Original Research Article

Flexural Behavior of Composite Slab

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ABSTRACT

Aims: This study deals with the enhancement of the longitudinal shear interaction at the concrete-profiled steel sheeting interface of composite slab by using shear connectors. The push out and flexural tests are carried out with the same shear connection details.

Place and Duration of Study: The test is carried out in RC laboratory at Faculty of Engineering in Benha, Benha University, Egypt, between May 2014 and March 2015.

Methodology: Fourteen push out specimens with different configurations were built in, of which five specimens with steel deck thickness of 0.7 mm and nine specimens with steel deck thickness of 1.2 mm. For each profiled steel sheeting thickness one specimen is assigned as a control specimen and the other specimens were enhanced with different types of shear connectors such as self-drilling screws with different length and spacing, cold formed members with different shapes (U & C) and different spacing . Eleven large scale specimens with different configurations were prepared. Four specimens were prepared with profiled steel sheeting of 0.7 mm thickness and seven specimens with profiled steel sheeting thickness of 1.2 mm. One control specimen for each profiled steel sheeting thickness was also prepared. The other specimens were enhanced with different types of shear connectors: self-drilling screws with different length and spacing and cold formed members with different shapes (U&C) with different spacing.

Results: The test results show that the failure mode of composite slab can be improved to ductile type and the load carrying capacity can be increased by the presence of the shear connectors. The load performance of the slab is also affected by changing the profiled steel sheeting thickness.

Keywords: Composite slab, Push out test, Shear connectors.

1. INTRODUCTION

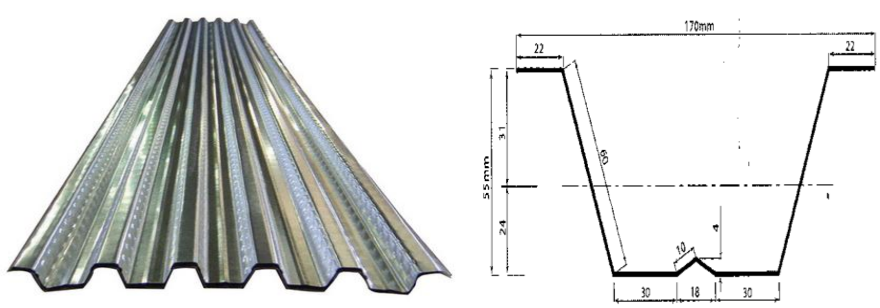
Cold-formed steel decks have been widely used in composite slab systems in steel Structures. The knowledge about the interaction between the composite elements and its mechanical behavior has progressed rapidly during the past two decades. The composite slab system has proven to be very desirable to structural designers because of many advantages in comparison with conventional systems of reinforced concrete slabs such as high rate of construction, shallow construction, saving in weight, safe method of construction, saving in transport, sustainability easy installation of services. Deck profile, thickness and strength of steel sheeting, span length and construction details affected the behavior and strength of composite slab. The composite slab under flexural has three modes of failure: first mode is flexural failure which happened when interaction at the interface between concrete and steel is completely achieved. Flexural failure type is usually occurs in long thin slabs. The vertical shear failure, which is the second mode, is occurs when the slab is very short and thick with a high concentrated load near the supports. Longitudinal shear failure, which is the third mode, which is commonly referred to as shear bond failure is the mode more likely to occur for most composite slab systems subjected to vertical loads. Shear bond strength can be divided into three components namely chemical bond, friction bond and mechanical bond. Chemical bond exerts shear resistance with no slip at the interface. Once this bond is lost, slip is initiated and the chemical bond strength reduces to zero and does not restore. The frictional bond is a direct result from the application of normal forces, which act perpendicular to the steel-concrete interface. Friction bond is directly proportional to the normal force, so that if the normal force is zero then there is no frictional force. Mechanical bond exists due to physical interlocking between the steel sheeting and the concrete. The interlocking is developed as a result of clamping action caused by the bending of steel deck, and forms the friction between the steel sheeting and the concrete due to surface roughness such as indentation or embossment on the steel surface. The interaction between the steel deck and the concrete is complex and difficult to model mathematically. So the design and analysis procedures available today have to pass on test data to account for the interaction parameter.

The main objectives of this study is to study the factors which affect the bond between steel sheeting and concrete by varying the spacing and types of shear connectors with different steel sheeting thickness.

2. EXPERIMENAL PROGRAM

2.1 Properties of Materials and Components

The slab is consists of steel deck, shear connectors and concrete. The profile shape was trapezoidal with embossments. The steel deck shape, geometric properties and embossment details are shown in Fig. 1. Steel deck yield stress obtained from manufactures was 2.4 t/cm² and the modulus of elasticity taken as 2100 t/cm².The specimens were provided with different types of shear connectors to improve the shear bond. Self-drilling screws with two different lengths (40 & 20 mm) were used as shown in Fig. 2 (a). The screws were installed with a simple portable drill. Cold formed members also used as shear connectors which were manufactured through cold roll forming of steel strips of 1.2 mm thickness. The used members are made of galvanized steel strips, cold formed in C, U profiles with size as shown in Fig. 2 (b).



(a) (b)

Fig. 1. The steel deck profile shape (a) and geometric properties (b).

