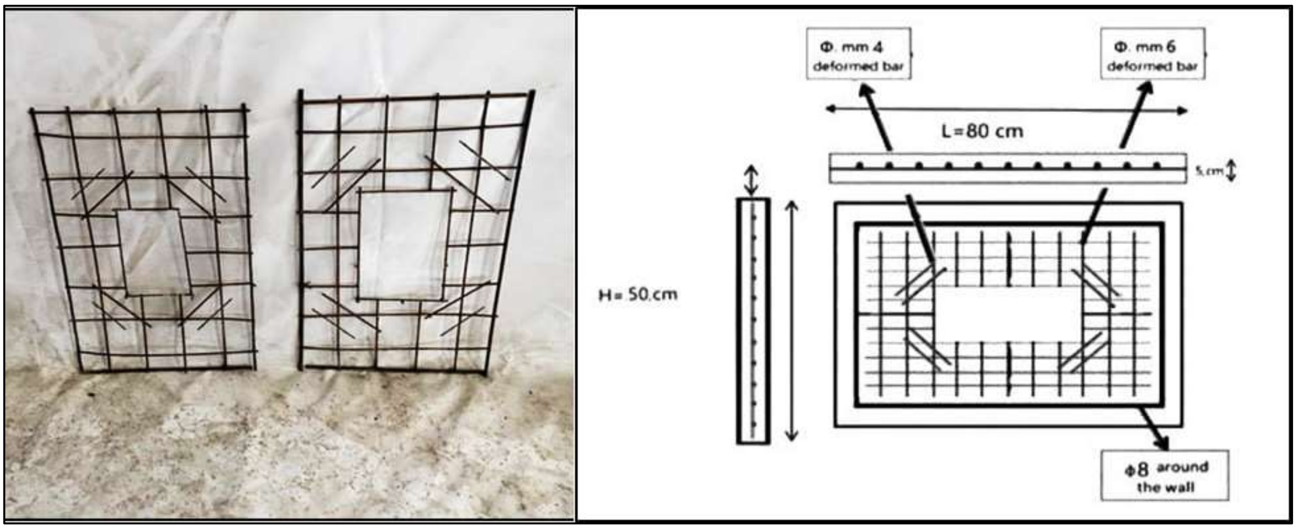

Figure 1. Steel reinforcement of wall panel

Table 2. The Reinforcement Mesh Specifications*

Property	**Diameter** 4 mm	**Diameter** 6 mm	**Diameter** 8 mm
Yield stress	630MPa	550 MPa	515MPa
Ultimate strength	1100 MPa	998 MPa	780 MPa
Elongation %	1.834	4.905	11.78
Location with mesh	Around openings	(10*10) cm (C/C)	Around mesh

*** Each value is an average of three specimens, by ASTM A615-86 [15]**

3.3. Concrete Mix

The first part of the experimental program includes a set of trial mixtures to get the desired characteristics of the SCC mix. Where the mixture is chosen that is compatible or commensurate with the standard properties of SCC by conducting the standard cone test and V funnel test, according to EFNARC 2005 [16], and then pouring the mixture into six cubes of size (10x10) cm and 3 prisms (10x50) cm to measure the compressive and tensile strength, respectively. This procedure or method is adopted for each mixture until the required properties are reached. After obtaining the mixture with the required properties of SCC, four mixtures with different proportions of attapulgite clay 0%, 10%, 15%, and 20% as a partial replacement of cement. as shown in Table (3) & (4). The mixture with a ratio of 10% attapulgite is chosen to be the control mixture because at this replacement percentage the highest pozzolanic activity occurred, so it consumed more Ca(OH)2 to produce more cement gel, thereby the voids between discrete cement and micro-cracks was reduced [5], because it is a good percentage as a relative substitute for cement, and the decrease in compressive strength is not significant, so it is suitable for pouring RCW samples. The proportions of the final mix are shown in Table (5). The second part of this work study includes testing ten opening RCW samples which are separated into four groups, each one containing three specimens to examine the effects of the following variable of SSCC wall samples.

1. Size of openings (SO): three sizes of openings at the center (15×25, 20×30, 20×40)cm
2. Location of openings (LO): presence of opening at (center, centerline near edge, corner)
3. Boundary condition (BC): the specimens are tested by one-way and two-way action

Table 3: Results of Trials Mixes of SCC with (0,10,15,20) % of Attapulgite

Self-compacting Concrete Mix	SCC With 0% ATP	SCC With 10% ATP	SCC With 15% ATP	SCC With 20% ATP
Compressive Strength of SCC for 7 days (MPa) on cube	30.13	32.2	24.57	22.03
Compressive Strength of SCC for 28 days (MPa) on cube	35.3	40.81	32.75	30.21

Table 4: Results of Trials Mixes of SCC with (0,10,15,20) % of Attapulgite

Self-compacting Concrete Mix	SCC With 0% ATP	SCC With 10% ATP	SCC With 15% ATP	SCC With 20% ATP
Modulus of rupture of SCC for days 28 (MPa) on prism	4.36	4.69	3.82	3.1

Table 5. Quantities of SSCC Mix.

Material	**cement**	**sand**	**gravel**	**limestone**	**Attapulgite**	**Water**
Quantities	315 kg/m^3	788 kg/m^3	890 kg/m^3	150 kg/m^3	35 kg/m^3	170 kg/m^3

4. Abbreviated naming of Wall Specimen

Panels are naming as (W x1 x2 x3), where:
W: Indicates to the Wall.
X1: Indicates the type of restrain (O= one-way action or T= two-way action).
X2: Indicates the number of the group, a group for each parameter (SO, LO, and BC)
X3: Indicates to numerous samples within the groups.
WOR: Indicate to one-way action reference wall
WTR: Indicate to two-way action reference wall

The full information of the wall samples is shown in Table (6) and Figure (2)

