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CONNECTION BEHAVIOR IN COMPOSITE PROFILED STEEL SHEET WITH FERROCEMENT (PSSF) SYSTEM

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ABSTRACT

This paper concerns with the behavior of the connections in the composite Profiled Steel Sheet with Ferrocement (PSSF) systems. The PSSF panels is a light weight composite panel consists of a profiled steel sheet (PSS) and ferrocement panel connected together by either mechanical fasteners or by epoxy adhesive resin. Ten push-out specimens were tested. The veriables were the strength of morter and the volume friaction of wire mesh for ferrocement panels, and types of connection between the two components. The ultimate load, the load slip relationship, and modes of failure were recorded. The results showed that the specimens connected by using* bolts of 10 mm diameter can sustain load greater by 64% than those connected by using bolts of 5 mm diameter. The ultimate load was found not to be inflenced** when the strength of ferrocement is increased from 35 MPa to 45 MPa. Also the effect of volume fraction of wire mesh was observed to enhance slightly the ultimate load when the layers of wire meshs is increased from 2 to 3 layers. For the specimens made by connecting the ferrocement components to the PSS by adhesive epoxy layer, a rigid connection was obtained and sudden separation occurred between the ferrocement component and steel sheet after local buckling of PSS.

KEYWORDS: Push-Out Test, Composite Panel, shear connectors, Profiled Steel Sheet Ferrocement Composite.

1. INTRODUCTION

The composite Profiled Steel Sheet with ferrocement (PSSF) panel is a structural system, consists of two main components, namely, profiled steel sheet (PSS) and the ferrocement component. A composite slab with profiled steel decking has been considered over the years to be one of the simpler, faster, lighter, and economical construction in steel-frames building system.

In composite systems the push out test method is required to determine the strength of type of connection between the components of these systems. Many investigations were conducted on different type of composite systems (ASTM D 1761-88, 1992; Johnson & Yuan, 1998; Kim et al, 2001; Lam & Ellobody, 2005; Lloyd & Wright, 1990).

Awang and Majid, (2010) studied the stiffness of the connectors of the PSSDB system by testing five groups of specimens under constant uniformly distributed loads in wet and dry conditions. They used one type of steel sheeting, Ajiya CL 660, and two different boarding, Primaflex and Cemboard, with different thicknesses. Two different types of self drilling, self tapping screw, DX 14 was used with Cemboard and DX-RW was used with Primaflex. The results showed that the modulus of connectors for specimens in wet condition was considerably less compared to the dry specimens. The reduction in values of stiffness of Primaflex and Cemboard in wet specimens were 15% and 25% respectively.

Thamer and Jasim, (2017) studied the behavior of the connections in the composite Profiled Steel Sheet Dry Board (PSSDB) system. The PSSDB is a light weight composite panel consisted of a profiled steel sheet PSS and cement board as dry board connected together by either mechanical fasteners or by epoxy adhesive resin. Ten push-out specimens with different size, shape, thickness of dry board, and types of connections were carried out. The ultimate load, the load slip relationship, and modes of failure were observed. The results showed that the specimens connected by epoxy adhesive resin can sustain load greater than that connected by mechanical fasteners up to 76%, and the ultimate load depend on the thickness of dry board.

In this paper push-out test was conducted to determine the strength capacity and the behavior of the proposed connections between the components of the composite Profiled Steel Sheet with Ferrocement panels. For such composite systems, there is no code for design them and no standard method concerning the push-out test. Therefore, test details resembling the push-out test of BS5400, for steel-concrete composite construction, are suggested. Some changes are proposed to make the specimens to be in conformity with the new composite system.

2. MATERIALS AND METHODS

2.1. Description of Specimens and Materials Properties

Three groups of specimens have been constructed using locally available profiled steel sheet (PSS), having depth of 37mm and 0.8mm thickness, and ferrocement panels with 10 mm thickness made of two mortar strengths (35MPa and 45MPa). Different volume fractions of wire mesh are used which are represented by 2 and 3 layers of wire mesh. Simple mechanical connectors in form of are bolts with nut and washer of (diameter 5mm and 10mm) and Epoxy adhesive resin, Sikadure-31CF, have been utilized to connect the ferrocement to the PSS. The properties of the material used, which are found by laboratory test, are given in Tables 1.