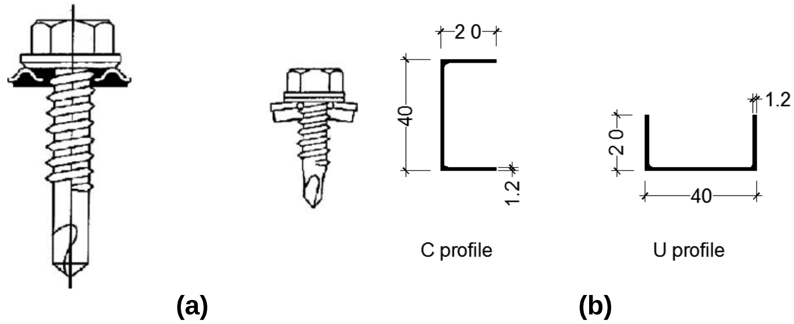


Fig. 2. Self-drilling screw used as shear connector (a) and Cold formed member shapes and size, all dimensions in mm (b).

The concrete used for the specimens was of normal weight, the compressive strength of the concrete was determined by compression test according to Egyptian code of practice .The average cube strength was 365 Kg/cm^2. The recorded slump was about 6.0 cm.

2.2 Small Scale Push out Test

The longitudinal shear resistance of the shear connectors can be identified by a small scale test known as a push out test. In this paper, a push out test is prepared to evaluate the pure longitudinal shear resistance of shear connectors.

Fourteen small scale specimens with different configurations were built in, of which five specimens with profiled steel sheeting thickness of 0.7 mm and nine specimens with profiled steel sheeting thickness of 1.2 mm. For each profiled steel sheeting thickness one specimen is assigned as a control specimen and the other specimens were enhanced with different types of shear connectors such as self-drilling screws with different length and spacing , cold formed members with different shapes (U & C) and different spacing .The profiled steel sheeting were cut with the required dimensions. For specimens enhanced with screws, the self-drilling screws of different lengths (20 & 40 mm) were drilled to the top flanges along the longitudinal length of the deck with spacing 100 mm and 200 mm. For specimens enhanced with cold formed members, cold formed members with different shapes (U & C) were welded to the top flange along the longitudinal length of the deck with spacing 100 mm and 200 mm. Specimen shape and dimensions are shown in Fig. 3.

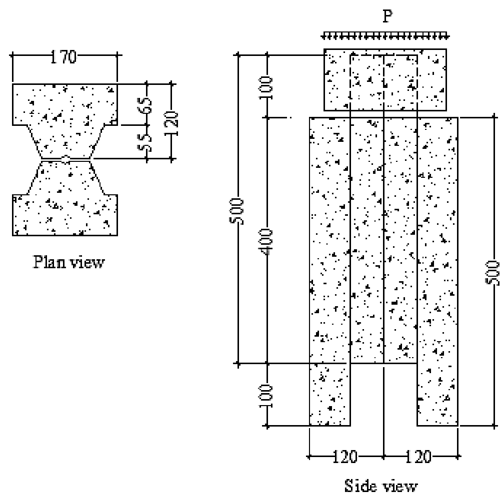


Fig. 3. Push out specimens shape and dimensions.

Fig. 4. (a and b) show the interior side of different specimens before concrete placing where the steel sheets were enhanced by using cold formed members and self-drilling screws, respectively. A concrete block was placed later around the end of steel sheets in order to load push out specimen uniformly.

(a)

(b)

Fig. 4. Specimens enhanced with cold formed members (U, C) (a) and enhanced with Self-drilling screws (b).

Fig. 5. shows the test set-up for push out. All the specimens were tested under vertical load which was applied using a hydraulic jack of 50-ton capacity and measured by using a proving ring of 10-ton capacity. Two Dial gauges of 0.01 mm accuracy and total range of 50 mm was installed on either side of the specimen to measure the longitudinal slip between concrete and steel sheets.

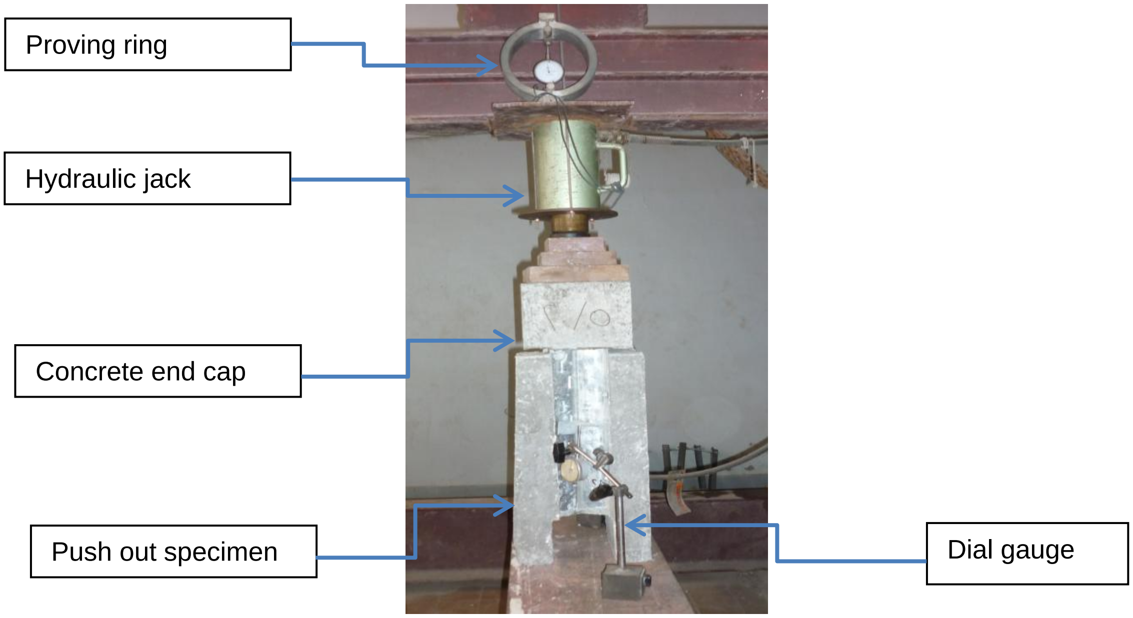


Fig. 5. General View of push out setup.