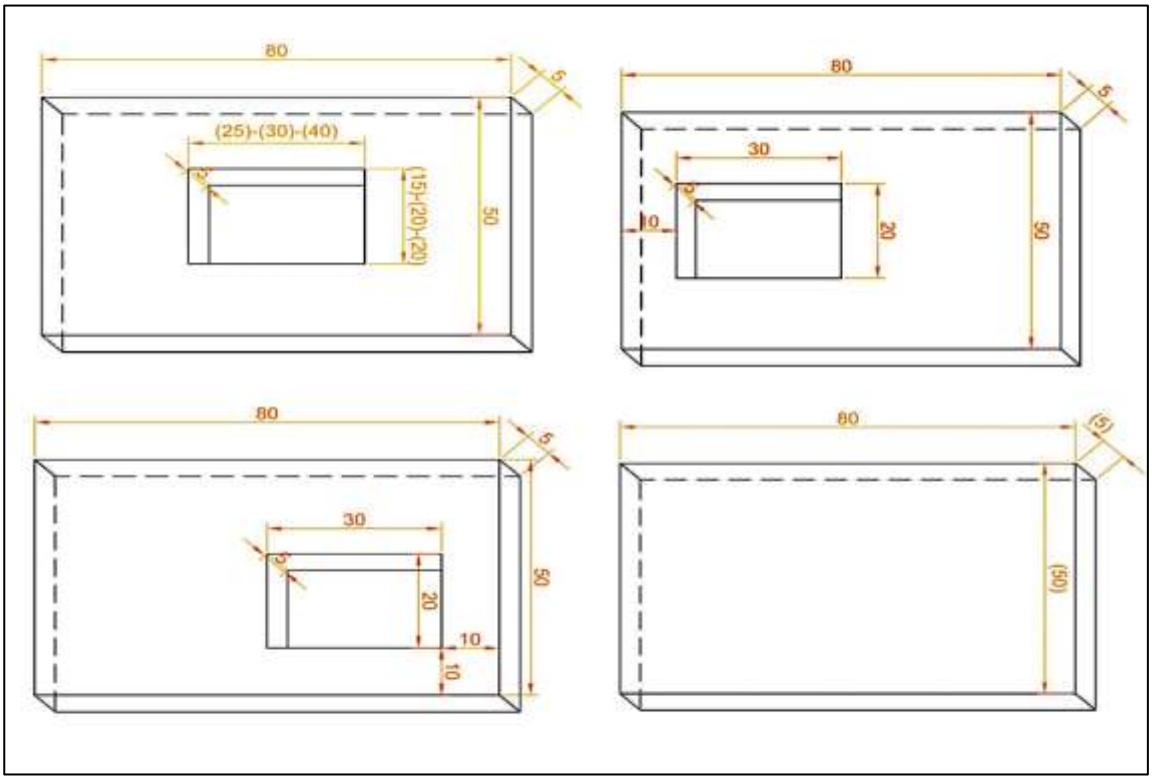

Figure 2: Wall Specimen configuration

Table 6: The wall Specimen details

NO.	Symbol	GROUP	Parameter value	BC
1	WO11	SO (1)	15X25	One way
2	WO12	SO (1)	20X30	One way
3	WO13	SO (1)	20X40	One way
4	WT21	SO (2)	15X25	Two way
5	WT22	SO (2)	20X30	Two way
6	WT23	SO (2)	20X40	Two way
2	WO31	LO (3)	At center	One way
7	WO32	LO (3)	C.L near edge	One way
8	WO33	LO (3)	At Corner	One way
5	WT41	LO (4)	At center	Two way
9	WT42	LO (4)	C.L near edge	Two way
10	WT43	LO (4)	At Corner	Two way
11	WOR	--------	-----------	One way
12	WTR	--------	-----------	Two way

5. Characteristics of Hardened SSCC

The tests of mechanical properties of hardened SCC mixes include the compressive, flexural, tensile strength, and modulus of elasticity.

1. Compressive Strength: Three cubes with (10) cm comply with B.S:1881: part116:1989 [17]
2. Splitting or indirect tensile strength test is carried out on three cylinders of (10x20cm) by ASTM C496/C 496M-17 [18].
3. Flexural strength (modulus of rupture) is tested by three prisms (10x10x50cm) with ASTM C78-15 [19].
4. Static modulus of elasticity is obtained by testing a 150x300 mm cylinder to get the statically elastic modulus according to ASTM C469/C 469M –14 [20].

Table 7: Characteristics of Hardened SSCC.

Compressive Strength (fc_u)	40.8 Mpa
Modulus of Rupture (f_r)	4.69 MPa
Splitting Tensile Strength (f_{ct})	5.11 MPa
Modulus of elasticity (E_C)	28650 MPa

6. Test setup and procedure

Based on previous research using platform tests, it has been detected that the closest one for this study is the platform test used by (Ganesan et al., 2013) [21] with some adjustments for lateral restraints, to make a simple, economic, and functional test platform (support simulation). The upper and lower fixed support conditions are simulated by joining a 32 mm diameter high-strength steel rod, two rods with 12 mm from sides in a thick plate (3x8) cm, and welding very well to achieve the eccentricity (t/6). The type of channel used, size (C 6 cm x 4 kg / m). The steel bar must be eccentric t/6. The vertical sides, top, and bottom are supported by channels 8 & 6 mm in depth, 50 mm wide, and 5 mm thick. Rectangular steel straps (50 mm wide and 3mm thick, 800mm, long are welded in an equidistant space along the panel to have interrelated lateral supports. This operation is carried out with great care and with high precision to guarantee that no spaces are allowed between the support and the welding. To meet the eccentricity when the load is applied, the load applied vertically to the wall panels gradually, in increments of 10 KN, until failure. A lateral deflection measuring device is placed with a tension face, which records the amount of displacement occurring with the applied load. It is placed at the center of solid walls, as well as walls whose openings are not in the center. As for walls whose openings are in the center, they are placed in the middle of height and a quarter of the length. Figure (3) explains the testing process.

