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Structural Behavior of Axially Loaded Composite Concrete-steel Plate Shear Walls

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ABSTRACT

composite concrete-steel plate shear walls are the most critical resisting structural members that resist lateral and axial loads. This type of wall consisting of two steel faceplates presenting the outer skin, infill concrete and shear connectors which are used to provide the composite action of the steel faceplates with infill concrete in order to increase the strength and to reduce the local buckling of steel faceplates. The experimental investigation of composite concrete - steel plate shear walls under axial loads is presented in this research. The aim of this study is to evaluate the effect of concrete compressive strength and the thickness of the wall on the axial capacity, lateral displacement and axial shortening of the walls. The obtained results indicate that the increase in compressive strength of concrete enhances the ultimate axial load capacity of the wall and it should have an effect on crushing strength of the composite wall which can affect the failure loads of the composite walls. In addition, the concrete strength increased by enlarging the thickness of wall from 55mm to 70mm and this is because the concrete participation leads to large assistance to avoid relatively steel plate from premature buckling as well as, the concrete plays an important role in avoiding instability of steel plate. Thus, the failure load, lateral displacement at top and mid-height of the wall as well as the axial shortening at failure load increased by increasing the compressive strength and increasing the wall thickness of the wall. The failure of the composite walls was started by local buckling of the steel plates, cracking and crushing of the concrete infill in the top region of the composite wall.

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1. INTRODUCTION

Composite walls are one of the most critical components in a high-rise or super high-rise buildings which have long been the innovative type of lateral force resisting structural members that resist lateral and axial loads. With the increase of building height and the advance function requirements of architecture, the high performance demand for shear walls was proposed. Composite concrete-steel plate structural walls which have already been employed in actual practice in recent years become one of the new style structural walls. This type of wall consisting of steel faceplates, infill concrete, and connectors which are used to provide the composite action of the steel faceplates with infill concrete, to increase the strength and to reduce the local buckling of steel faceplates. This composite system found practical applications in sea-wall, underwater tunnel, blast walls, air-craft hangers, wave-energy generation systems and bridges [1]. Full bond should be ensured all stages of loading by providing either full –length studs, crossbars or overlapping studs of certain spacing.

Composite steel-concrete walls are also being used for third-generation nuclear plants and also being considered for small modular reactors. Safety-related nuclear structures have involved steel faceplates and infill unreinforced concrete where the earthquake resistance without the introduction of internal steel framing for gravity-load resistance. Tsuda et al. [2] tested four steel-concrete walls as bearing elements in nuclear power plants. The test specimens showed high ductility, high energy dissipation, and high blast resistance. The application of this system in construction requires a special joint system between the composite wall and the base to prevent wall and slippage which was the most critical problem for this system. Thus, the composite walls are traditionally used as axial and seismic load- resisting systems [2].

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The axial compression loading is regarded as a critical case because of the relative motion happens between the faceplate and infill concrete. Study on local buckling of steel faceplate of the steel-concrete wall can be traced back to 1980s when this type of such construction was first used. Steel-concrete construction in safety-related facilities takes great attention on local buckling and plate slenderness ratio. Several researchers have experimentally studied the compressive behavior of steel-concrete composite walls. Kanchi et al. [3] executed compression tests on 11 SC wall having slenderness ratios varying from 20 to 50. These walls divided into C4 series had 4.5mm thick plate with S/tp ratio of 20, 25, 30 and 50, also C6 series walls had 6mm thick steel faceplate with S/tp ratio of 20, 25, 30, 35 and 40. In addition, there were two supplementary specimens fabricated using steel plate with diverse yield strength [3]. Hao et al. [4] investigated the axial compression behavior of a composite shear wall, having different layout forms of steel plate. A total of three tests were carried. Two composite wall with built-in steel plate, and the other one with two skins of steel plate. The experimental results showed that the different layout forms of steel plate have a great influence on its buckling which can affect the bearing capacity of the plate. The axial compressive strength of SC shear wall with confined concrete increases according to the buckling effect of steel plate. The calculated equation of axial compression of composite wall was put forward, and the calculated results were in good agreement with the test results [4]. An experimental investigation on the punching shear strength of reinforced concrete flat plate slabs with spearhead collars carried out by Majeed and Abbas [5] Eight reinforced concrete slab specimens were cast and tested under static load tests. The effect of the shapes, diameter, and the number of stiffeners have been discovered for spearheads through studying its effect on load-deflection behavior, ultimate capacity, cracking load, failure mode, stiffness, ductility, and energy absorption of tested specimens [5]. Emeka et al. [6] studied the engineering behavior of erodible soil-quarry dust composite at a proportion of 50% quarry dust and 10% cement. The behavior of steel plate shear walls with the various connection of infill plate to columns in multi-span moment frames studied by Raisszadeh et al. [7]. The results showed that reducing the infill plate connection to columns will reduce the axial forces in columns. Rastegarian and Sharifi [8] studied the correlation between inter-story drift and structural performance objectives of RC intermediate moment frame. Fadhil et al. [9] evaluate the effect of the corrugation angle and its direction on the performance of CSPSW under cyclic loading. It indicates that the use of CSPSW with vertical corrugation provides higher strength, stiffness, and ductility compared to CSPSW with horizontal corrugation. According to this review, it is clear that there is a need to study the behavior of composite concrete-steel plate shear wall with embedded connectors welded vertically to the faceplates parallel to the height of the wall which delay the buckling of steel faceplate. In this study, strengthening of the concrete walls by using external steel faceplates have a significant effect on raising the bearing capacity of the walls and reducing the lateral and axial displacement in comparison with the concrete walls, by varying some parameters such as compressive strength and thickness of wall.

2. EXPERIMENTAL PROGRAM AND MATERIALS

The plan of experimental work consists of casting and testing six of composite walls divided into two groups, each group consisted of three composite walls, the first one with normal compressive strength (39MPa), the second with high compressive strength (55 MPa) and the third with high compressive strength (63MPa) as shown in Table 1. The experimental program used in this study is shown in Figure 1. The composite walls for each group with dimensions of total length (600mm), a height of (1000mm), same aspect ratio (H/L=1.667mm), the same thickness of steel plates (tp=1.5mm), same slenderness ratio (S/tp=100), but with different thickness of the wall.