All specimens were loaded incrementally every 1 ton until failure. Load value and the corresponding slip were recorded at each increment. As the load increased, the concrete slabs began to crack. A longitudinal crack occurred on the side of the concrete and further loading caused splitting of the concrete slab. The maximum load and corresponding slip for push out test specimens are listed in Table 1.

The relationship between the shear strength and the ultimate load in push-out can be expressed as follows [9]

$$t_{po} = \frac{P_u}{A_{con}} \quad (1)$$

Where, t_{po} is the longitudinal shear stress, P_u is the ultimate load, and A_{con} is the contact area between the steel sheet and the concrete. Using the push-out data experimental results, the pure longitudinal shear strength of the tested specimens are computed as shown in Table 1.

Table 1. Push out specimen test results.

Specimen ID	Thickness of steel deck (mm)	Shear dowels type	Spacing (mm)	Pu. (ton)	slipx10² (mm)	Longitudinal shear strength (t_{po}) (kg/cm²)
1.2 CONTROL	1.2	Control	-	3.5	178	2.54
1.2 U 200	1.2	U-cold formed	200	11	100	6.74
1.2 U 100	1.2	U-cold formed	100	11	298	6.22
1.2 C 200	1.2	C-cold formed	200	7.5	197	4.8
1.2 C 100	1.2	C-cold formed	100	8.25	307	5.27
1.2 LS 200	1.2	Screws of 40 mm length	200	6.5	149	4.78
1.2 LS 100	1.2	Screws of 40 mm length	100	8.5	336	6.25
1.2 SS 200	1.2	Screws of 20 mm length	200	7.5	126	5.51
1.2 SS 100	1.2	Screws of 20 mm length	100	5.5	173	4.04
0.7 CONTROL	0.7	Control	-	1	120	0.74
0.7 U 200	0.7	U-cold formed	200	5.5	271	3.37
0.7 C 200	0.7	C-cold formed	200	4	171	2.94
0.7 LS 200	0.7	Screws of 40 mm length	200	3	111	2.21
0.7 SS 200	0.7	Screws of 20 mm length	200	3.75	545	2.76

2.3 LARGE SCALE SLAB TEST

Eleven large scale specimens with different configurations were prepared. Four specimens were prepared with profiled steel sheeting of 0.7 mm thickness and seven specimens with profiled steel sheeting thickness of 1.2 mm. Control specimen for each profiled steel sheeting thickness was also prepared. The other specimens were enhanced with different types of shear connectors: self-drilling screws with different length and spacing and cold formed members with different shapes (U&C) with different spacing. The steel sheeting was cut with the required dimensions. Self-drilling screws were drilled to the top flanges along the length of the deck with spacing 100 mm and 200 mm in specimens enhanced with screws. Cold formed members were welded to the top flange along the longitudinal length of the deck with spacing 100mm and 200mm in specimens enhanced with cold formed members. Specimen shape and dimensions are shown in Fig. 6. The dimensions and test parameters of the large scale slab specimens are listed in Table 2.

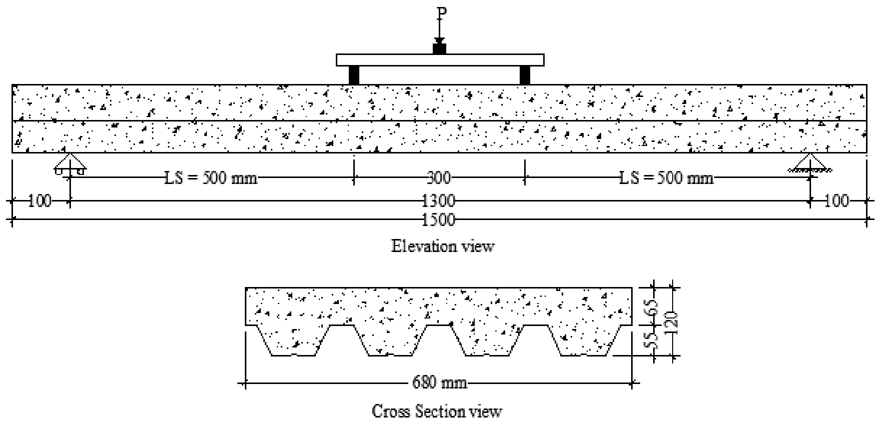
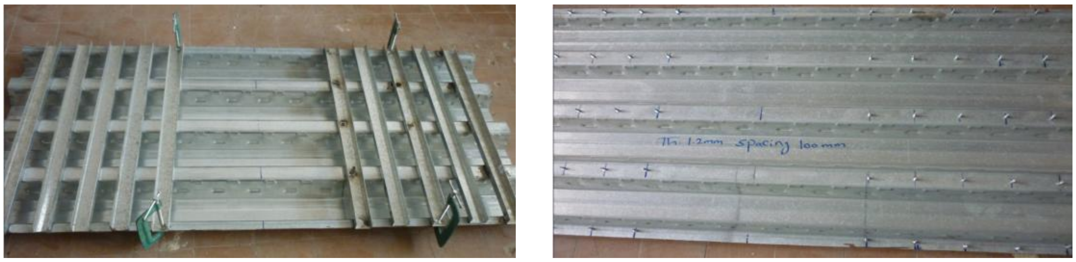


Fig. 6. Large scale slab specimens shape and dimensions.

