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[Thamer* *et al.*, 6(9): September, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

CONNECTION BEHAVIOR IN COMPOSITE PROFILED STEEL SHEET DRY BOARD (PSSDB) SYSTEM

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DOI: 10.5281/zenodo.886754

ABSTRACT

This paper studied the behavior of the connections in the composite Profiled Steel Sheet Dry Board (PSSDB) system. The PSSDB is a light weight composite panel comprised 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 samples connected by epoxy adhesive resin can sustain load greater than that connected by mechanical fasteners up to 76%, and the ultimate load affected by the thickness of dry board. The capacity of connecter (self drilling-self tapping screw with 4.2 mm diameter) is about 1.736 kN/screw. This value increased by about 20% with the increase in dryboard thickness to double (from 8 mm to 16 mm). The Ultimate load sustained by the specimens connected by using epoxy adhesive resin is about 37 kN/m and 137 kN/m for the DB connected to ribs and trough sides of PSS, respectively. These values increased by about 14% with the increase in dryboard thickness to double.

KEYWORDS: Push-Out Test, Composite Panel, shear connectors, PSSDB.

INTRODUCTION

All The composite Profiled Steel Sheet Dry Board (PSSDB) is a structural system, comprise of two main components, namely, profiled steel sheet (PSS) and a Cement board as a Dry Board (DB).The PSSDB system was first proposed by Wright and Evans in United Kingdom in 1986 as an alternative to traditional timber joist floor [1]. A composite slab with profiled steel decking has provide over the years to be one of the simpler, faster, lighter, and economical construction in steel-frames building system. Several investigation have been conducted,,to study the,behaviour of the system,,as walling, roofing and flooring units and to study the connection between the components, PSS and DB, of the composite PSSDB system.

Wright and Evans (1989) [2] studied the behavior of the PSSDB panel subjected to, out of plane, bending along its, major axis., It was shown, that the bending, stiffness of the, bare profiled steel, sheet could be, increased by approximately, 30% when, the dry boarding, was attached using, fixings at 300mm canters to canters along each trough, of the profile. It, was found that, the PSSDB system, could be designed, to be 100 mm, less deep than, the traditional system, for a 4 m span, floor carrying domestic, loading.

Badaruzzaman and Wright (1998) [5] carried out a study of structural performance and applications of Bondek II/Cemboard Composite Floor Panel (BCCFP) system by using various types and thicknesses of dry boards. The full-scale bending tests of floor panels of 2.2 m spans with cover width of 600 mm have been conducted. The main variables was the types and thickness of board, the effect of attachment of the dry board and the effect of spacing of connectors.

Badaruzzaman et al. (2003) [8] investigated the role of the dry board in the Bondek II/Cemboard Flooring Panel (BCCFP) system and the performance of the system using various types and thicknesses of dry board. Also, they studied the effect of varying the spacing of screws on the panel performance. Three types of dry board used were playwood, chipboard and cemboard, which was the most preferred choice in the BCCFP system. From the test result, they found that the application of dry boards in BCCFP increased the flexural stiffness by 12.8% to as high as 26.3% compared to that of the steel sheeting alone for the various tested specimens. Also they found that the closer spacing of connectors clearly improves the stiffness and performance of the composite panel.

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Shodiq (2004) [12] presented a method to enhance the structural performance of the PSSDB system by introducing concrete as infill material. Full scale bending tests were conducted on PSSDB floor system to investigate the floor behaviour and to find out the improvement of the system. Based on study conducted, it was proven that concrete as infill material can increase the performance of the floor system compared to the system without infill material. The deflection at the mid-span of the PSSDB floor system was reduced up to 19%.

Johan (2007) [14] extended the work on the PSSDB (which has a single profiled steel sheeting) to a twin deck profiled steel sheeting known as Twin- Deck Dryboard Sandwich Panel (TDDSP). The behaviour of TDDSP system with an opening that may be used as core walls in framed construction was investigated. Nine small - scale specimens were tested under pure shear loading. The results showed that TDDSP composite system significantly improved the performance of the PSSDB composite system against cut- out through wall. The tests of small scale specimens confirmed that the diagonal tension limit state should be the design criterion.