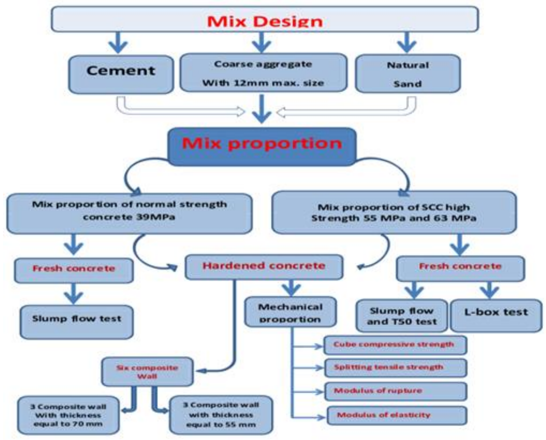


Figure 1. Schematic representation of the experimental program

TABLE 1. Details of all groups

GrouGroup	Wall Dimensions	Cube Compressive strength	Thickness of plate tp (mm)	Steel plate Slenderness ratio (s/tp)	Aspect ratio H/L	Rein. Ratio
1	1000*600*55	39 55 63	1.5	100	1.667	5.4%
2	1000*600*70	39 55 63	1.5	100	1.667	4.2%

The composite wall thickness of the first group (55mm) while the thickness of the composite wall of the second group(70mm) which led to various reinforcement ratio (2tp/T=5.4%) for the first group and (4.2%) for the second group. Where S represents the distance between steel channels equal to (150mm). The details of all groups can be shown in Figure 2.

In all groups, the test walls consisted of a test -wall portion and a base. The wall base was (350mm) thick, (400mm) width, and (600 mm) length and reinforced by using ϕ12 mm deformed steel bar as longitudinal reinforcement (4 ϕ 12) top and (4 ϕ 12) (Bottom reinforcement) and using of ϕ 10 mm deformed steel@125mm as stirrups shear reinforcement which makes it stronger compared to the wall panel as shown in Figure 2 (a). The steel plate is embedded into the wall base through the cage reinforcement as shown in Figure 2 (d).

The mechanical properties for both rebar and steel plates were obtained from the tensile testing of three samples according to ASTM designation (C370 – 05a, 2005) [10]. See Tables 2 and 3.

Ordinary Portland cement (Type I) of (Tasluja factory), natural sand (AL-Ukhaider) as well as crushed gravel with a maximum size of particles (12mm) were used in this study for the normal and high strength. The grading curve for the materials used can be shown in Figure 3. Thus the normal strength mix can be obtained without using admixture and it was designed according to literature [11] while high strength mix consisted of the Superplasticizer which is commercially known as (Sika discrete, 5930), as well as Silica Fume which is used to produce the self-compacting concrete mix (SCC) which was designed according to literature [12]. The weight of materials for the normal strength mix and (SCC) mix used in the present work can be shown in Table 4. The adding of superplasticizer which meets with standards [13] types G and F led to improve in workability of the concrete mix. Superplasticizer concrete exhibited a large raising in a slump without segregation. Besides, adding of silica fume improve the durability of the concrete and gives good improvement of the rheological mechanical and chemical properties, good resistance segregation due to its high level of finesse and practically spherical shape of it which results in good cohesion as well as the mechanical and chemical properties.

3. INSTRUMENTATIONS AND MEASUREMENTS

A series of strain gages, dial gages instruments as well as handled data logger (TC-32K) are used to monitor the response of the tested walls in order to measure critical

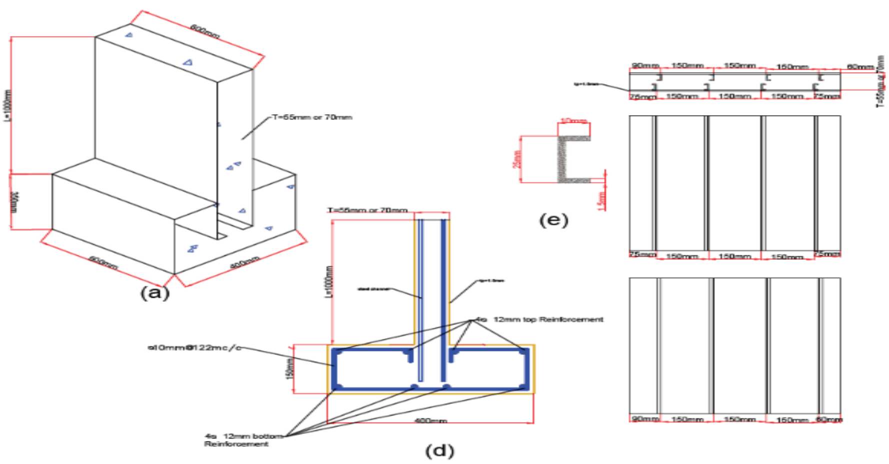


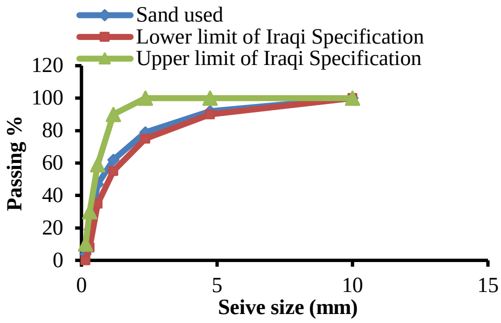
Figure 2. Details of all groups (a) isometric view of wall (b) top of the wall (c) right plate with steel channel (d) section through all wall (e) dimension of steel channel (f) left plate with steel channel