Table 2. Large scale slab specimen's dimensions and details.

Specimen ID	Thickness of steel deck mm	Shear dowels type	Spacing mm
1.2 CONTROL	1.2	Control	-
1.2 U 200	1.2	U-cold formed	200
1.2 U 100	1.2	U-cold formed	100
1.2 C 100	1.2	C-cold formed	100
1.2 LS 200	1.2	Screws of 40 mm length	200
1.2 SS 200	1.2	Screws of 20 mm length	200
1.2 SS 100	1.2	Screws of 20 mm length	100
0.7 CONTROL	0.7	Control	-
0.7 U 200	0.7	U-cold formed	200
0.7 LS 200	0.7	Screws of 40 mm length	200
0.7 SS 200	0.7	Screws of 20 mm length	200

Specimens with different types of shear connectors are shown in Fig. 7. before pouring concrete.



(a) **(b)**

Fig. 7. Specimens enhanced with cold formed members (a) and specimens enhanced with self-drilling screws (b).

Flexural test was conducted by applying two line loads. The specimens were supported by hinged and roller type supports with an overhang of 100 mm at both ends. Static load was applied by a hydraulic jack of 50-ton capacity and measured by using a load cell of 100-ton capacity. The point load was transmitted to the specimen by means of rigid steel beam which distributed the acting load into two equal concentrated loads, and then the two concentrated loads were spread onto the slab as line load by spreader beams. The line loads were acted at 500 mm from each support, which is the shear span, Ls. The central deflection was measured with two LVDTs which were placed under the center of the specimen. The deflection at mid span is determined as the average of the two measures of LVDTs. The slip between steel sheet and concrete was measured with two LVDTs which installed at the specimen end. Fig. 8. shows the test setup. Strain at the bottom of the steel sheets was measured by a linear strain gauge. Load, deflection, strain and end slip data were recorded at each load increment until failure. The failure was determined when load increment was no longer possible. At this stage, large deflection, large end slip, and large major cracking of the concrete under line load were observed. The maximum load and the corresponding deflection, strain and slip for large scale test specimens are listed in Table 3. The equivalent length in shear near the support is well known as effective slab depth, de, and the relationship between the vertical shear force and the longitudinal shear strength in this area can be expressed as follows [9]

$$t_b = \frac{V_u}{A_{con}} \qquad (2)$$

Where, t_b is the longitudinal shear stress, V_u is the vertical shear force, and A_{con} is the contact area between the steel plate and the concrete within equivalent length in shear, d_e.

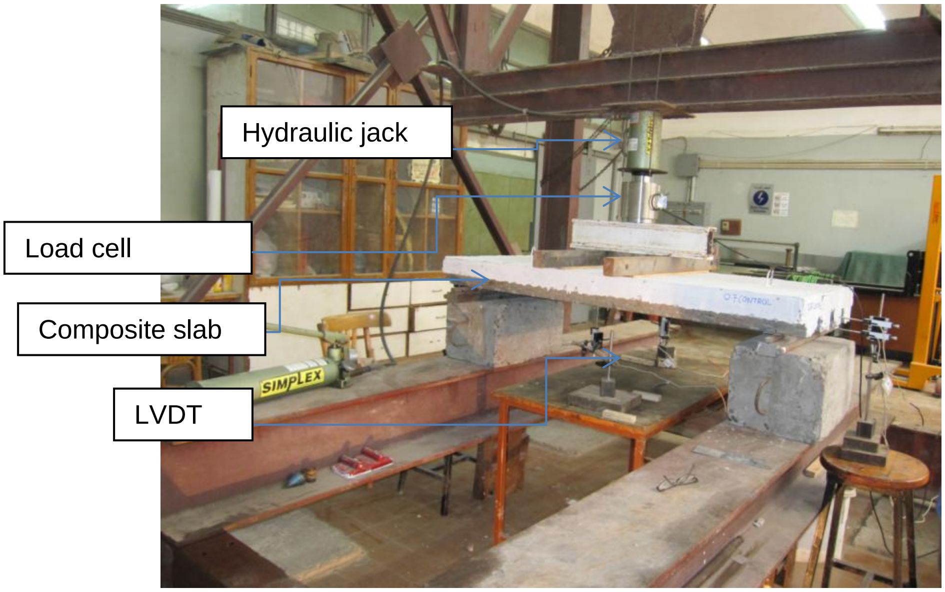


Fig. 8. General view of test setup.

Table 3. Flexural specimens test results.