Hamzah and Badaruzzaman (2009) [17] carried out a finite element analysis to determine the effect of screw spacing on the PSSDB wall panel under axial compressive load. The spacing selected was between 100 mm to 500 mm, at an increment of 100 mm in each different model. The deformation profile of the PSSDB wall panel system showed a single curvature deformation profile, maximum lateral displacement at two-thirds wall panel height and critical sections at the upper corners of the square opening. It was concluded that the model with a screw spacing of 200 mm apart was identified as the effective panel to be considered for construction as load bearing wall panel.

Awang and Majid (2010) [19] studied the stiffness of the connector s of the PSSDB system by testing five groups of specimens under constant uniformly distributed loads in wet and dry condition. 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.

Vafa et al.(2013) [29,32] investigated numerically the effect of varying cover widths of PSSDB panels on the strength-to-weight ratio of the system. A nonlinear analysis was conducted on three different PSSDB systems of various PSS cross sections and different pitch numbers. The results of 137 parametric studies were presented in terms of charts. The results showed that the effect of changes in the cover width of the PSSDB panels on the strength to weight ratio of the system is negligible. It was concluded that the strength to weight ratio can be adopted as a standard comparison for optimization of the PSSDB system.

All previous publications reported works on PSSDB system use the self drilling self tapping screw to connect the two main component of the composite system. This paper study the efficiency of Epoxy Adhesive resin and self drilling self tapping screw as a connection in the composite PSSDB system. Figure (1) shows the typical PSSDB composite panel.

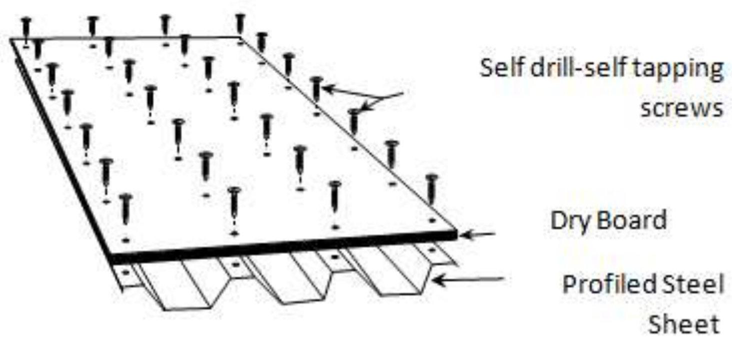

Figure (1) A typical PSSDB composite panel

Experimental push-out test was conducted to determine the strength capacity and the behavior of the proposed connections between the components of the composite PSSDB panels.

For this composite system, there is no standard method concerning the push-out test for the adhesive and mechanical connections. Therefore, test details resembling the push-out test of BS 5400, for steel-concrete composite construction, are used. Some changes are suggested to make the specimens to be in conformity with the new composite system

MATERIALS AND METHODS

Description of Specimens and Material Properties

Three groups of specimens have been assembled using locally available profiled steel sheet (PSS), having depth of 37.5mm and 0.8mm thickness, and a type of a cement board Known as Vnext board with 8mm and 16mm thickness. Self drilling-self tapping screw (4.2mm diameter and 25.4, 38.1mm length) and Epoxy adhesive resin, Sikadure-31CF, have been utilized to connect the dryboard to the PSS. The properties of the material used, which found by laboratory test, are given in tables (1) to (3).

Table 1: Profiled Steel Sheet Properties

Thickness (mm)	Yield Stress (MPa)	Ultimate Tensile Strength (MPa)	Young Modulus (GPa)
0.8	232.03	253.23	200.14

Table 2: Structural Properties of Dry Boards

Modulus of Elasticity (MPa)	3930
Compressive strength (MPa)	
- In plane of the sheet	14.18
- Perpendicular to the plane	33.12
Tensile strength (MPa)	6.5

Table 3: Mechanical Properties of Sikadur-31CF Resin Adhesive

Compressive Strength (MPa)	Flexural Strength (MPa)	Tensile Strength (MPa)	Modulus of Elasticity(MPa)
35	30	15	4300

The specimens of the first and second groups consisted of two dry board connected to double profiled steel sheets. The reason behind using double profiled steel sheeting is to produce a symmetric specimens. The first group specimens were connected by self-drilling self tapping screw at a distance of 100 mm in the longitudinal direction. The lengths of the PSS and the dry board were 300 mm, while the width was either 440 mm or 370 mm depending on whether the dry boards were attached to trough or ribs of the PSS, respectively. The second group specimens were made by replacing the self drilling self tapping screw by adhesive layer of 3 mm thickness. The configuration of these specimens are shown in Figs. (2)and (3).