TABLE 2. Mechanical properties of steel bars reinforcement

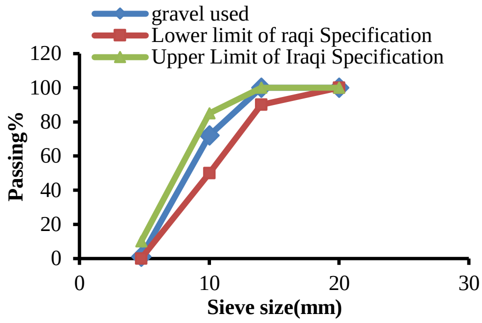
Nominal diameter	Surface texture	Yield stress (MPa)	Ultimate stress (MPa)	*ES* (GPa)	Elongation%
12	deformed	550	640	200	10.5
10	deformed	565	655	200	8.5

TABLE 3. Mechanical properties of the steel plate and steel channel

Materials	Thickness (mm)	Surface texture	Yield stress (MPa)	Ultimate stress (MPa)	*ES* (GPa)	Elongation%
Steel plate	1.5	mild steel	270	350	192	34.2
Steel channel	1.5	mild steel	275	355	193	34.2



(a)Sand



(b)Gravel

Figure 3. Grading curves for materials

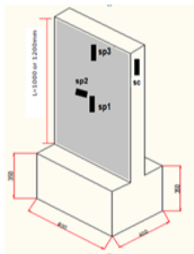
TABLE 4. Mix proportions of normal strength and high strength concrete

Mix No.	w/c	Water (kg/m3)	Cement content (kg/m3)	Sand content (kg/m3)	Gravel content (kg/m3)	S.P (L/m3)	Silica Fume (kg/m3)	Cube compressive Strength f'c MPa (28 days)
1	0.55	203	370	750	792	-	-	38.6
2	0.46	185	400	798	760	5.5	20	52
3	0.36	160	440	770	880	13.5	22	61.4

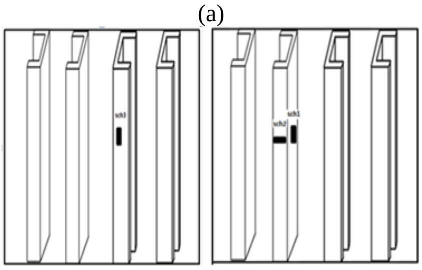
response quantities. Strain gages were used to provide supplementary information on load levels at which rebar and steel plate yielding achieved which were attached at different positions on the walls. TML strain gauges of type (FLA-6- 11-3 LJC) were used for steel plate and steel reinforcement in which the gage length equal to 6mm and its width equal to 2.2mm and have a resistance of 120 Ω, while (PL -6- 113LJGF) is represent the type of strain gage equal to 60 mm length and 1 mm width and a resistance of 120Ω which used for concrete as shown in Figure 4. Several dial gages instrumentation of 0.01 mm accuracy were used to measure both axial (vertical) and lateral deformations at different positions at mid-height, at a distance from top as well as at top and bottom of each wall specimens as shown in the plate (See Figure 5).

4. CASTING AND CURING

All walls were cast and cured in laboratory conditions at the structures laboratory, Department of Civil Engineering, Diyala University. Before casting the wall specimens, the formwork was cleaned firstly and placed on a plane floor. Then it painting with oil to prevent the concrete from lubricated sticking to the shuttering surface e.g. plywood. All reinforcement bars were earlier prepared, then the reinforcement cage was put in its position. Then after that, the steel plate was inserted in the wall base. Through the reinforcement cage and they are fixed by using a horizontal wooden beam as shown in Figure 6 which they are connected by using the control of the balanced of the wall using spirit level. The materials were mixed and the fresh properties of concrete were tested. Three 150mm x 150mm x 150mm cubes



(a)



(b)

Figure 4. Location of strain gages on (a)steel plate(b)steel channel

Figure 5. Location of a dial gauge

were cast and used to measure the compressive strength (f'c), three cylinders of 150mm x 300mm used for measuring split tensile strength (fct), and three 500mm x 100mm x100mm prisms were cast and used for determining the modulus of rapture for concrete (fr) for each group. Then after that, the walls were cast. After finishing the casting of walls. They were demolded 24 hours, and then after that, the mold and the wooden beams removed. After that they cured by using dump blanket (cover) and sprinkled continuously with water for 28 days. After the end of curing period, the walls were white-painted to help in the observation of local buckling of steel plate and crack improvement through testing (See Figure 6).

5. TEST-SET UP

A hydraulically universal testing machine of (3000 kN) capacity available was used to test all walls specimens. The tested walls were composite walls subjected to an axial compressive load by making some arrangements before the test. The composite walls were prepared for testing by setting the positions of them over steel plate of dimension (2cm x 44cm x 70cm) (thickness x width x length). The dial gauges were fixed in their position. After the top hinge support steel frame I-section has been fixed tightly to the test machine by many clamps at top, the composite walls were subjected to monotonic-static loads in successive increments, until failure.

6. FAILURE MODES

The failure mode of all the tested walls was closely witnessed during the axial compression tests. For the case of composite walls, the steel plates experienced local buckling in the left and the right side of the composite wall. The concrete infill was capable of avoiding the composite wall from local buckling. In all cases, failure of the concrete infill in the top region of the composite wall. Suddenly, a macro-crack was started at front and the backside of the composite wall, in addition to concrete cracks which were gathered at the base of the wall. Concrete is crushed at the top height of the front and backside of the composite wall. There no separation of the steel plate from the concrete core was observed until near failure, indicating that the steel channel was able to hold the steel sheeting and the infill together to enable them to resist the applied load in composite action. The failure mode of the two groups are shown in Figures 7 and 8.

Figure 6. The casting of the walls

7. RESULTS AND DISCUSSION

The general behavior of the tested walls under axial load is studied while varying some parameters, such as concrete strength and thickness of the wall.