Specimen ID	Maximum load (ton)	Average def. at mid-point at max. load, (mm)	Strain at max. load	Slip at max. load, mm	Longitudinal shear strength (t_b) (kg/cm²)
1.2 CONTROL	4.57	2.06	6.10E-04	0.34	3.5
1.2 U 200	5.56	6.76	1.38E-03	0.98	4.26
1.2 U 100	6.68	4.76	7.80E-04	0.21	5.12
1.2 C 100	4.7	8.84	6.73E-04	0.87	3.6
1.2 LS 200	5.54	41.09	4.83E-03	3.37	4.24
1.2 SS 200	5.63	3.21	8.88E-04	0.13	4.31
1.2 SS 100	5.68	12.86	2.89E-03	1.01	4.35
0.7 CONTROL	3	2.56	3.75E-04	0.24	2.3
0.7 U 200	3.77	2.94	8.17E-04	0.11	2.89
0.7 LS 200	3.75	14.04	1.84E-03	2.58	2.87
0.7 SS 200	3.75	18.85	1.49E-03	2.68	2.87

3. ANALYSIS AND DISCUSSION OF LARGE SCALE TEST RESULTS

3.1 Effect of Steel Deck Thickness

Two types of profiled steel sheeting are used in this study. The two types have the same shape but with different thickness (0.7 mm and 1.2 mm).
To study the effect of steel deck thickness on the behavior of tested composite slabs, the specimens are divided into four groups which are control specimens, specimens with long screws of 200 mm spacing, specimens with short screws of 200 mm spacing and specimens with horizontal channel (U) of 200 mm spacing.
For control specimens with steel deck of 0.7 mm and 1.2 mm thickness the two compared specimens were not enhanced with any type of shear connectors. It is shown that ultimate load for the specimen with profiled steel sheeting with thickness of 1.2 mm is increased by 52.33% than that of the specimen with profiled steel sheeting with thickness of 0.7 mm. The load-deflection curve in the two specimens behaved almost linearly prior to first end slip. After the end slip has initiated, the load dropped drastically with a major crack occurred in the concrete below the acted line loads. Failure in this manner is classified as brittle. Such failure which is known as shear bond failure is principally occurred due to the large slippage between the steel sheeting and the concrete.

The two compared specimens were enhanced by using self-drilling screws with 40 mm length and 200 mm spacing as shear connectors. It is shown that ultimate load for the specimen with profiled steel sheeting with thickness of 1.2 mm is increased by 47.73% than that of the specimen with profiled steel sheeting with thickness of 0.7 mm. The load-deflection curves indicate that the loads dropped slightly when the first end slip had initiated, but further it is increased and sustained for a longer period beyond the first end slip. The failure mode of the tested specimens has been improved from brittle to ductile type where the failure was delayed.
The two compared specimens were enhanced by using self-drilling screws with 20 mm length and 200 mm spacing as shear connectors. It is shown that ultimate load for the

specimen with profiled steel sheeting with thickness of 1.2 mm is increased by 50.13% than that of the specimen with profiled steel sheeting with thickness of 0.7 mm. Also using 20 mm length self-drilling screws as shear connectors improved the failure mode of the tested specimens, specially the specimen with 0.7 mm steel sheeting (0.7 SS 200), where a ductile behavior were observed.
The two compared specimens were enhanced by using horizontal channel (U) with 200 mm spacing as shear connectors. It is shown that ultimate load for the specimen with profiled steel sheeting with thickness of 1.2 mm is increased by 47.48% than that of the specimen with profiled steel sheeting with thickness of 0.7 mm. Also using horizontal channel (U) as shear connectors improved the failure mode of the tested specimens where a ductile behavior was observed.

3.2 Effect of Shear Connector Type

The effect of shear connector type on the mechanical behavior of the composite specimens was experimentally investigated for specimens with shear connector of 100 mm and 200 mm spacing and with steel deck of 0.7 mm and 1.2 mm thickness.
Fig. 9. shows the effect of shear connector type for specimens with steel sheeting thickness of 0.7 mm and enhanced with shear connectors 200 mm spacing. It is shown that the ultimate load of the specimens with short screws (SS) or long screws (LS) increased by 25% than that of the control specimen which was not enhanced with any shear connector ,so the length of screw does not affect the ultimate load value of the tested specimen. The ultimate load of specimen with horizontal channel (U) increased by 25.7% than that of the control specimen. The experimental results show also that the specimen with self-drilling screws is more ductile than the control specimen and the specimen enhanced with horizontal channels (U). The effect of shear connector type is not clear in case of 200 mm spacing. The specimens with long screws are more ductile than the specimens with other types of shear connectors.
The length of self-drilling screws has not a clear effect on the ultimate load of the tested specimens. Also the results revealed that the ductility of the tested specimens was not affected by the length of the screws, where using long length or short length led to increase the ductility of the tested specimens.

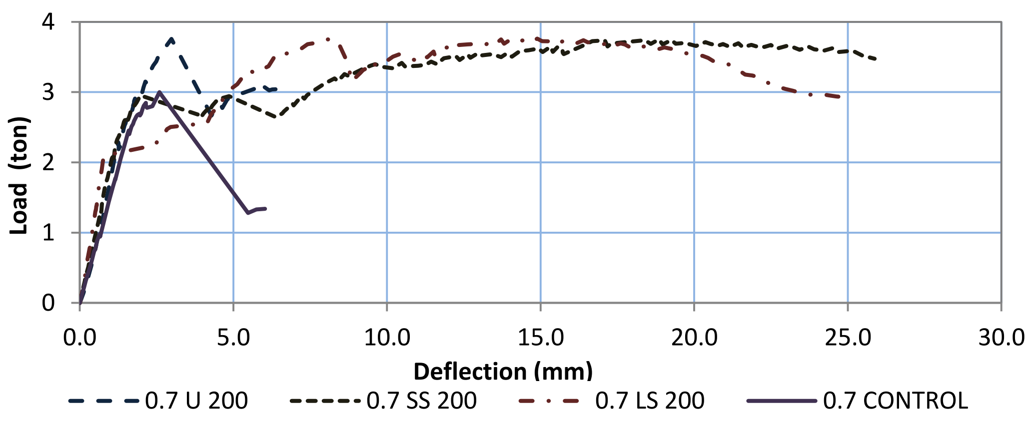


Fig. 9. Load-Deflection curves for specimens (0.7 U 200), (0.7 SS 200), (0.7 LS 200) and (0.7 CONTROL).