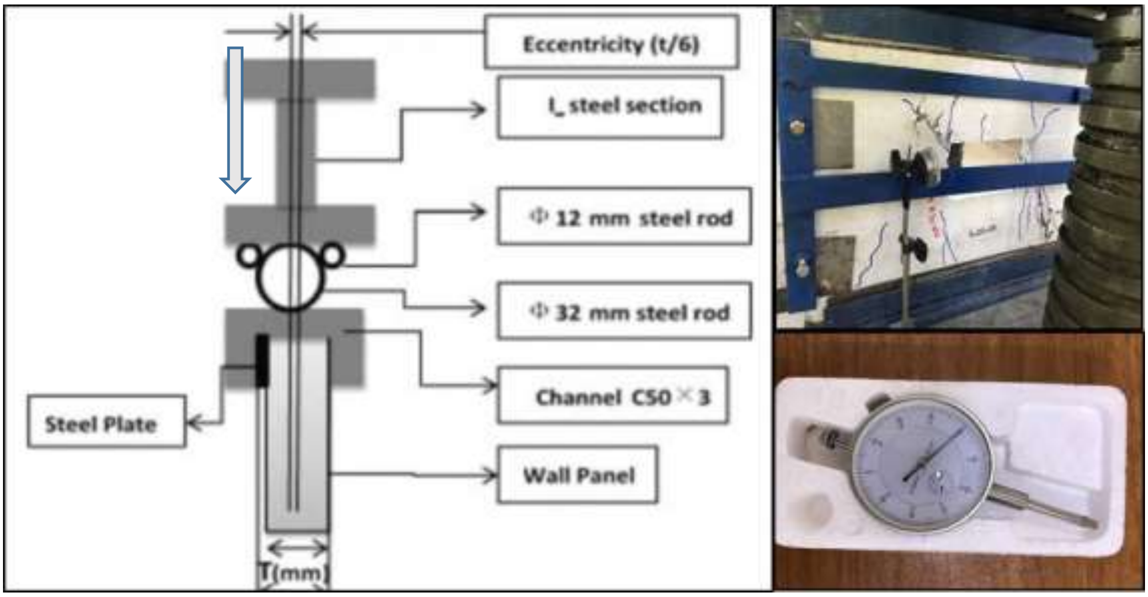

Figure 3. Detail of Supports that used in the Present Study

7. Results and Discussion

This part studies the relationship between loading capacity and lateral displacement under the effect of size and location of openings (SO)&(LO) under the boundary condition one-way and two-way action for all RC specimens and compares with references solid specimens.

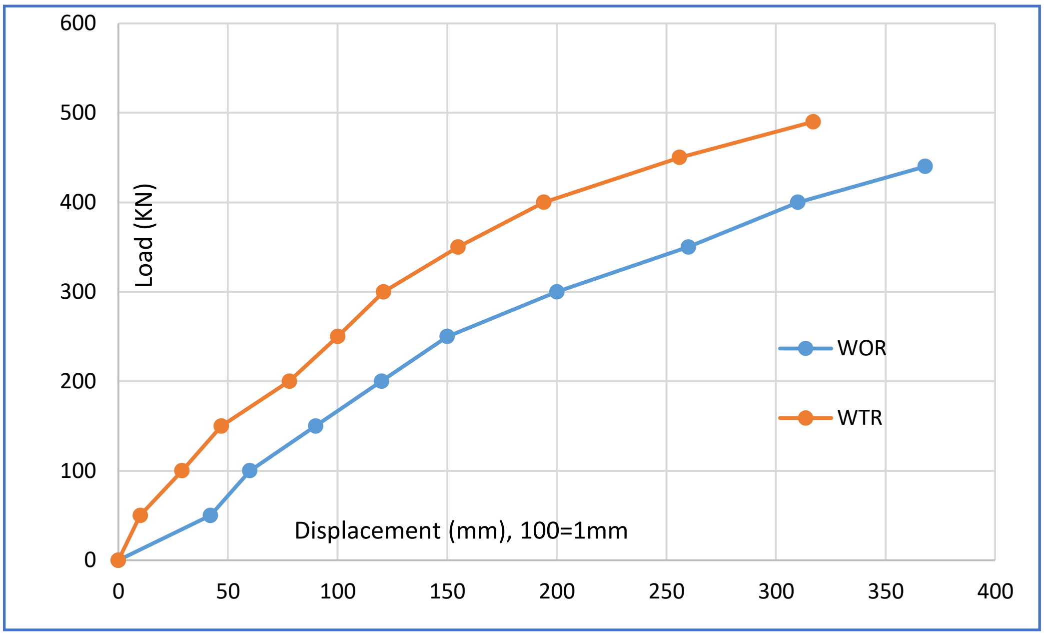

Figure 4. Ultimate load And Lateral Displacement of reference panels

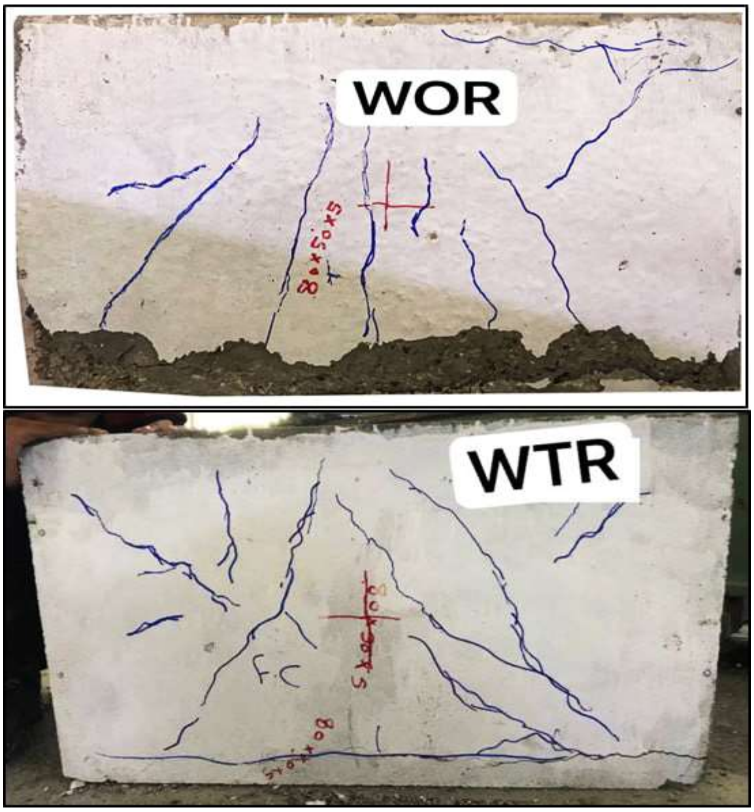

Figure 5. The crack pattern of reference panels

7.1.Size of Openings by one-way action

The effect of the size of openings (SO) on ultimate load and lateral displacement is shown in Figure (6) & (8), can be noticed in the following:

a. The loading capacity of RC wall specimen drops with increasing (SO) from (15×25 to 20×40).