The third group includes two specimens consisted of two dry board connected on both sides of a single profiled steel sheet by self drilling self tapping screw. This configuration of specimens was suggested in previous research work by others. The specimens are 440 mm wide and 270 mm length. The PSS was connected to the

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dry board by means of eight mechanical connectors. Figure (4) illustrates the details of these specimens. Table (4) gives the summary of the tests performed under the push-out test program.

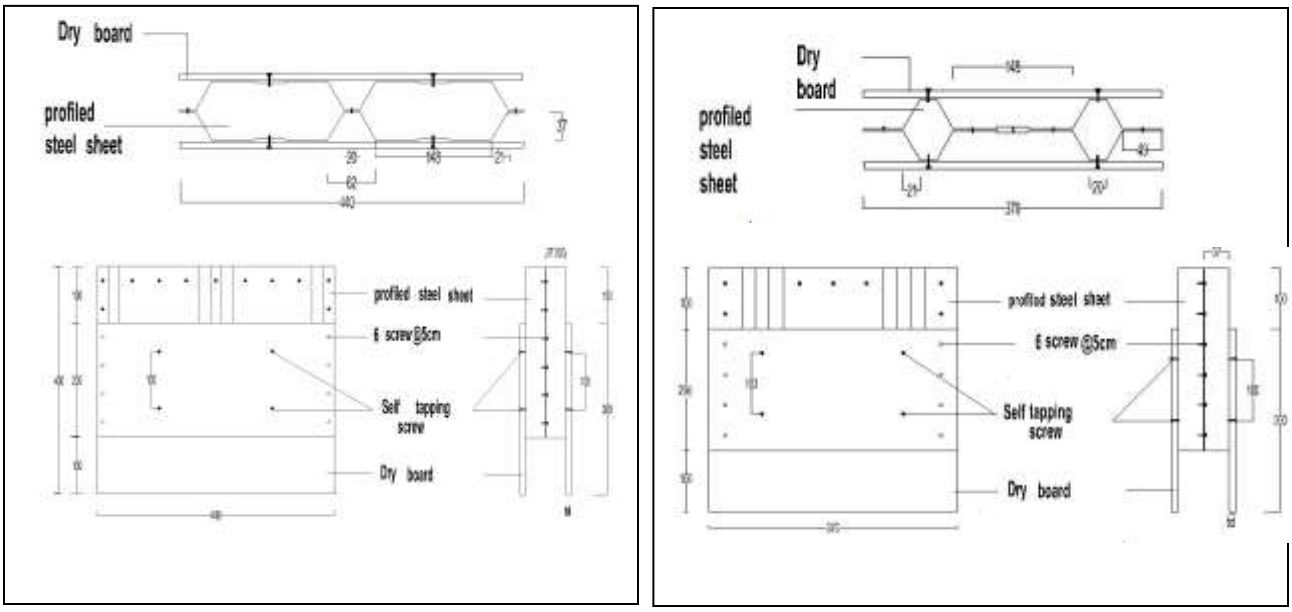

Figure (2):Details of specimens connected by screw on (a) Troughs (b) Ribs

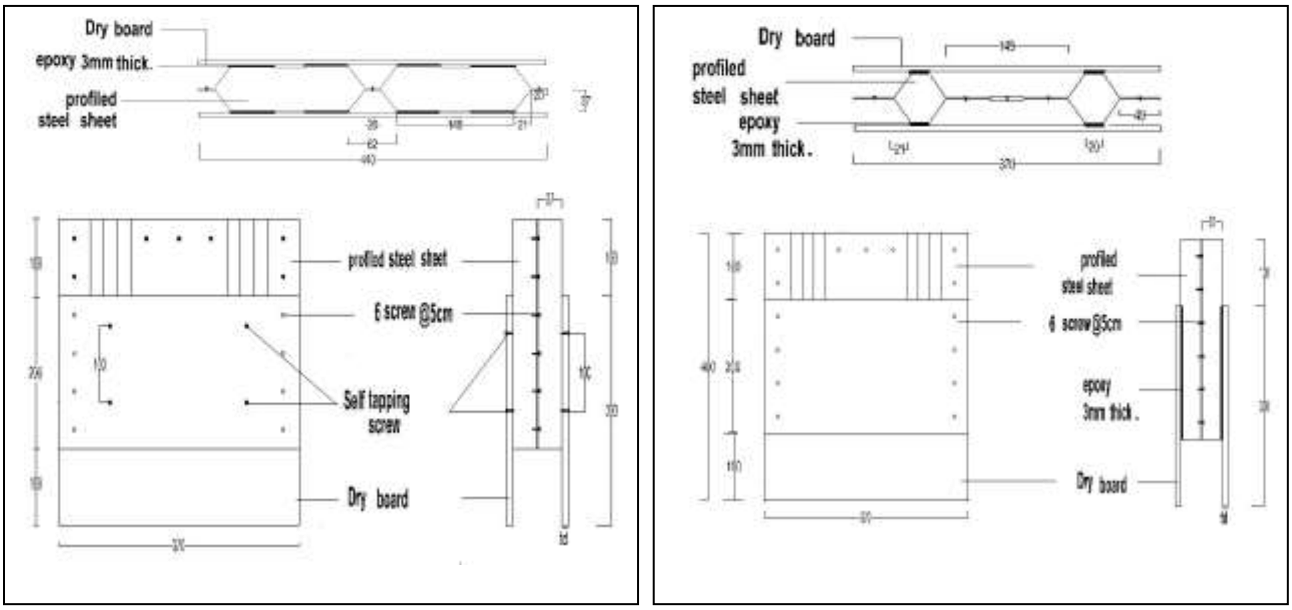

Figure (3):Details of specimens connected by Epoxy adhesive resin on (a) Trough (b) Rib

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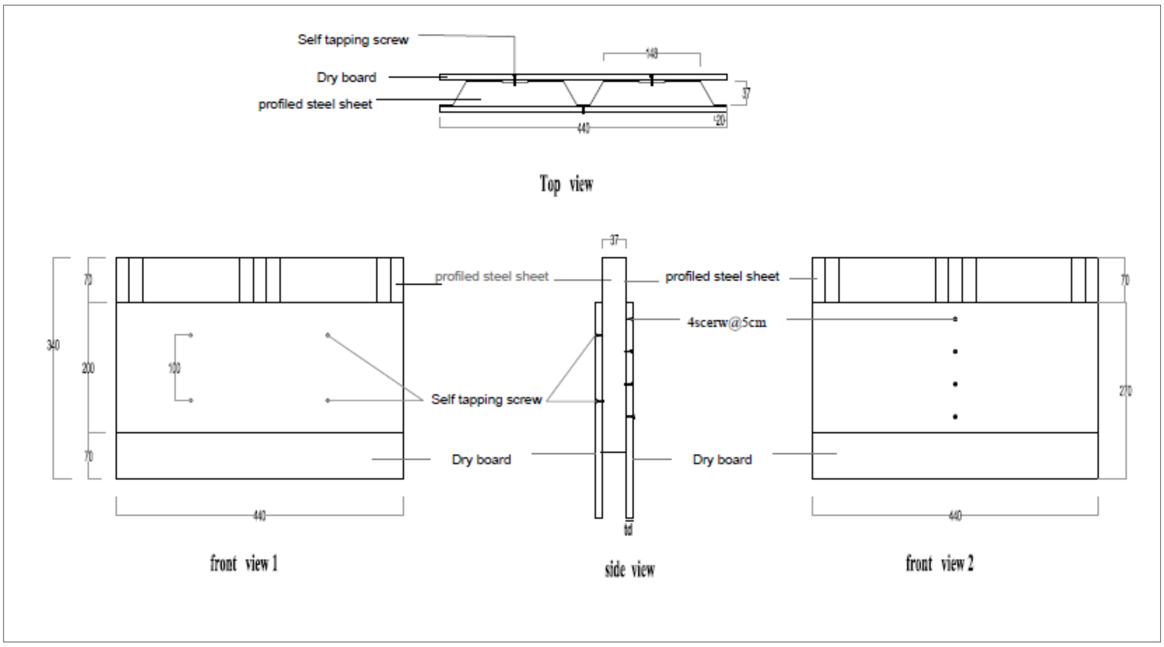