Table 1. Materials properties.

Materials	properties	value
Mortar	Young's modulus (MPa)	30000
	Compressive strength (MPa)	35 ,45
	Flexural strength *fr* (MPa)	5.5
Steel Mesh	Diameter, mm	1
	Grid size, mm	12.5 x 12.5
	Young's modulus, MPa	92000
	Yield stress, MPa	415
	Ultimate Tensile Strength (MPa)	625
Profiled Steel Sheet	Elastic Modulus(MPa)	200000
	Density(kg/m3)	7850
	Ultimate Tensile Strength (MPa)	255
	Yield strength(MPa)	230
Epoxy Adhesive Resin	Density l/cm3	1650
	Poisson's ratio	0.4
	Elastic Modulus MPa	3300
Mechanical Connectors	Bolt Diameter (mm)	10, 5 (locally available)***

The specimens were prepared and tested. The specimens of the first and second groups consisted of two precast ferrocement components connected to double profiled steel sheets. The ferrocement components are used 28 days after casting. This configuration for test specimens is suggested in this study to produce a symmetric specimens. The first group specimens were connected by bolts with diameter (5mm) at a distance of 100 mm in the longitudinal direction. The second group specimens were connected by bolts with diameter (10mm) at a distance of 100 mm in the longitudinal direction. The lengths of the profiled steel sheets and the ferrocement components were 300 mm, while the width was either 440 mm or 370 mm depending on whether the ferrocement panels were attached to the trough or rib of the profiled steel sheets, respectively. The third group specimens were made by replacing the bolts by adhesive layer of 3mm thickness. Table 2 gives the summary of the test specimens used in the push-out test program. Figs. 1 and 2 shows the configuration of these specimens. Fig. 3 show the methods of preparation and final shape of specimens.

Table 2. Details of the Push-Out test Specimens.

Test Group	Specimen Designation	Connection		Diameter of bolts (mm)	Width of Specimens (mm)	Portion of Steel Sheet on Which connection Provided	Figure
		No. of bolts	Area of Epoxy (cm2)				
1	F2C35B5	8	---	5	440	trough	Fig. 1
	F2C45B5			5	440	trough	
	F3C35B5			5	440	trough	
	F3C45B5			5	440	trough	
2	F2C35B10	8		10	440	trough	
	F2C45B10			10	400	trough	
	F3C35B10			10	440	trough	
	F3C45B10			10	440	trough	
3	F3C35Be	---	160	--	370	rib	Fig. 2
	F3C45Be			--	370	rib	

The symbols in Designation (Fn Cm Bd/e) mean:

F; Ferrocement panel.
n; Number of wire mesh layers.
C; mortor.
m; Compressive strength MPa.
B; Bond material.
d/e; Diameter of bolt
or **e**; epoxy