7. 1. Effect of Concrete Strength

In order to study the effect of increasing the compressive strength of concrete on the behavior of walls, three targets of cube

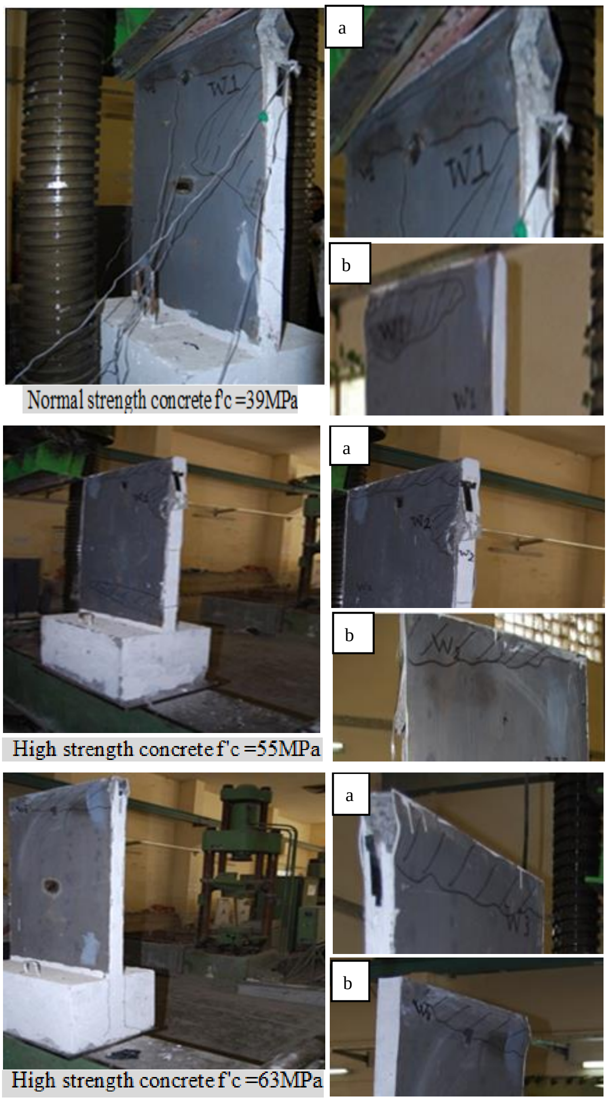


Figure 7. The failure mode of the tested walls (group1), (a) Right side, (b)Left side

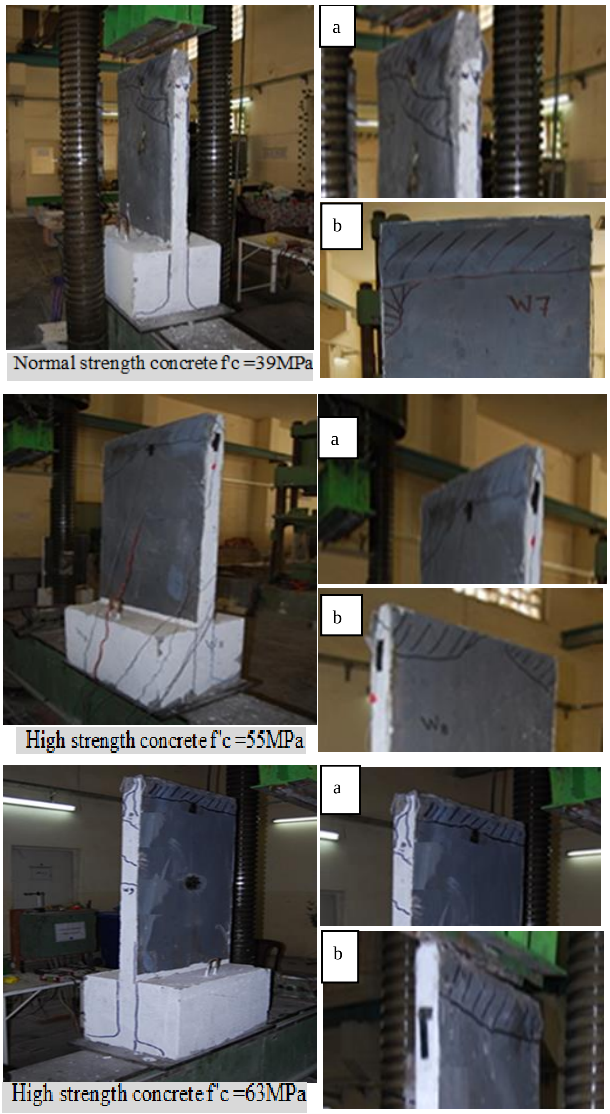
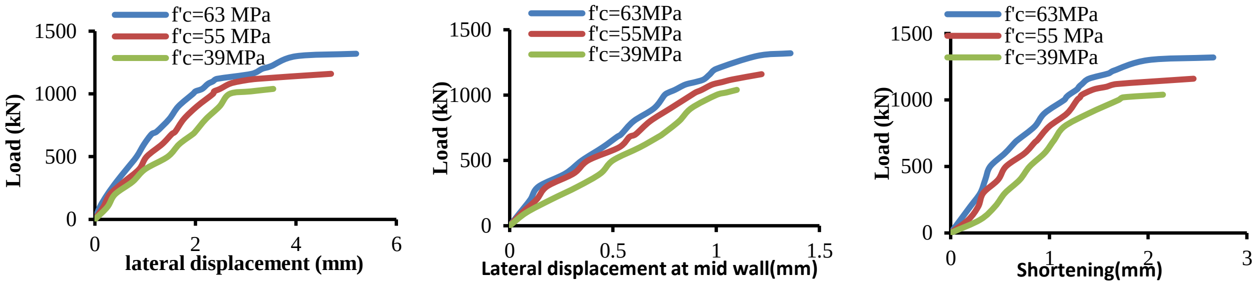


Figure 8. The failure mode of the tested walls (group2), (a) Right side, (b) Left side

strength values of 39 MPa, 55MPa and 63MPa, were provided for each group in this study to assess their effect on the axial capacity of the wall. The increase in compressive strength of concrete enhances the ultimate axial load capacity of the wall and it should have an effect on the crushing strength of the wall which can affect the failure loads of walls. It can be obtained that the lateral displacement and the shortening of the walls decrease with an increase in compressive strength at the same load. For the case of composite wall with thickness 55mm, the obtained results indicate that the failure load, the corresponding lateral displacement at top and mid-height of the wall as well as the axial shortening increased by about (11.5, 32.3, 10.9 and 14.4%), respectively as the compressive strength increased from (39MPa) to (55MPa) and by about (13.8, 10.6, 11.5 and 8.1%), respectively as concrete strength increased from (55MPa) to (63MPa). Accordingly, the increase in failure load was (26.9% increase), as compressive strength increased from (39MPa) to (63MPa) (See Figure 9).