Figure (4):Details of specimens connected by screw on ribs and trough

Table (4) Details of the Push-Out test Specimens

Test Group	Specimen Designation	No. of steel sheet	connection		Dry board Thickness (mm)	Width of Specimens (mm)	Portion of Steel Sheet on Which connection Provided
			No. of screw	Area of Epoxy (cm^2)			
1	POD8R	2	8	---	8	370	Rib
	POD16R				16	370	Rib
	POD8T				8	440	Trough
	POD16T				16	440	Trough
2	POD8R#	2	--	160	8	370	Rib
	POD16R#			160	16	370	Rib
	POD8T#			800	8	440	Trough
	POD16T#			800	16	440	Trough
3	POS8	1	8	---	8	440	---
	POS16				16	440	---

The symbols in Designation [(D,S) (8,16) (N,W)] means:

D,S: double or single profiled steel sheet.

8,16:thickness of the dry board (8mm or 16mm).

R, T : the dry board connected to the rib or trough of the PSS.

: the PSS and the dry board were connected by adhesive layer.

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Test Setup and Instrumentation

All the specimens are setup at the pressing frame as shown in Fig (5). Each specimens was subjected to a uniform line load. The load was applied gradually and maintained constant while the vertical slip between the profiled sheet and the board was measured. Laser displacement sensor was used to measure this slip at the interface of the PSS and the board. The specimens were loaded to ultimate load without unloading. The test was stopped when a sudden reduction in applied load was observed or when the dry board was separated from the PSS.

Figure (5) Test Setup

RESULTS AND DISCUSSION

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

For the first and third groups of specimens made by connecting the dry boards to the PSS by self drilling-self tapping screws, the specimens showed nearly identical failure behavior depending on the thickness of the dry boards. Two modes of failure were observed. The first mode is noticed in POD16R, POD16T and POS16 specimens, which are made by using dry boards of 16 mm thickness. The failure of these specimens occurred by separation of the dry board from the PSS, where the connectors failed by shearing as shown in Fig.(6). The second mode of failure was observed in specimens POD8R, POD8T and POS8, in which the thickness of dry boards used was 8 mm. Here the failure occurred by spalling of the dry board with the screws head still being attached. The screw head has gradually sunk into dry board and bulging of the dry board surface at screw area, as shown in Fig(7)