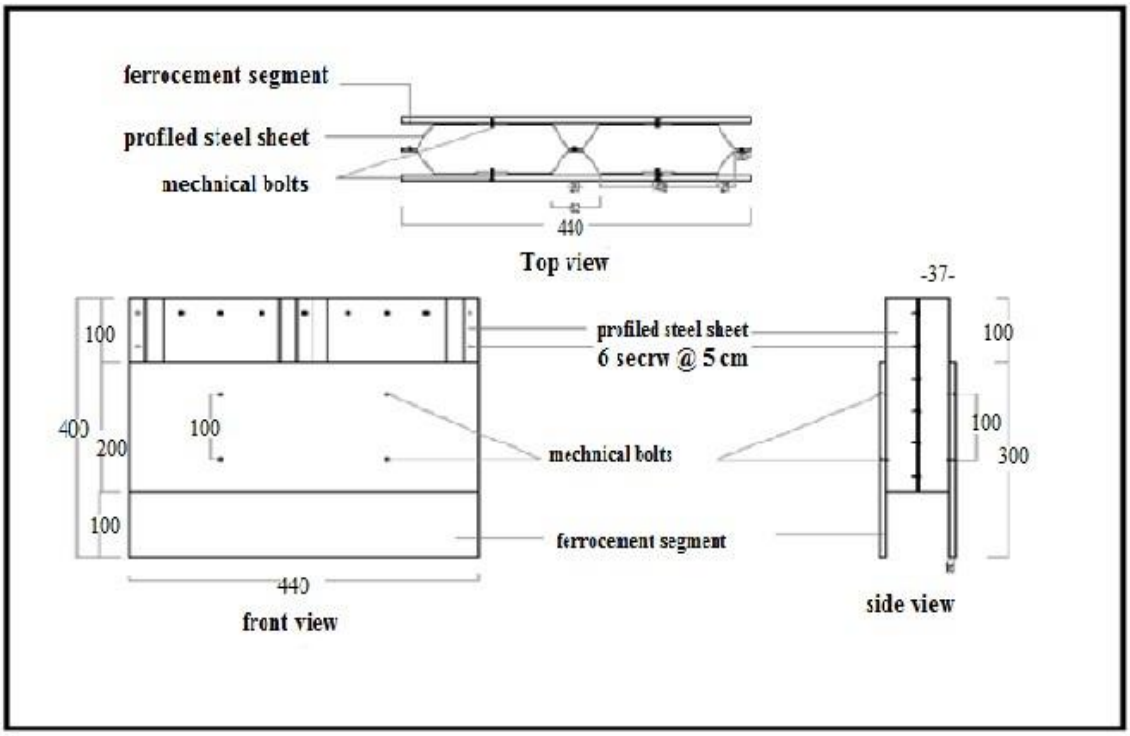


Fig. 1. Push-Out Test Specimens with bolts Connected To trough.

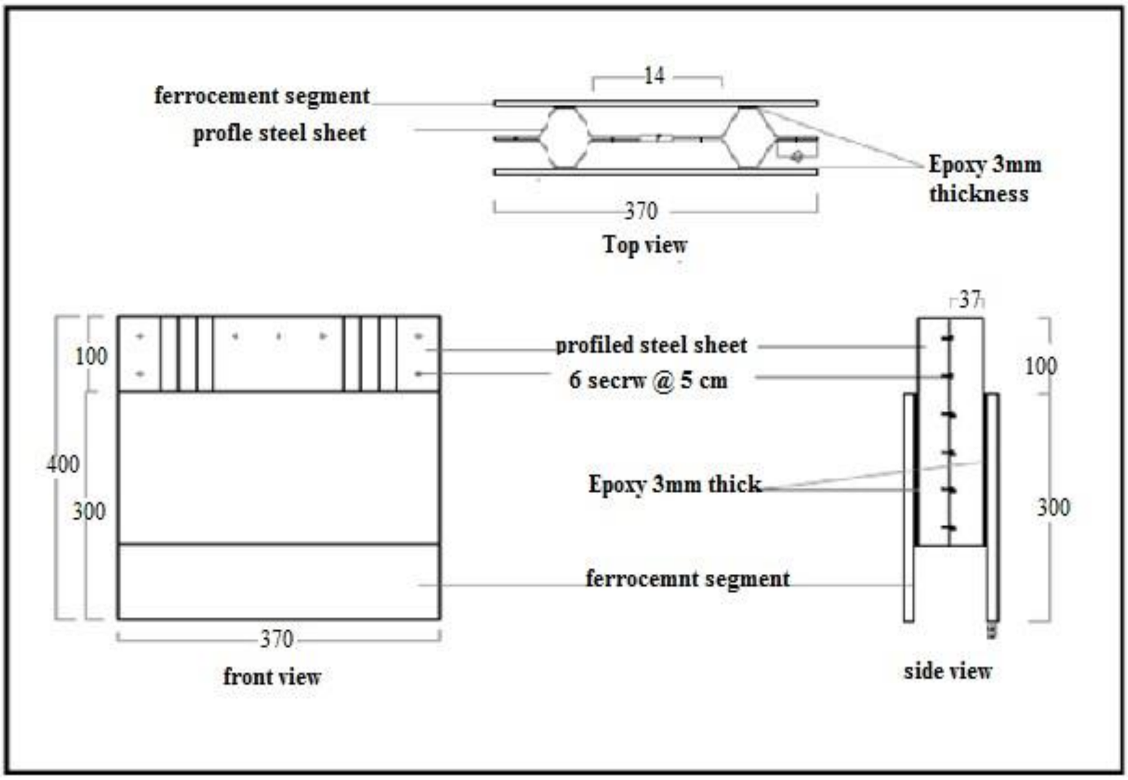


Fig. 2. Push-Out Test Specimens connection by epoxy on ribs.