b. The decreasing of final load for wall specimens as compared with solid wall is about 13.63%, 22.72%, and 34.09% for SO (15×25), (20×30), and (20×40) respectively.

c. The decreasing of lateral displacement for wall specimen as compared with solid wall is about 12.23%, 24.45%, and 39.94% at SO (15×25), (20×30), and (20×40) respectively.

d. The decreasing of final load for the SCC wall specimen is about 10.52 %, 14.7%, and 23.68% for an increase in (SO) from (15×25 to 20×30), (20×30 to 20×40) and (15×25 to 20×40) respectively.

e. For the SCC wall specimen, the reduction in lateral displacement is accompanied by a growth in the size of openings (SO). When (SO) increased from (15×25 to 20×30), (20×30 to 20×40), and (15×25 to 20×40), the decrease in lateral displacement is approximately (19.39%, 20.86%, and 31.88%) respectively.

f. For all panels of this group, cracks spread around the corners of the openings and follow the path closest to the corners of the sample, so the larger the size of openings, the faster the failure

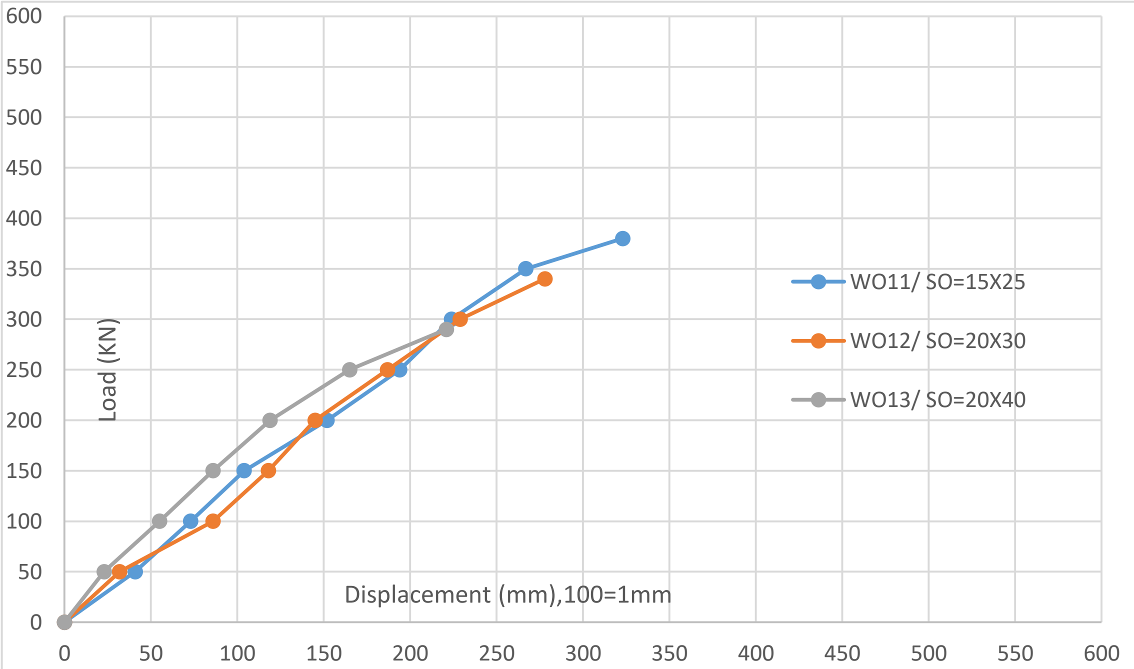

Figure 6: Opening's size (SO) effect On Ultimate load And Lateral Displacement

7.2. Size of Openings by two-way action

The effect of the Size of openings (SO) on ultimate load and lateral displacement is shown in Figure (7) & (9), can be noticed in the following:

a) The loading capacity of RC wall specimen drops with increasing (SO) from (15×25 to 20×40).

b) The decreasing of final load for wall specimen as compared with solid wall is about 16.32%, 26.35%, and 36.7% at SO (15×25), (20×30), and (20×40) respectively.

c) The decreasing of lateral displacement for wall specimen as compared with solid wall is about 9.14%, 4.41%, and 25.2% at SO (15×25), (20×30), and (20×40) respectively.

d) The decrease of final load for SSCC wall specimen is about 12.195 %, 13.88%, and 24.39% for an increase in (SO) from (15×25 to 20×30), (20×30 to 20×40) and (15×25 to 20×40) respectively.

e) For the SSCC wall specimen, the reduction in lateral displacement is accompanied by growing (SO) from (20×30 to 20×40), and (15×25 to 20×40), the decrease in lateral displacement is approximately 21.78% and 17.71%, respectively. but from (15x25 to 20x30)there was an increase in lateral displacement by 5.21%.

f) For all panels of this group, cracks also spread around the corners of the openings.