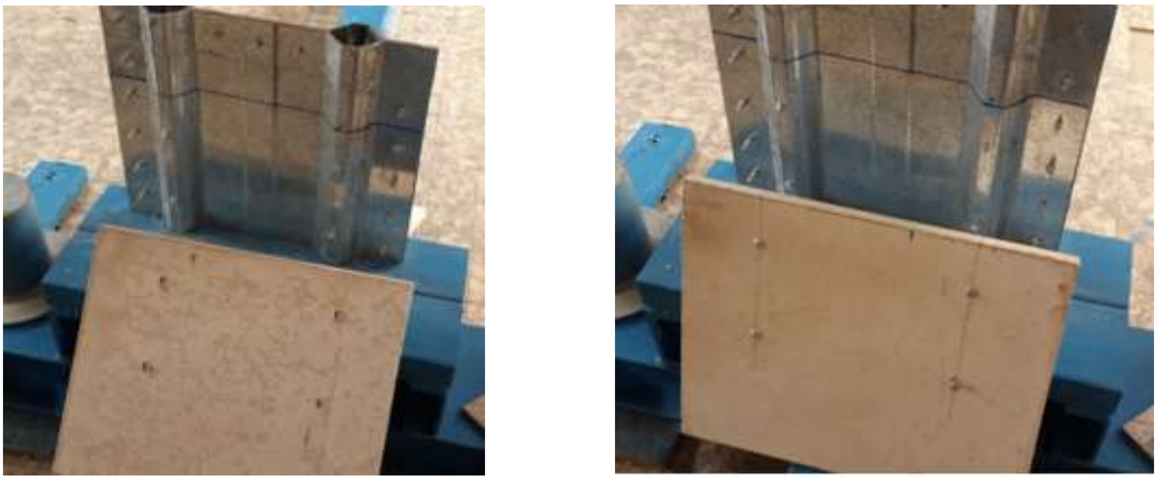

Figure (6) Shear Failure of connectors

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Figure (7) Failure of specimens by spalling of the dry board with the screws head still being attached

For the second group (POD8R#, POD16R#, POD8T# and POD16T#) specimens made by bonding the dry board to the PSS by adhesive epoxy layer, a sudden separating occurs between the dry board and steel sheet after a local buckling of PSS, as shown in Fig.(8).

Figure (8) Failure of Specimens Connected by Epoxy by Separating The Dry Board From PSS

The details and results of tested push-out specimens are summarized in Table(5) and figures (9) to (11), which showed the variation of measured slip with the total load on specimens, where the ultimate slip was obtained by extrapolation of the experimental results.
It can be seen from figure (9) that the mechanical connectors have a good resistance to the applied shear. The maximum extrapolated slips is 8 mm for POD8T specimen. Therefore this type of connection (using self drilling- self tapping screw) may be considered as a flexible connection. While figure (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 dry board panel occurs with maximum extrapolated slips of 0.97 mm and 0.85 mm for POD8R#, POD16R# specimens, respectively and 1.84 mm and 1.78 mm for POD8T#, POD16T# specimens, respectively. Therefore this type of connection (using adhesive material) represent a rigid connection.
The using of single PSS instead of double PSS, as in the third group, has no effect on the resistance of the specimens, as shown in Table (5) and Fig. (11).

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As expected, the different thickness of dry board will produce different strength value of connection. The capacity of connecter (self drilling-self tapping screw with 4.2 mm diameter) is about 1.736 kN/screw. This value increased by about 20% with the increase in dryboard thickness to double (from 8 mm to 16 mm). The Ultimate load sustained by the specimens connected by using epoxy adhesive resin is about 37 kN/m and 137 kN/m for the DB connected to ribs and trough sides of PSS, respectively. These values increased by about 14% with the increase in dryboard thickness to double.

Table (5): Experimental results of Push-Out Test

Test Group	Specimen Designation	Total Ultimate Load (kN)	Strength of Connection		Extrapolation Slip at Ultimate Load (mm)
			Load per mm Length (kN/mm)	Load Per Connector (kN)	
1	POD8R	13.89	---	1.736	6.34
	POD16R	16.57	---	2.071	5.8
	POD8T	13.89	---	1.736	8
	POD16T	16.87	---	2.109	4.55
2	POD8R#	14.88	0.037	---	0.85
	POD16R#	16.87	0.042	---	0.6
	POD8T#	54.68	0.137	---	1.93
	POD16T#	63.00	0.157	---	2.05
3	POS8	13.53	---	1.735	8.3
	POS16	15.70	---	2.055	5.01