Fig. 3. Preparation of Push-Out Test Specimens.

3. TEST SETUP AND INSTRUMENTATION

All the specimens were subjected to a uniform load, as shown in Fig. 4. The load was applied gradually while the vertical slip between the profiled steel sheet PSS and the ferrocement components was measured. Laser displacement sensor was used to measure this slip at the interface of the PSS and the ferrocement components. The test was stopped when a sudden reduction in applied load was observed or when the ferrocement components separated from the PSS.

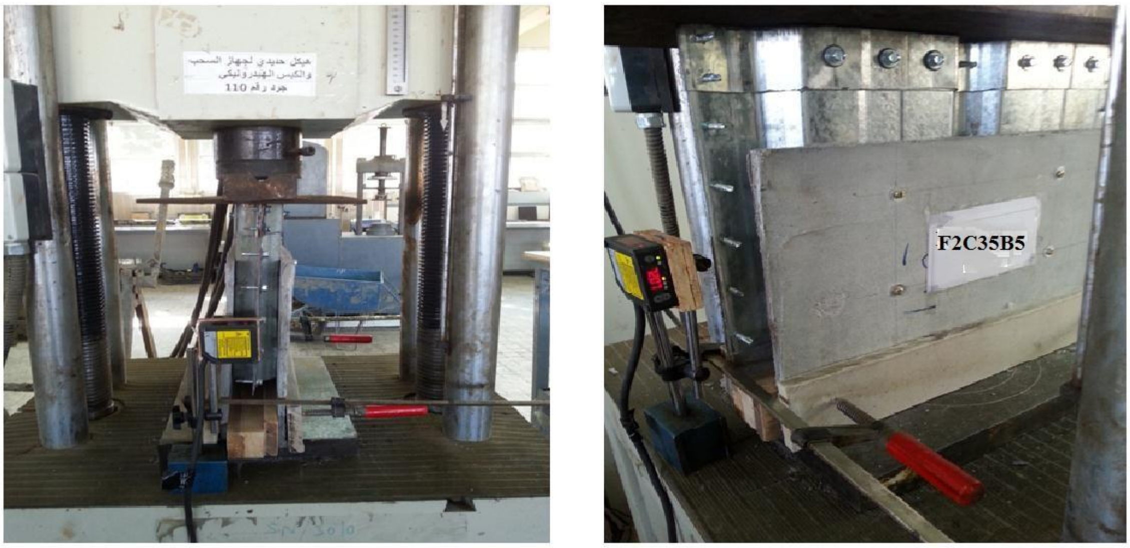


Fig. 4. Push-Out Test Arrangement.

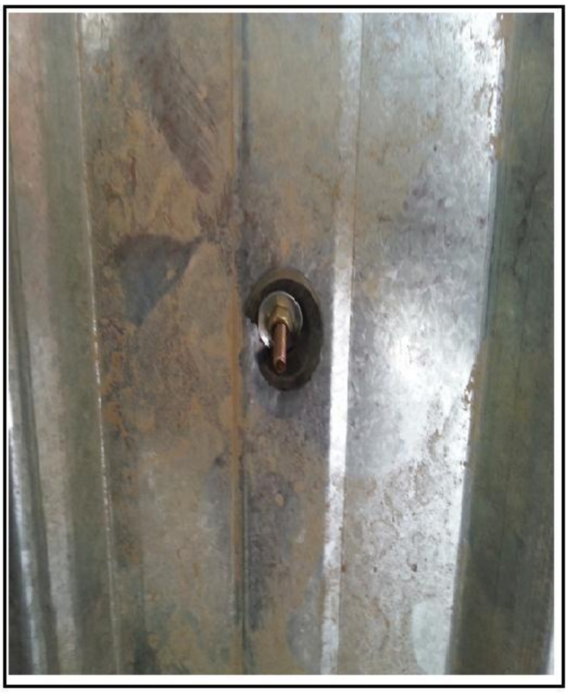
4. RESULTS AND DISCUSSION

The results of the push-out test, include the ultimate load, the load -slip relationship, and modes of failure.