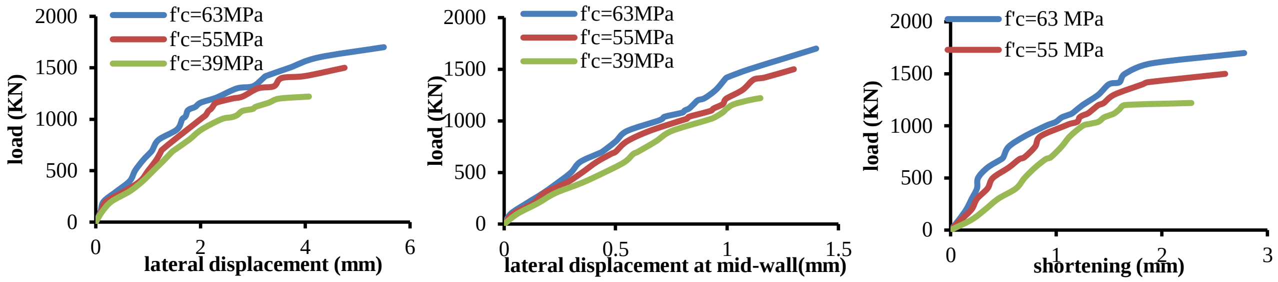
From Figure 10, for the case of composite wall with thickness 70mm, it can be obtained that increasing compressive strength from (39MPa) to high strength (55MPa) results in increasing the failure load, the corresponding lateral displacement at top and mid-height of the wall as well as the axial shortening by about (22.9, 16.7, 13 and 14%), respectively and by about (13.3, 15.6, 7.7 and 6.9%), respectively as concrete strength increased from (55MPa) to (63MPa). Thus, the increase in failure load was (39.3% increase) as compressive strength increased from (39MPa) to (63MPa).

7. 2. Effect of Wall Thickness The effect of wall thickness on the behavior of walls was evaluated by using two different wall thicknesses (55mm) and (70mm). Several observation can be made from analyzing the characteristic concerning the axial behavior of the wall specimens: firstly, it can be observed that the concrete strength increased by increasing the wall thickness and this is because the concrete participation lead great assist to avoid relatively steel plate from previous buckling and thereof utilizes the bearing capacity of steel side plate to fullest extent. Besides, the concrete plays an important role in avoiding the instability of the steel plate. As the wall thickness increased, the ultimate axial load capacity increased.



(a) (b) (c)

Figure 9. Results of the first group (a) load versus lateral displacement at the top height of the wall (b) load versus lateral displacement at mid-wall (c) load versus axial shortening



(a) (b) (c)

Figure10. Results of the second group (a) load versus lateral displacement at the top height of the wall (b) load versus lateral displaceme at mid-wall (c) load versus axial shortening

Thus, it could be obtained that increasing thickness of wall which led less reinforcement ratio with retained all other parameters constant led to increasing the failure load and the corresponding lateral displacement as well as axial shortening of the wall.

According to Figure 11, it can be obtained that the increasing in lateral displacement at the top, mid-height of the wall, as well as the axial shortening, was about (17.3, 14.6, 4.5 and 6%), respectively as the thickness of the composite wall varied from 55mm to 70mm at compressive strength equal to 39MPa.

For the case of composite walls with same compressive strength (55MPa), increasing the wall thickness from 55mm to 70mm results in increasing the failure load and the corresponding lateral displacement at top and mid height of the wall as well as the axial shortening at failure load by about (29.3, 1, 6.6 and 5.7%), respectively as shown in Figure 12.

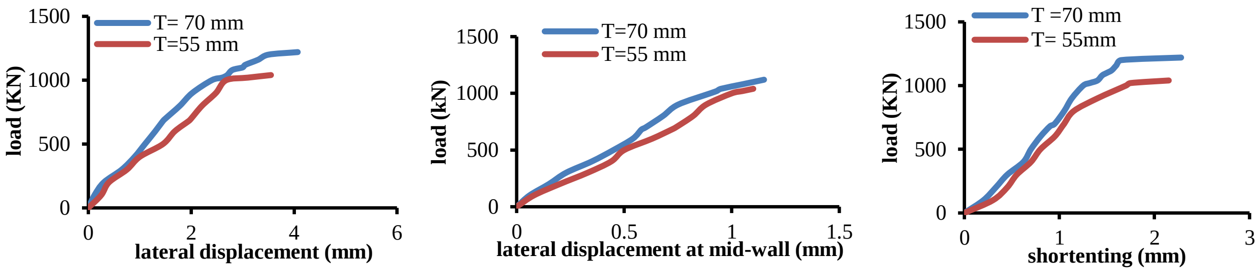
A compressive strength (63MPa), increasing the wall thickness from 55mm to 70mm led to increasing the failure load and the corresponding lateral displacement at top and mid-height of the wall as well as the axial shortening by about (28.8, 5.8, 2.9 and 4.5%), respectively (See Figure 13).

8. AVERAGE STEEL PLATES STRAINS

In order to measure the strain in steel plates. Three strain gauges were used for this purpose. Two strain gauges were bonded at mid-height of each wall specimen in order to measure strains in the outer surface of the steel plate including vertical and horizontal layout. One strain gage attached at a distance from top at the outer surface of steel plate in vertical layout. Figures 14 (a) to 19 (a) describes the curves of the axial load versus the steel plate strain, which are the average values of the top and mid-height strains, with the negative value corresponding to the compression and with a positive value corresponded to the tension strain (transverse strain).