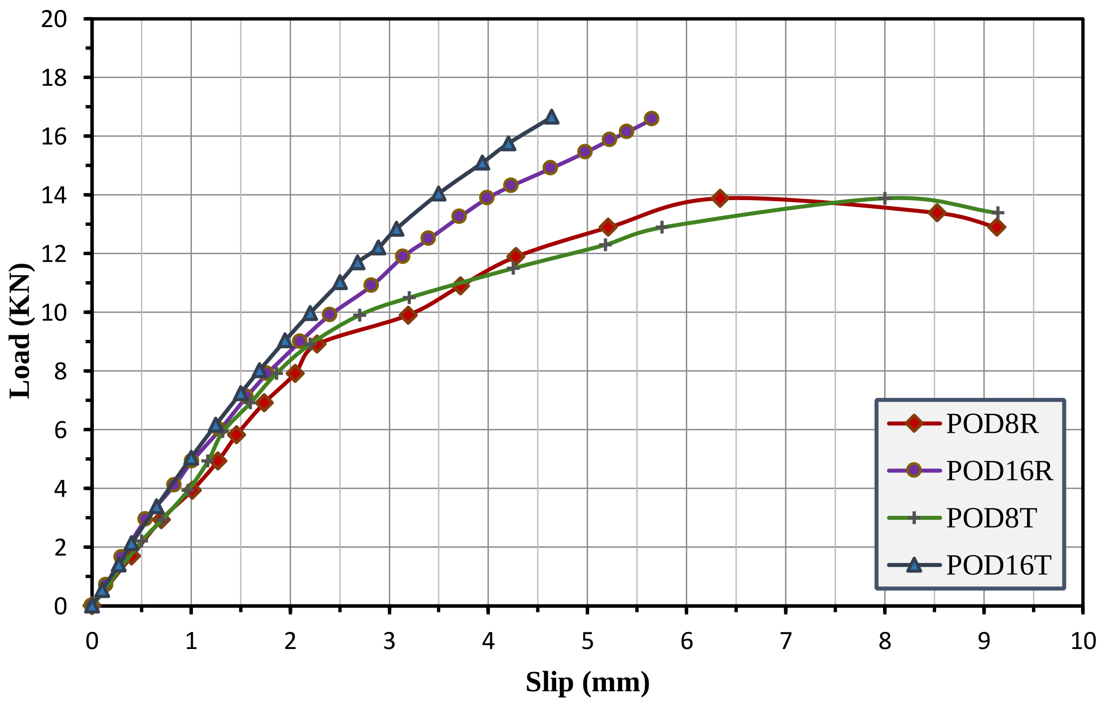

Figure (9) Load Slip Relationship for Push – Out Test

(1st Group: Specimens Connected by Mechanical Connectors)

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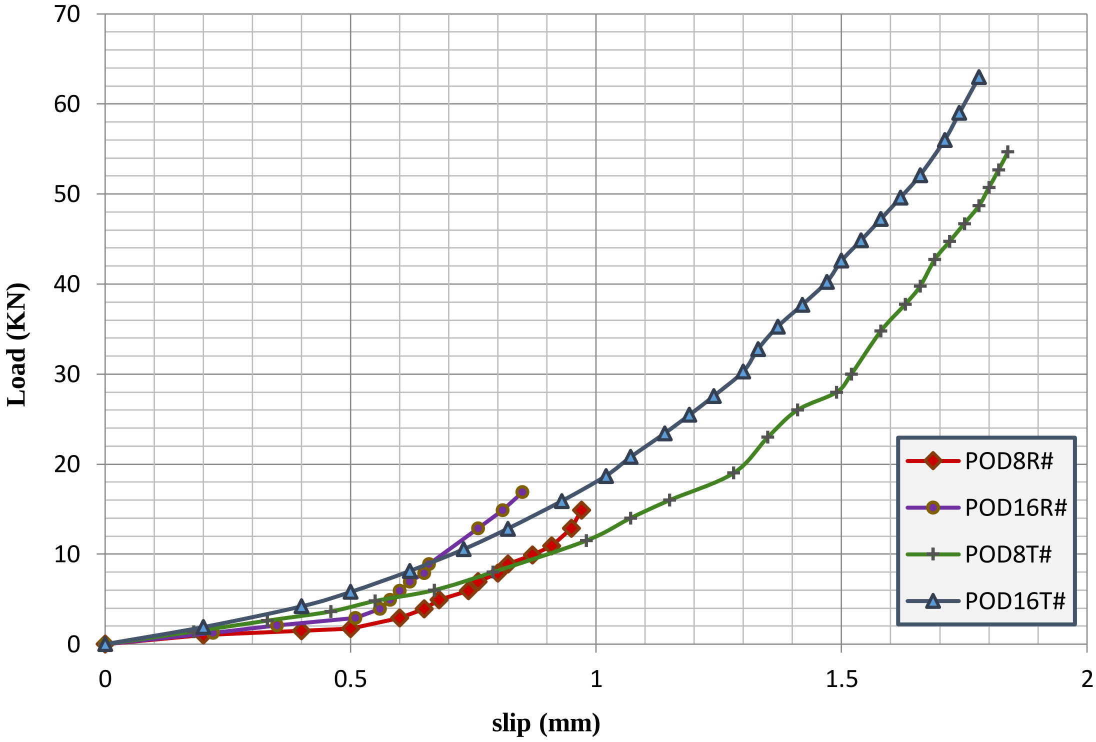