For the first and second groups of specimens (Table 2), made by connecting the ferrocement component to the PSS by bolts, the specimens showed nearly identical failure behavior depending on the diameter of the mechanical bolts. Two modes of failure were observed. The first mode is noticed in the first groups of specimens, which are connection by using bolts of 5 mm diameter. The failure of these specimens occurred by tearing failure of profile steel sheet and the flexure of bolts and crushing of mortar near the head of bolts as shown in Fig. 5. The second mode of failure was observed in second groups of specimens, in which the diameter of bolts was 10 mm. Here the failure occurred by crushing of mortar of the ferrocement component. The bolts head has gradually sunk into ferrocement segments and the ferrocement surface at bolts area cracked, as shown in Fig. 6.

For the third group specimens made by connecting the ferrocement components to the PSS by adhesive epoxy layer, rigid connection was obtained and a sudden separation occurred between the ferrocement component and steel sheet after a local buckling of PSS, as shown in Fig. 7.

Crushing of mortar



Flexural failure of bolts **Tearing of PPS**

Fig. 5. Failure modes of first group (connecters are bolts of diameter 5mm).

Fig. 6. Failure mode of second group (connecters are bolts of diameter 10mm).

Fig. 7. Failure mode of third groups (adhesive epoxy layer).

The details and results of tested push-out specimens are summarized in Table 3, where the ultimate slip is obtained by extrapolation of the experimental results (the obtained curve is extended to the ultimate load with maintaining the curve trend).

Table 3. Experimental results of Push-Out Test.

Test Group	Specimen Designation	Total Ultimate Load (kN)	Strength of Connection		Extrapolated Slip at Ultimate Load (mm)
			Load per mm Length (kN/mm)	Load Per Connector (kN)	
1	F2C35B5	29.14	---	3.64	13.5
	F2C45B5	31.86	---	3.98	13.8
	F3C35B5	32.5	---	4.06	14.4
	F3C45B5	32.8	---	4.1	13.2
2	F2C35B10	51	---	6.37	16.3
	F2C45B10	49	---	6.12	10.37
	F3C35B10	52.44	---	6.55	12.8
	F3C45B10	53.12	---	6.64	13.4
3	F3C35Be	32.75	0.409	---	5.38
	F3C45Be	33.1	0.413	---	5.95

The variation of measured slip with the total load on specimens is plotted in Figs. 8 and 11 show that the mechanical connectors (bolts of 10mm diameter) have a good resistance to the applied shear. The maximum extrapolated slips range from (10.37 mm to 16.3 mm) for second group of specimens. Therefore, this type of connection (using bolts of diameter 10 mm) may be considered as a flexible connection. Also, the mode of failure of this group occurred by crushing of mortar only.

Figs. 9 and 11 show that bolts of 5 mm have less resistance to the applied shear than that of the bolts of 10 mm diameter. Also the figure shows that the 5 mm bolts are more flexible which may lead to less interaction between the two components of such composite system

Fig. 10 shows that the epoxy may be used for connection and has a good resistance to the applied shear if it is applied in the suggested procedure. When the ultimate load is reached, sudden separation of a ferrocement panel occurs with maximum extrapolated slips of 5.38 mm and 5.95 mm for **F3C35Be**, **F3C45Be** specimens, respectively. Therefore, this type of connection (using adhesive material) represents a rigid connection.