Fig. 10. shows the effect of shear connector type on the mechanical behavior of the tested specimens with the same steel sheeting thickness of 1.2 mm thickness and enhanced with

shear connectors of 100 mm spacing. It is shown that the ultimate load of the specimen enhanced with short screws (SS) increased by 24.3% than the control specimen. However, the ultimate load of the specimen with vertical channels (C) and horizontal channels (U) increased by 2.8% and 46.2%, respectively, than the control specimen. The experimental results show also that the specimens with self-drilling screws and vertical channels (C) are more ductile than the control specimen and the specimen enhanced with horizontal channels (U). The effect of shear connector type on the ultimate load is very clear in case of steel sheeting of 1.2 mm thickness with shear connectors 100 mm spacing, in this case the horizontal channels was the best type. The specimens with short screws are more ductile than the specimens with other types of shear connectors. The experimental results revealed that the orientation of channels used as shear connectors is very important variable, where its effect on the ultimate load of the tested specimens was very strong, using horizontal channel in place of vertical ones led to increase the ultimate load by 42.1%.

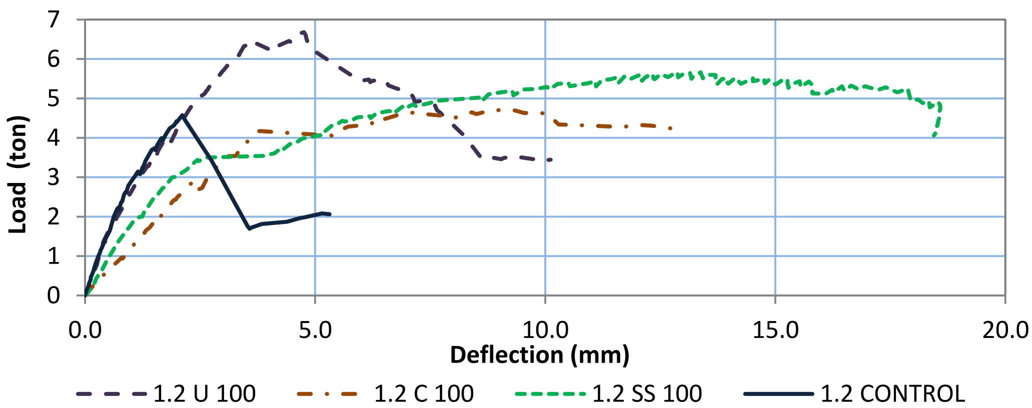


Fig. 10. Load-Deflection curves for specimens (1.2 U 100), (1.2 SS 100), (1.2 C 100) and (1.2 CONTROL).

Fig. 11. shows the effect of shear connector type on the mechanical behavior of the tested specimens with the same steel sheeting of 1.2 mm thickness and enhanced with shear connectors 200 mm spacing. It is shown that the ultimate load of the specimen enhanced with short screws (SS) increased by 23.2% than the control specimen. However, the ultimate load of the specimen with long screws (LS) increased by 21.2% than the control specimen, and the ultimate load of the specimen with horizontal channels (U) increased by 21.7% than the control specimen. The experimental results show also that the specimen with long screws is more ductile than the control specimen and the specimen enhanced with horizontal channels (U) and short screws (SS).

The length of self-drilling screws has not a clear effect on the ultimate load of the tested specimens. However, the results revealed that the ductility of the tested specimens was affected by the screws length where using long length in place of short length led to increase the ductility of the tested specimens.

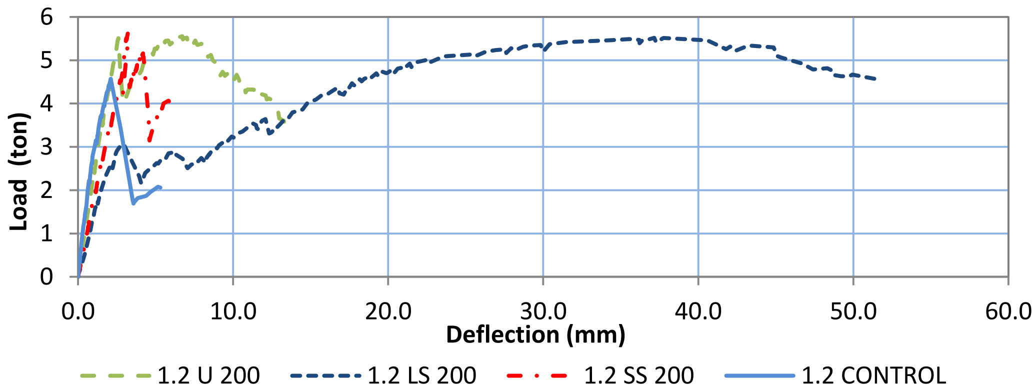


Fig. 11. Load-Deflection curves for specimens (1.2 U 200), (1.2 LS 200), (1.2 SS 200) and (1.2 CONTROL).