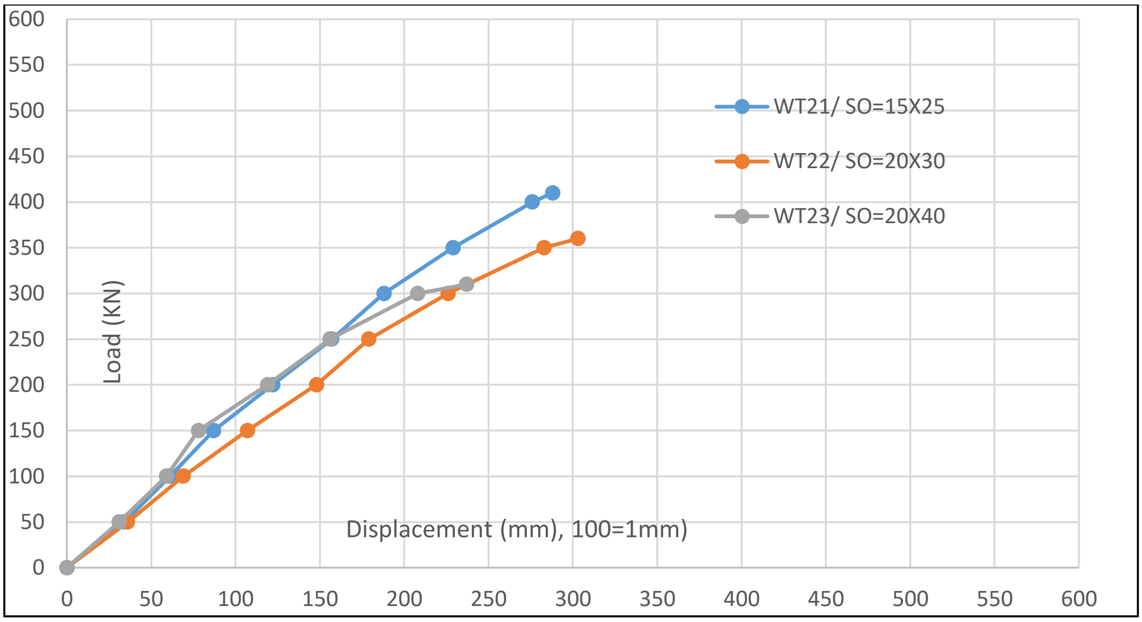

Figure 7: Opening's size (SO) effect On Ultimate load And Lateral Displacement

Furthermore, Figures (6) & (7) reveal the following results (one-way and two-way action):

a) The loading capacity of the SSCC wall panel increases by two-way action as compared with one-way action.

b) The rate of increase decreased and then increased as the opening size increased.

c) The increase in ultimate load for SSCC wall panels for change from one-way to two-way action was about 7.89%, 5.88%, and 6.89% at (SO) =15×25, 20×30, and 20×40 (cm) respectively.

d) The change of lateral displacement for SSCC wall panels for change from one-way to two-way action was about 10.83% decreasing at (SO) = (15×25), 8.99%, and 7.24% increase at (SO) = (20×30) and (20×40) respectively.

e) The number of cracks and their width differs between the two groups, as the increase in load capacity concerning the second condition of restriction made the cracks more numerous and widespread, in addition to the crack width being greater than in the first case.