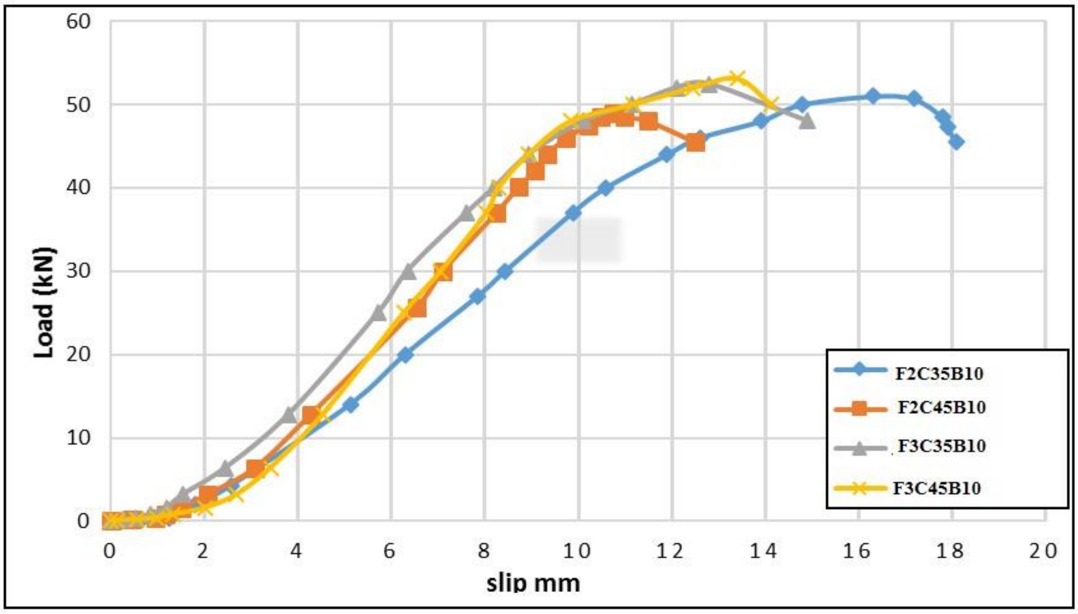


Fig. 8. Load Slip Relationship for Push – Out Test
(2nd Group: Specimens Connected by Mechanical Connectors).

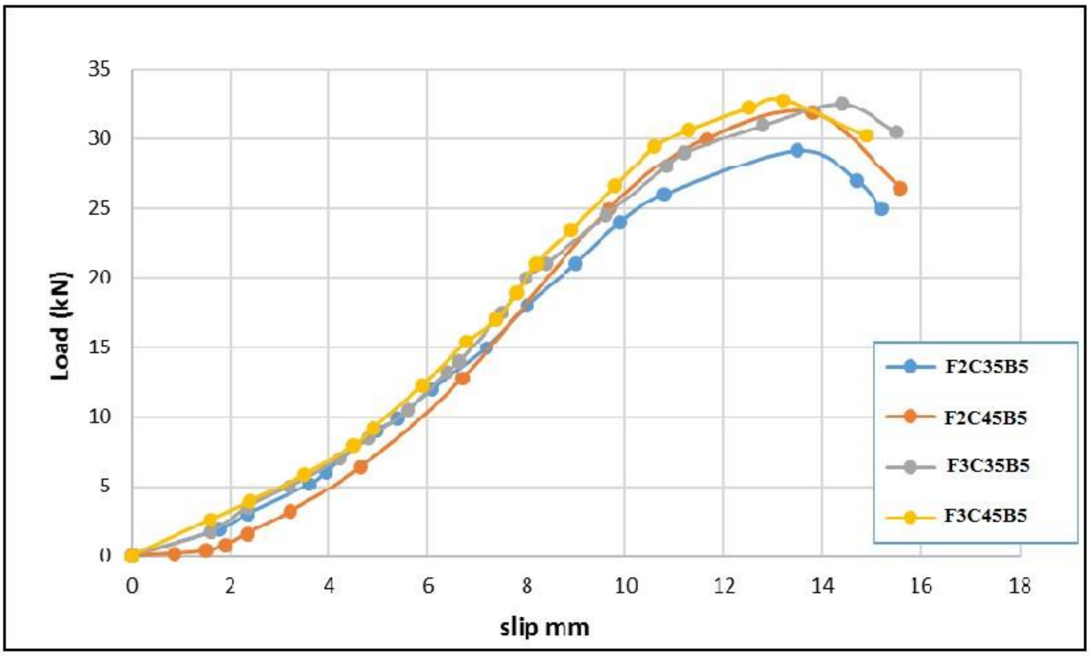


Fig. 9. Load Slip Relationship for Push – Out Test
(1st Group: Specimens Connected by Mechanical Connectors).