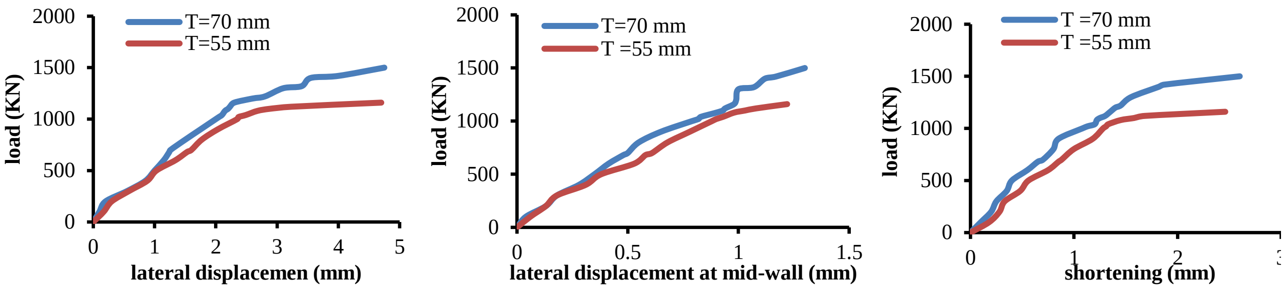
It was observed that the throughout the total loading process, the increase rate of the vertical strain was greater than that of the transverse strain, which shown that vertical deformation became the major, as well as the vertical strain at top height of steel plate, was greater than both of vertical strain and the transverse strain at mid-height of the wall.

Local buckling of steel plates happens previous than the steel plate yielding. The steel plate bends slightly after buckling because of uniform compression, and the deflection in the central section at top height of the composite walls is more than that at the two edges. The flexural shortening in the central section outweighs that at the two edges, which intends that the stress redistribution happens with larger stress at the two edges, and fewer stress in the central section. After local buckling of the steel plate takes place, the stress at the two edges continue to increase, till the yielding of the steel plate, as well as the stress in the central section no longer increases.



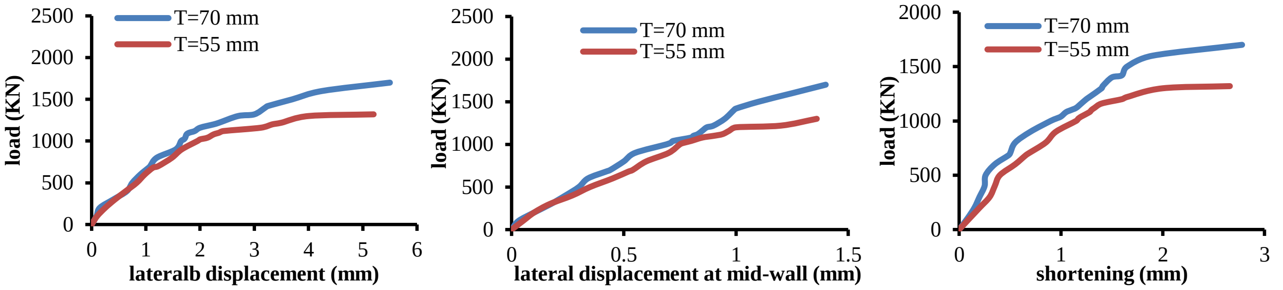
(a) (b) (c)

Figure 11. Comparison at compressive strength equal to 39MPa (a) load versus lateral displacement at the top height of the wall (b) at mid-height of the wall (c) load versus shortening



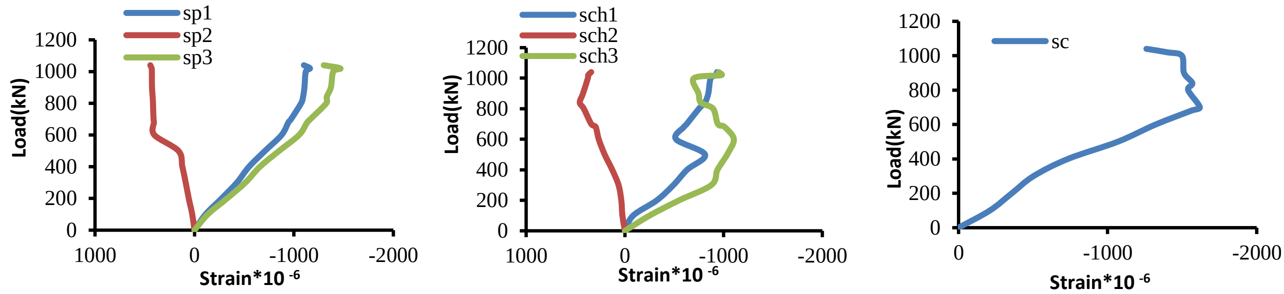
(a) (b) (c)

Figure 12. Comparison at compressive strength equal to 55MPa (a) load versus lateral displacement at the top height of the wall (b) at mid-height of the wall (c) load versus shortening



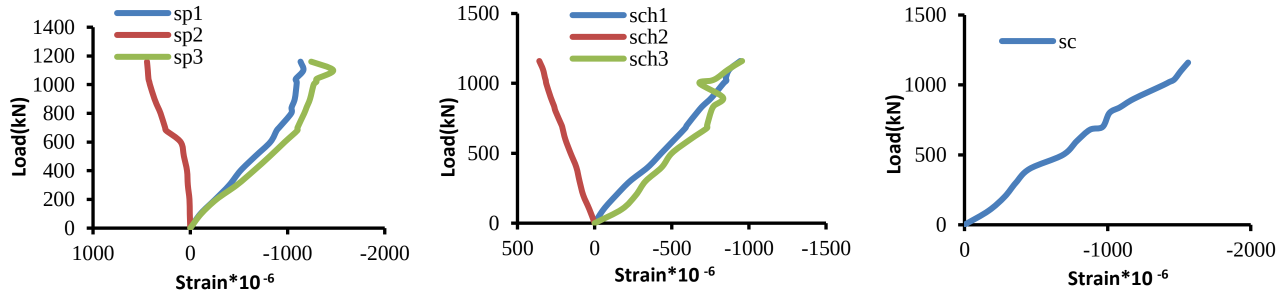
(a) (b) (c)