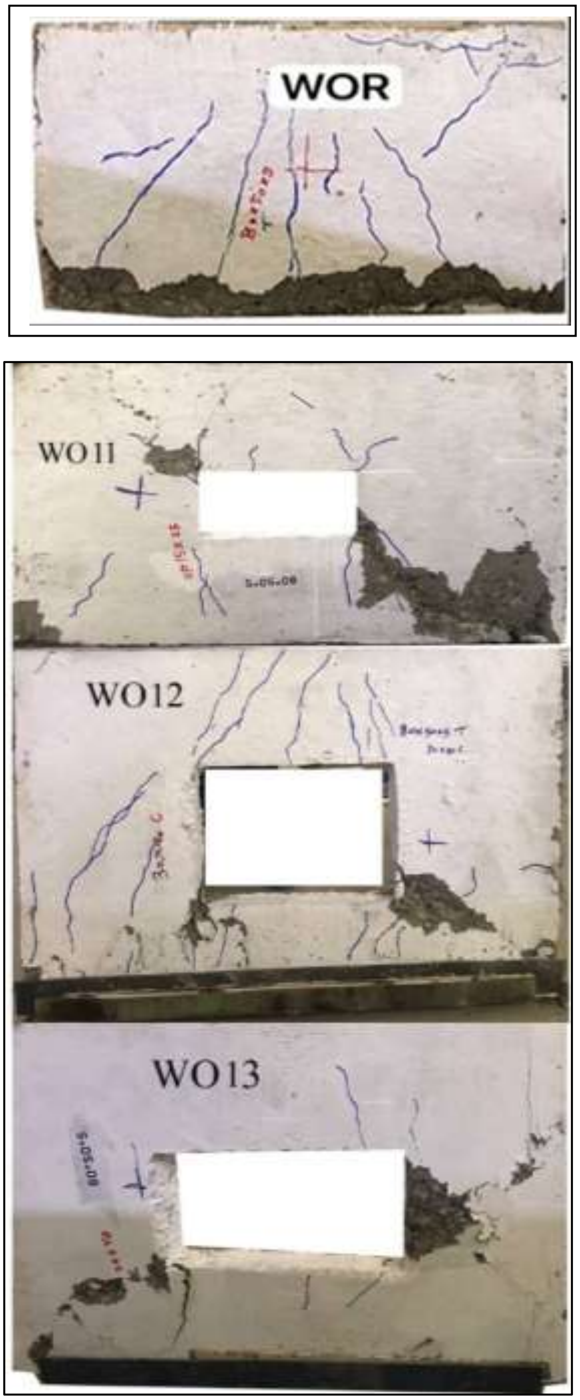

Figure 8: Crack pattern of first group

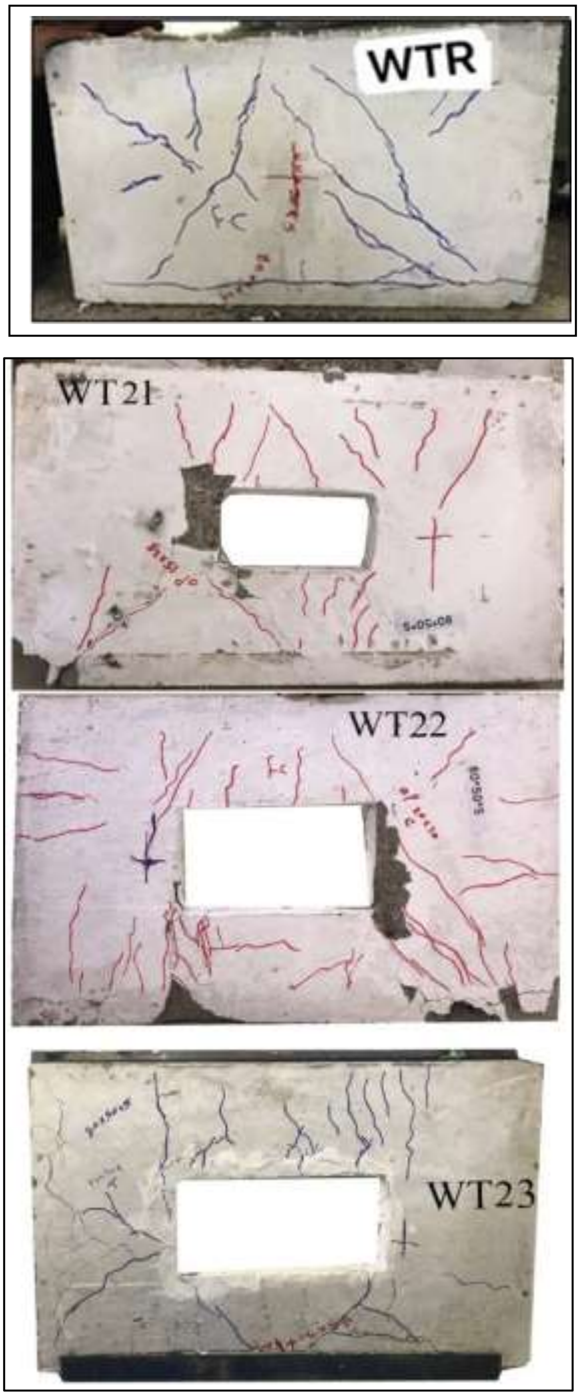

Figure 9. The crack pattern of the second group

7.3. Location of Openings by one-way action

The Effect of the location of openings (LO) on ultimate load and lateral displacement is shown in Figure (10) & (12) can be noticed in the following:

a. The loading capacity of the RCW specimens was affected by changing the location of the opening (LO) at the center, centerline near the edge, and at the corner.

b. The decreasing of final load for wall specimen as compared with solid wall is about 22.72%, 31.8%, and 38.6% with (LO) at the center, centerline near the edge, and corner respectively.

c. The decreasing of lateral displacement for wall specimen as compared with solid wall is about 24.45%, 15.7%, and 54.89% with (LO) at the center, centerline near the edge, and corner respectively.

d. The reduction of final load for SSCC wall specimens is about 11.76 % for change from center to centerline near the edge, 10% decreasing when change from the last to corner, and 20.58% for the change in location from center to corner.

e. The change in lateral displacement that accompanies the difference in the opening's location for SCC wall panels is about 11.51 % increasing for change from center to centerline near edge, 46.45% decreasing when change from the last to corner, and 40.28% decreasing for the change in location from center to corner.

f. The hole in the corner has less bearing and more cracking, unlike what it was in the middle, due to the decrease in the failure path from the corners of the holes to the corners of the sample.

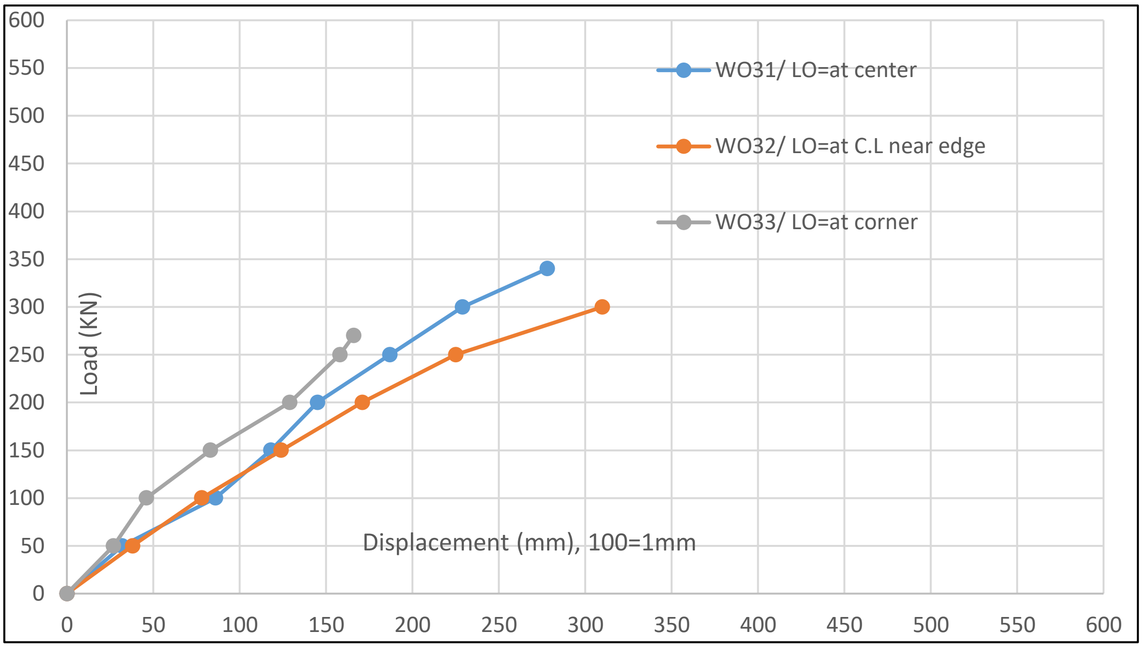

Figure 10: Effect of the location of openings (LO) On Ultimate load And Lateral Displacement

7.4. Location of Openings by two-way action

The Effect of the location of openings (LO) on ultimate load and lateral displacement is shown in Figure (11) & (13), and can be noticed in the following:

a. The loading capacity of the RCW specimens was affected by changing the location of the opening (LO) at the center, centerline near the edge, and at the corner.

b. The decreasing of final load for wall specimen as compared with solid wall is about 26.35%, 36.7%, and 38.7% with (LO) at the center, centerline near the edge, and corner respectively.

c. The decreasing of lateral displacement for wall specimen as compared with solid wall is about 4.42%, 8.83%, and 54.88% with (LO) at the center, centerline near the edge, and corner respectively.

d. The reduction of final load for SSCC wall specimens is about 13.88 % for change from center to centerline near edge, 3.2% decreasing when change from the last to corner, and 16.66% for the change in location from center to corner.

e. The change in lateral displacement that accompanies the difference in the opening's location for SSCC wall panels is about 4.62 % increasing for change from center to centerline near edge, 50.52% decreasing when change from the last to corner, and 52.81% decreasing for the change in location from center to corner.