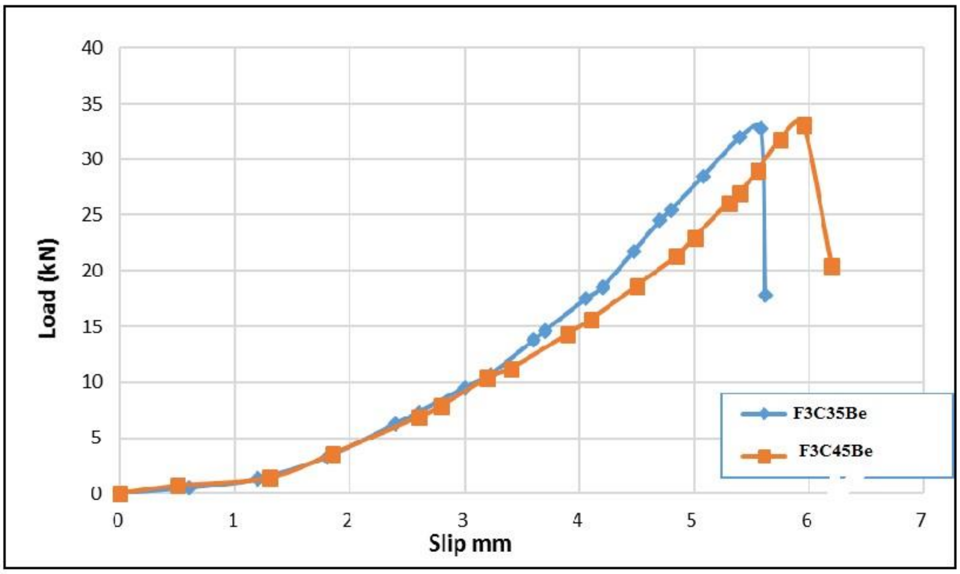


Fig. 10. Load Slip Relationship for Push – Out Test
(3rd Group: Specimens Connected by Epoxy Adhesive Resin).

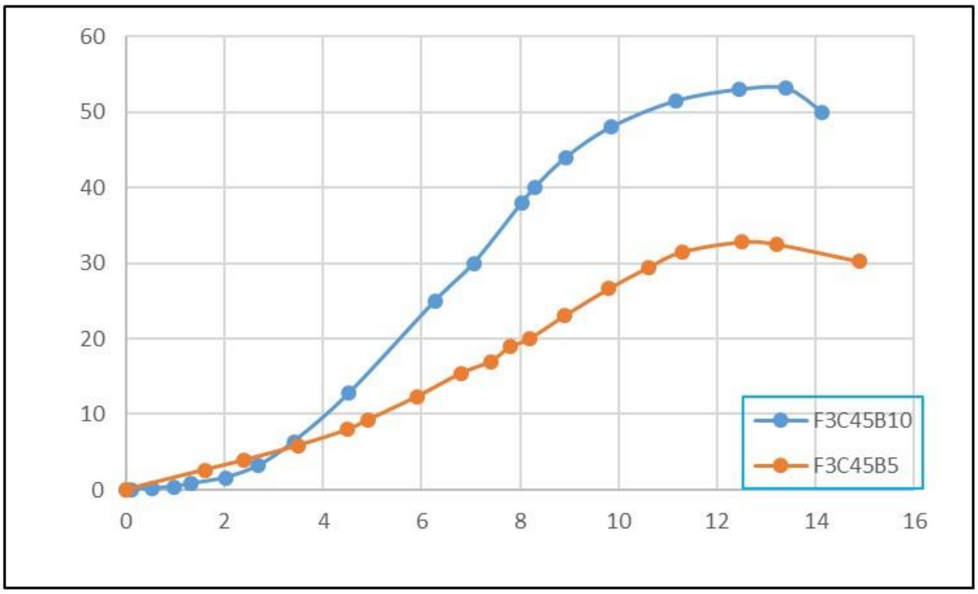


Fig. 11. Comparison of Load-slip Relationships of Push – Out Test for Specimens Connected by bolt diameter (10 mm and 5mm).

5. CONCLUSIONS

A symmetric push out specimens is proposed to determine the strength of connection in a new suggested (PSSF) composite panel. In this proposed push out specimens, the ferrocement component may be attached to the profile steel sheet to the trough and rib of it. Two type of connection are investigated, which are mechanical by bolts and continuous by adhesive layer. The adhesive layer shows rigid connection and the bolts give flexible connection. Bolts of 10 mm diameter seems to be better than those 5 mm diameter with respect to the strength and stiffness.

6. REFERENCES

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