3.3 Effect of Connector Spacing

Fig. 12. shows the effect of spacing for specimens of 1.2 mm steel sheeting thickness and enhanced with short self-drilling screws. It is shown that the ultimate load for the specimens with short screws (SS) with 100 mm and 200 mm spacing increased by 23.2% and 24.3%, respectively, than the control specimen. The experimental results show also that the specimen enhanced with short screws of 100 mm spacing is more ductile than the control specimen and the specimen enhanced with short screws of 200 mm spacing.

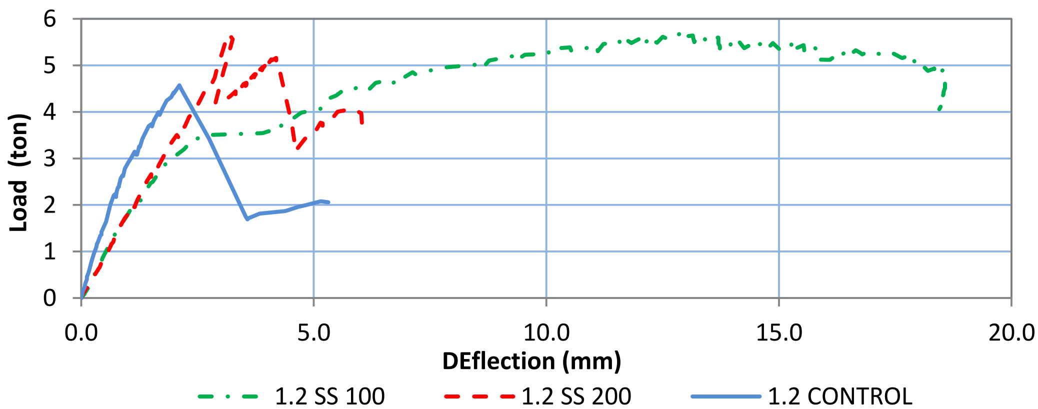


Fig. 12. Load-Deflection curves for specimens (1.2 SS 100), (1.2 SS 200) and (1.2 CONTROL).

Fig. 13. shows the effect of spacing for specimens of 1.2 mm thickness and enhanced with horizontal channels (U) as shear connectors every 100mm and 200 mm spacing. It is shown that the ultimate load for the specimens enhanced with horizontal channels (U) of 100 mm and 200 mm spacing increased by 47.2% and 21.7%, respectively, than the control specimen.

Moreover using horizontal channels with both spacing led to increase the ductility of tested specimens in comparison with control specimen.

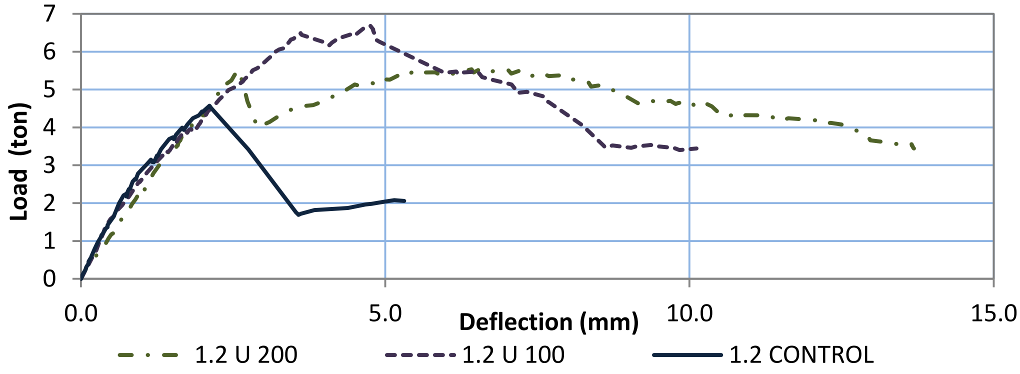


Fig. 13. Load-Deflection curves for specimens (1.2 U 100), (1.2 U 200) and (1.2 CONTROL).

3.4 Crack Pattern

All the tested specimens failed due to the slippage between steel deck and concrete. As the load increased, an initial crack occurred at the bottom of the concrete. As the load further increased, a number of cracks at the bottom of the concrete progressively spread towards the top of the concrete with concentration at the applied loading point. At the same time, they spread towards the support in the longitudinal direction and also caused separations and slips between the steel sheerings and the concrete. Fig. 14. shows the crack patterns .
The studied variables concerning with the type of shear connectors and its spacing had no clear effect on the observed crack pattern. However, using shear connectors led to increase the number of transversal cracks.

Fig. 14. Crack pattern for tested specimen (0.7 LS 200)

3.5 Strain Gage Result

It was not possible to observe yielding during the test. For yielding measurement it was assumed that the steel decks began to yield at the strain, εy = fy / Es, where the steel deck yield stress (fy) is taken equal to 2.4 t/cm2 (according to the manufacture), and the modulus of elasticity (Es) is taken equal to 2100 t/cm². Therefore, the load corresponding to yield strain (Py) was obtained from the Load-Strain plots. Table 4.presentes the values of yield load and ultimate load for all tested specimens. As shown in Table 4. the steel deck for all specimens have reached the yield except the control specimens of 0.7 mm and 1.2 mm thickness and also, the specimen enhanced with vertical channel (C) of 100 mm spacing.