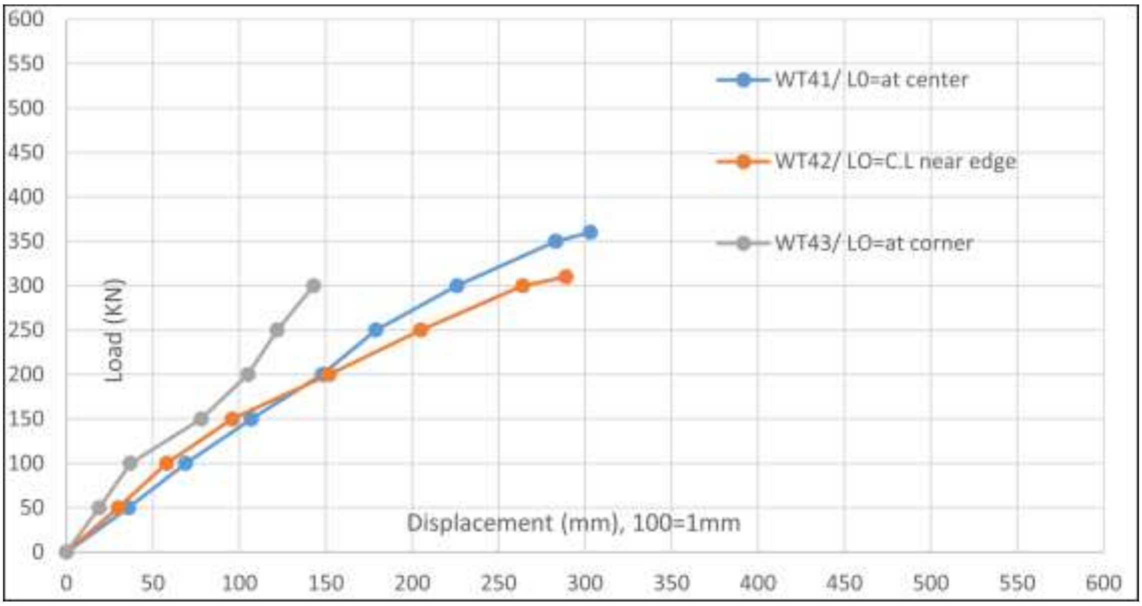

Figure 11: Effect the location of openings (LO) On Ultimate load And Lateral Displacement by two-way action

Furthermore, Figures (10) & (11) reveal the following results (one-way and two-way action)

- **a)** The loading capacity of the SSCC wall panel increases by two-way action as compared with one-way action.
- **b)** The rate of increase decreased and then increased as the location of the opening near to edges.
- **c)** The increase in ultimate load for SSCC wall panels for change from one-way to two-way action was about 5.88%, 3.33%, and 11.11% when (LO) is at the center, centerline near the edge, and at the corner respectively.
- **d)** The change of lateral displacement for SSCC wall panels for change from one-way to two-way action was about 8.99% increasing when opening at the center, 6.77%, and 13.85% decreasing when (LO) at the centerline near the edge and at the corner respectively.
- **e)** The cracks in the fully restrained case are more numerous and wider than those that appeared in one-way group samples as shown in Figure (12) & (13).