Figure 13. Comparison at compressive strength equal to 63MPa (a) load versus lateral displacement at the top height of the wall (b) at mid-height of the wall (c) load versus shortening



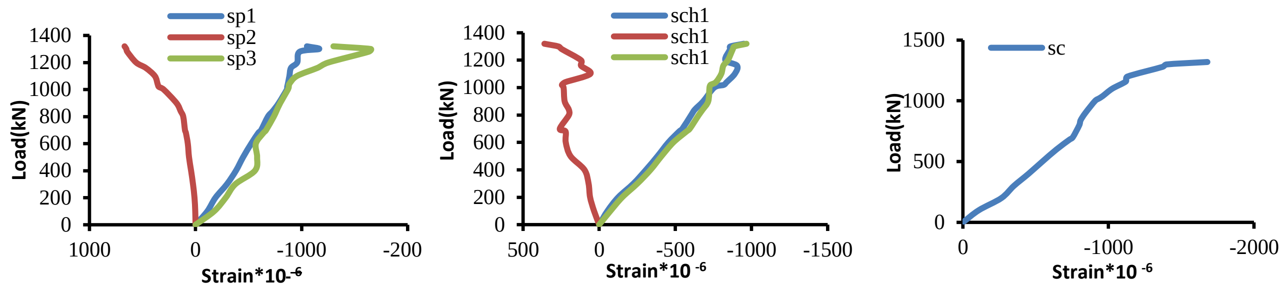
(a) (b) (c)

Figure 14. Applied load versus steel and concrete strains for composite wall with compressive strength 39MPa and thickness 55mm (a) strain in steel plates (b) strain in steel channel (c) strain in concrete



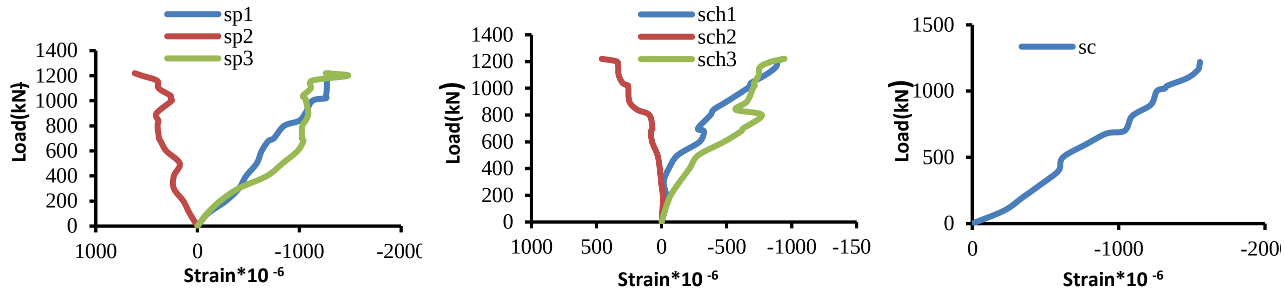
(a) (b) (c)

Figure 15. Applied load versus steel and concrete strains for composite wall with compressive strength 55MPa and thickness 55mm (a) strain in steel plates (b) strain in steel channel (c) strain in concrete



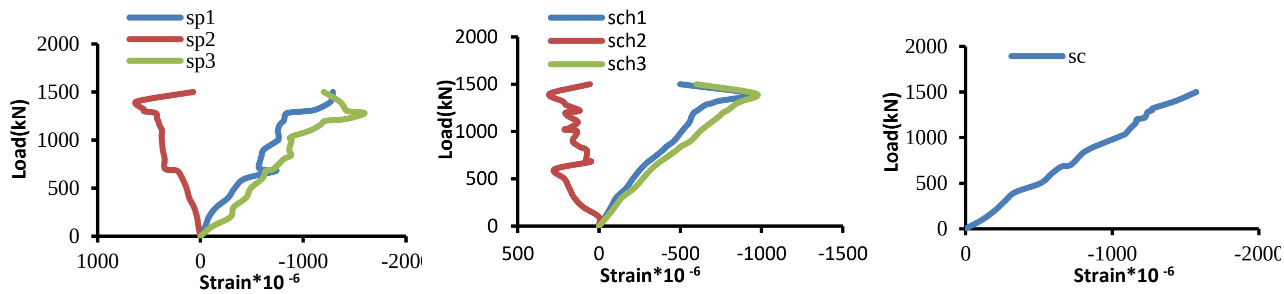
(a) (b) (c)

Figure 16. Applied load versus steel and concrete strains for composite wall with compressive strength 63MPa and thickness 55mm (a) strain in steel plates (b) strain in steel channel (c) strain in concrete



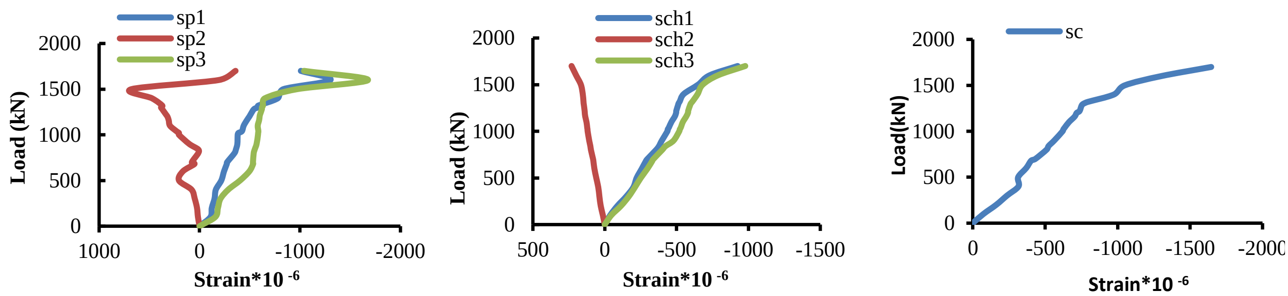
(a) (b) (c)