Table 4. Loads measured at yielding of steel sheets.

Specimen ID	Experimental Load corresponding to yield strain P_y (ton)	Experimental Ultimate load P_{ult} (ton)	P_{ult}/ P_y
1.2 CONTROL	NA	4.57	NA
1.2 U 200	5.36	5.56	1.04
1.2 U 100	3.46	6.68	1.93
1.2 C 100	NA	4.7	NA
1.2 LS 200	3.31	5.54	1.67
1.2 SS 200	3.56	5.63	1.58
1.2 SS 100	4.06	5.68	1.40
0.7 CONTROL	NA	3	NA
0.7 U 200	3.69	3.77	1.02
0.7 LS 200	3.27	3.75	1.15
0.7 SS 200	3.5	3.75	1.07

3.6 Longitudinal Shear Stress Comparison

The longitudinal shear strength deduced from push out test results was compared with the corresponding one deduced from bending test results. Table 5. show the comparison between the results of push out test and flexural test.

Table 5. Ratio of longitudinal shear strength from push out test to the corresponding from bending test.

Specimen ID	t_{Po}/t_B
0.7 CONTROL	0.32
0.7 SS 200	0.96
0.7 LS 200	0.77
0.7 U 200	1.17
1.2 CONTROL	0.74
1.2 SS 100	0.93
1.2 SS 200	1.28
1.2 U 100	1.22
1.2 U 200	1.58
1.2 C 100	1.47
1.2 LS 200	1.13
MEAN=	1.05
Standard deviation=	0.36

4. CONCLUSION

Experimental study has been carried out to investigate the behavior and load carrying capacity of steel deck-concrete composite slabs with different steel sheet thickness and enhanced with different shear connectors such as cold formed members and self-drilling screws at the steel concrete interface. Two types of tests are carried out; Push out test and flexural test. For push out test, fourteen composite specimens of different steel sheet thickness were built and tested under vertical load with and without shear connectors. For flexural test, eleven composite slab specimens of different steel sheet thickness were built and tested with and without shear connectors. The former specimens were subjected to four-point bending test. Also, comparisons between the longitudinal shear strength obtained from push out test and that obtained from flexural test were carried out for different types of shear connectors. From the present investigation, the conclusions can be deduced as follows:

1. The shear-bond failure mechanism of composite slabs follows the procedure that firstly, the crack of bottom concrete in tension initiates; then the shear-bond slip and separation occurs, and finally the totally loss of shear-bond strength, and the composite deck slabs fail.
2. The failure mode of composite slab can be improved from brittle to ductile, the load carrying capacity and the horizontal shear strength can be increased by installing shear connectors at the steel-concrete interface.
3. The steel deck thickness directly affected the ultimate load of the tested specimens where the ultimate load of specimen with steel deck thickness 1.2 mm is increased by about 50% than that of specimen with steel deck thickness 0.7mm.
4. Shear connector spaced equal 200 mm with steel deck thickness 0.7 mm is directly affected the ultimate load of the slabs and it can be concluded that ultimate load of specimen with shear connector is increased by around 25% than that of specimen without shear connector and there is no much difference effect in using self-drilling screws and cold formed member with steel sheet thickness equal to 0.7mm.
5. The effect of shear connector type is not clear in case of 200 mm spacing regardless of the steel sheeting thickness.
6. The specimens with long screws are more ductile than the specimens with other types of shear connectors.
7. The effect of spacing between shear connectors was obvious in case of horizontal channels (U) where using spacing of 100 mm led to increase the ultimate load by 20.1% in comparison with specimens of 200 mm spacing.
8. The ultimate load has not been affected by changing the spacing between shear connectors in case of short self-drilling screws. However, the spacing between short self-drilling screws affected the ductility of the tested specimens which behaved more ductile as the spacing deceased.
9. The orientation of channels used as shear connectors is very important variable, where its effect on the ultimate load of the tested specimens was very strong, using horizontal channel in place of vertical ones led to increase the ultimate load by 42.1%.
10. The length of self-drilling screw has not a clear effect on the ultimate load of the tested specimens of 0.7 mm and 1.2 mm steel sheet thickness. However, the results revealed that the ductility of the tested specimens of 1.2 mm steel sheet thickness were affected by the screws length where using long length in place of short length led to increase the ductility of the tested specimens, while tested specimens of 0.7 mm steel sheet thickness were not affected by the length of the screws, where using long length or short length led to increase the ductility of the tested specimens.

11. The studied variables concerning with the type of shear connectors and its spacing had no clear effect on the observed crack pattern. However, using shear connectors led to increase the number of transversal cracks.
12. The steel deck for all specimens have reached the yield except the control specimens of 0.7 mm and 1.2 mm thickness and also the specimen enhanced with vertical channel (C) of 100 mm spacing..
13. The bending test ultimate loads are overestimated in comparison with the push out ones in case of control specimen.
14. The mean for the ratio of push out test strength to bending test strength is 1.36 with the standard deviation 0.2, which indicates that the bending test results are in good agreement with the push out values for the specimens enhanced with cold formed channels sections (C&U) as shear connectors.
15. The comparison reveals good agreement between the ratio of push out test strength to bending test strength for tested specimens enhanced with self-drilling screws with steel sheet thickness of 0.7 mm and 1.2 mm, and enhanced with self-drilling screws of different length (20 mm & 40 mm) and different spacing (100 mm & 200 mm).

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