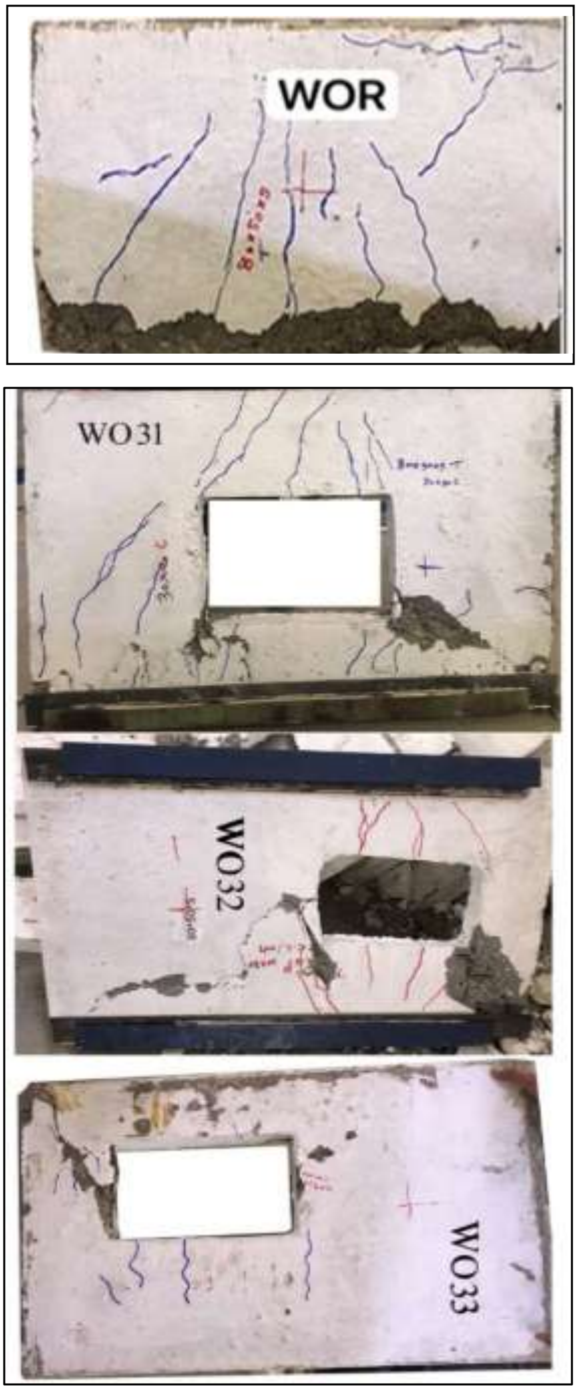

Figure 12. The crack pattern of the third group

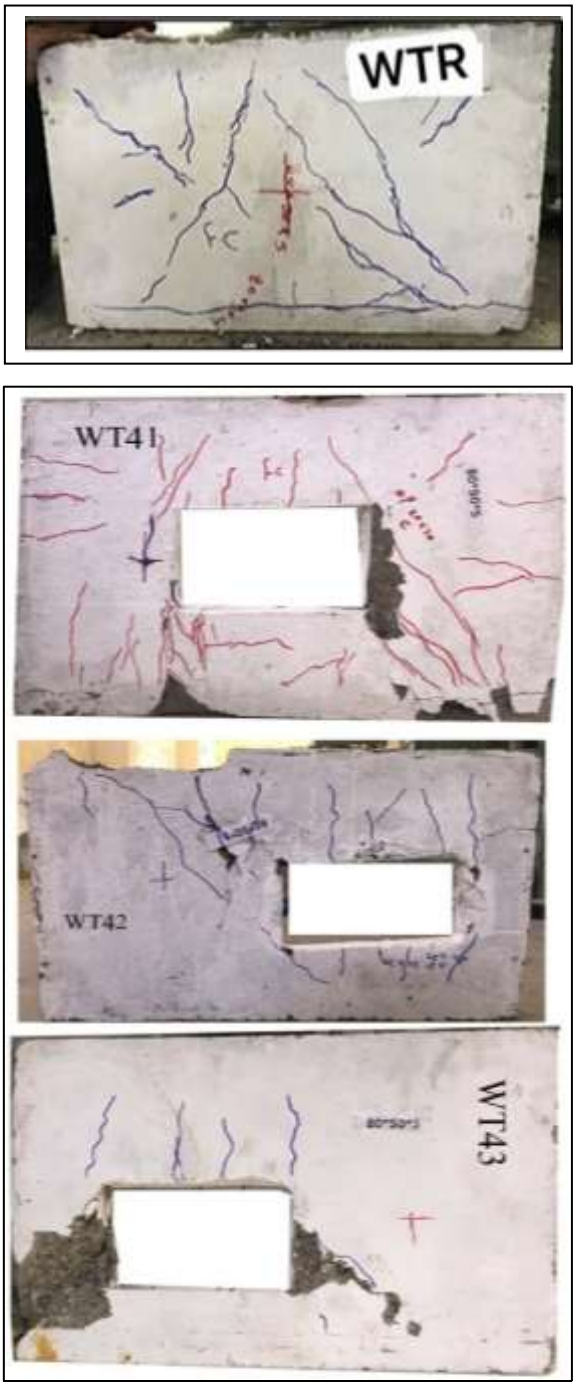

Figure 13. the crack pattern of the fourth group

8. Conclusion

1. The mechanical properties of Self-compacting concrete which was produced by using Attapulgite as a partial replacement of cement, improved after the Attapulgite addition.
2. Local manufactured Attapulgite is possible to be used for producing concrete mix as partial replacement of cement after grinding and burning it, to become an effective pozzolanic material.
3. The replacement ratio of 10% is optimal as compared with other portions of replacement, so it was adopted in the control mix.
4. The final load of RCW samples clearly and significantly decreased when opening dimensions increased, which decreased the bearing capacity of RCW samples.

5. Lateral restraints increase load capacity and reduce lateral displacement. As for the cracks, they are more numerous and widespread due to the additional load absorption as compared with one-way action which fails with single large main cracks.
6. In comparison to the uniaxial support, the support from all sides had a higher load capacity because it delays the bending and failure process by stopping the bending at the side margins of the walls.
7. As a result of establishing the stresses at the center of samples by two-way action, the failure mechanism is more likely to be crushing failure than bending, so the larger the openings or the closer to the edges, the less gained by side restrictions.
8. The change in the opening's location has a weighty influence on the final load, despite the similarity of the dimensions of the walls and openings.
9. The difference in the opening's location causes a change in the mechanism of failure and load transmission. When the openings were located at the center, it was the point farthest from the edges than the others.
10. The distance between the corners of the opening to the ends of the sample is considered the failure path, so the greater this distance the greater the loading capacity. This corresponds to the difference in the sizes of openings or their locations.

9. Recommendations for Future Works

1. Studying the effect of Attapulgite addition and glass powder together as a partial alternative to cement.
2. Studying the effect of Attapulgite addition with flexible plastic waste fibers.
3. Studying the effect of Attapulgite addition as an alternative to cement and an alternative to aggregate together.
4. Studying the effect of increased spacing of reinforcement mesh.
5. Studying the effect of increasing the eccentricity

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تأثير حجم وموقع الفتحات على السلوك الإنشائي لجدران الخرسانة المسلحة ذاتية الرص المتضمنة الأتابولجيت كبديل جزئي للسمنت

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المستخلص

هذا البحث تجريبي حول الأداء الإنشائي للجدران ذات الفتحات والخرسانة المستدامة ذاتية الرص معرض لأحمال محورية لامركزية موزعة بانتظام، تم دراسة تأثير الفتحات (الموقع والأبعاد) كذلك تأثير المساند ذات الاتجاه الواحد والمساند ذات الاتجاهين. يتضمن البرنامج التجريبي اختبار اثنا عشر لوح حائطي، نظام الانحراف المركزي لنظام التحميل يعادل سدس العمق. تم تقسيم هذه الألواح الجدارية إلى أربع مجموعات تتكون كل واحدة منها من ثلاث نماذج بالإضافة الى نموذجين مرجعيين، جميع النماذج بأبعاد(5×50× 80) سم. أوضحت المجموعة الأولى والثانية تأثير الفتحة بطريقة الفحص أحادية وثنائية الاتجاه وبأبعاد مختلفة للفتحات (15×25، 20×30، 20×40) سم، أشارت النتائج إلى انخفاض حمل الفشل بحوالي 10.52%، 14.7%، 23.68% للاتجاه الواحد و12.195% و 13.88% و 24.39% للاتجاهين عندما زادت أبعاد الفتحة من (15×25 الى 20×30) و(20×30 الى 20×40) و(15×25 الى 20×40) على التوالي. المجموعة الثالثة والرابعة لتأثير مواقع الفتحات من خلال الاسناد في اتجاه واحد وفي الاتجاهين، انخفض حمل الفشل عند اقترابها من الحواف 11.76%، 10% في الاتجاه الواحد، و13.88%، 3.2% في حالة الاتجاهين من (المركز إلى خط الوسط بالقرب من الحافة ومن الأخيرة إلى الزاوية) على التوالي.

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