Figure 17. Applied load versus steel and concrete strains for composite wall with compressive strength 39MPa and thickness 70mm (a) strain in steel plates (b) strain in steel channel (c) strain in concrete



(a) (b) (c)

Figure 18. Applied load versus steel and concrete strains for composite wall with compressive strength 55MPa and thickness 70mm (a) strain in steel plates (b) strain in steel channel (c) strain in concrete



(a) (b) (c)

Figure 19. Applied load versus steel and concrete strains for composite wall with compressive strength 63MPa and thickness 70mm (a) strain in steel plates (b) strain in steel channel (c) strain in concrete

Based on the testing results of steel plates, the yield strain ε_{yield} of the steel plate with the thickness (1.5mm) (1406$\mu\varepsilon$) while the yield strain of the steel channel was (1425$\mu\varepsilon$). For all the tested wall, it can be seen that the strain increased linearly at the initial stage of applying load. Nevertheless, the strain rapidly increased with increasing applied load. The average strains recorded by strain gage sp3 -attached vertically on top of the tested walls-were higher than yield strain for all specimens. While the average strain of other strain gages (sp1, sp2, sch1, sch2 and sch3) of the tested walls were less than its yield strain. In addition, three strain gauges were attached to the web and flange of the steel channel. One of them attached vertically on the web of steel channel, the second is the transverse strain on the flange of the steel channel. The last is a vertical strain on the flange of the steel channel.

Figures 14 (b) to 19 (b) shows that the vertical strains are more than a transverse strain as well as the strain gage attached vertically on the flange surface of steel channel have strain readings more than the readings of strain gage attached vertically on the web of steel channel.

9. AVERAGE CONCRETE SURFACE STRAINS

Measuring the concrete strains gave an idea regarding the maximum concrete surface strains and showed how the formation of the first crack took place. Besides, concrete strain gauges assisted in better understanding the flow of forces from the load point to the nearest support. One strain gauge attached on the top thickness of wall sc). At early periods of loading, all-composite walls behaved linearly and the developing surface concrete strains were small. During a further increase in the applied load, a sudden change in the average strain values took place which meant the formation of first cracks. Then, concrete cracking became observable and strains increased at a rising rate with respect to the applied load. Gauges on the concrete were affected at first by cracks initiation; then, their readings increased directly after first cracks were widened. It has been observed from strain diagrams shown in Figures 14 (c) to Figure 19 (c), that the maximum compressive strain of the tested walls was about (0.0016).

10. CONCLUSION

Reinforcement of the concrete wall by using external steel faceplates plays an important role in raising the constancy of steel plates, whereas the steel plates serve as enduring formwork for the concrete infill also have an effect on rising the bearing capacity of the walls and decreasing the lateral and axial displacement. Based on the results obtained in this research the following points are concluded:

1. The lateral displacement and the shortening of the composite will depend on the concrete strength and the thickness of wall.
2. As the concrete strength increased, the lateral displacement and shortening decrease at the same load.
3. As the thickness of the wall increased, the lateral deflection decrease at the same load.
4. The failure load for the tested wall increased with an increase in compressive strength. Accordingly, increasing the compressive strength f′c from 39 to 63.3 (i.e. 62.3%increase) results in increasing the failure load about (26.9 and 39.3%) for case of composite wall with thickness (55 and 70mm), respectively.
5. The failure load for the tested wall increased with the increase in the thickness of wall. Accordingly, increasing the thickness of wall from 55 to 70mm led to increasing the failure load by about (17.3, 29.3 and 28.8%) at compressive strengths (39MPa, 54.75MPa, 63.3MPa), respectively.
6. The failure mode of all the tested walls was local buckling of the steel faceplate as well as cracking and crushing of concrete in the top region of the composite wall.

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Structural Behavior of Axially Loaded Composite Concrete-steel Plate Shear Walls

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چکیده

دیوارهای برشی صفحه بتونی فولادی کامپوزیت مهمترین اعضای سازه مقاوم در برابر بارهای جانبی و محوری هستند. این نوع دیواره متشکل از دو روکش فلزی است که دارای قسمت بیرونی پوست، اتصالات بتونی و برشی است که برای تأمین عملکرد کامپوزیت روکش‌های استیل با بتن تزریق به منظور افزایش استحکام و کاهش فشار داخلی جبهه‌های فلزی استفاده می‌شود. در این پژوهش تجربی دیوارهای برشی صفحه بتنی- فولادی با بارهای محوری ارائه شده است. هدف از این مطالعه بررسی تأثیر مقاومت فشاری بتن و ضخامت دیواره بر ظرفیت محوری، جابجایی جانبی و کوتاه شدن محوری دیوارها است. نتایج بدست آمده حاکی از آن است که افزایش مقاومت فشاری بتن باعث افزایش ظرفیت بار محوری نهایی دیواره می‌شود و بایستی در مقاومت خردکننده دیواره کامپوزیت تأثیر داشته باشد که می‌تواند بر بارهای خرابی دیواره‌های کامپوزیت تأثیر بگذارد. علاوه بر این، استحکام بتن با بزرگنمایی ضخامت دیواره از ۵۵ میلی‌متر به ۷۰ میلی‌متر افزایش یافته و دلیل آن این است که مشارکت بتن منجر به کمک بزرگی برای جلوگیری از صفحه نسبتاً فولادی از کمانش زودرس می‌شود و همچنین بتن نقش مهمی در جلوگیری از بی‌ثبات بودن بشقاب استیل دارد. بنابراین با افزایش مقاومت فشاری و افزایش ضخامت دیواره دیافراگم، بار خرابی، جابجایی جانبی در بالا و ارتفاع متوسط دیواره و همچنین کوتاه شدن محوری در بار خرابی افزایش می‌یابد. خرابی دیواره‌های کامپوزیت با کمانش محلی صفحات فولادی، ترک‌خوردگی و خرد کردن لکه‌های بتونی در قسمت بالای دیواره کامپوزیت آغاز شد.

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