Figure (10) Load Slip Relationship for Push – Out Test

(2nd Group: Specimens Connected by Epoxy Adhesive Resin)

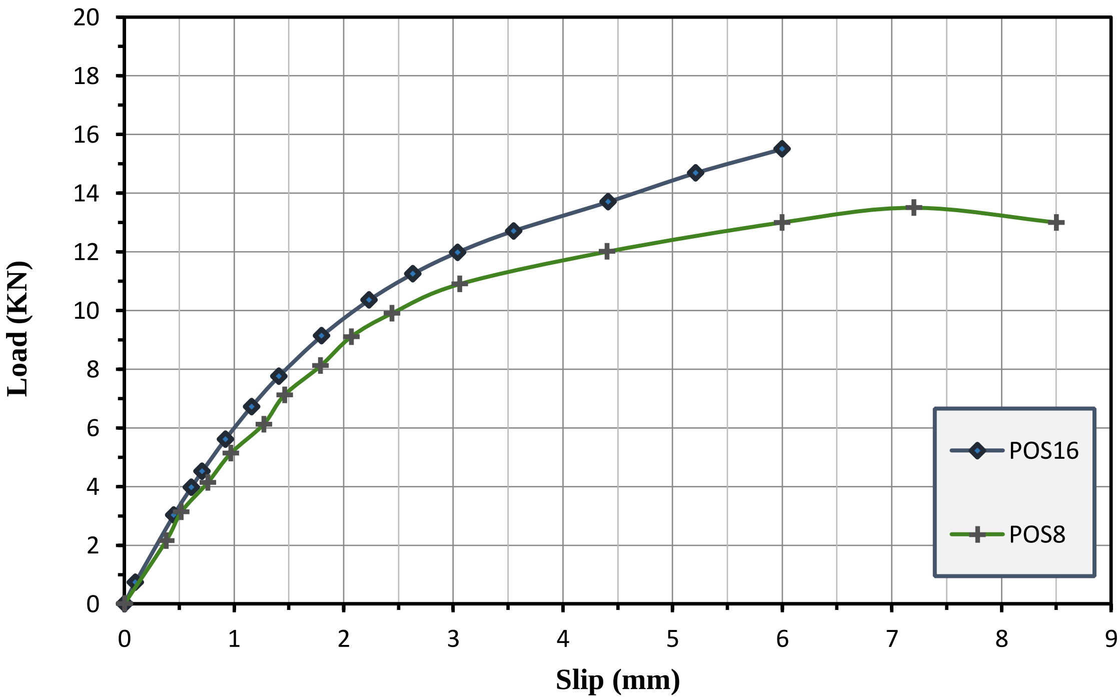

Figure (11) Load Slip Relationship for Push – Out Test

(3rd Group: Specimens Connected by Mechanical Connectors)

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CONCLUSION

The connectors behaviour of the PSSDB system have been presented and discussed. Two types of connection are proposed, mechanical connector and epoxy adhesive resin, to connect the PSS and dry board to achieve the composite action of the PSSDB system. An experimental investigation has been done to observe the behaviour of connectors under constant uniformly distributed load.

Two methods were used in fabricating the push-out specimens. The first by using two DB connected to double PSS. This specimen was connected by either mechanical fasteners or epoxy adhesive resin on rib or trough sides of PSS. The second method by using two DB and single PSS instead of double, and were connected by mechanical fasteners only. It was noticed that, the use of single PSS instead of double PSS, in fabricating the push-out specimens connected by screw, has no effect on the resistance of the specimens.

The mode of failure of push-out specimens depends on the type of connection. In specimens connected by mechanical fasteners, two significant modes of failure are observed. The first, occurred by the bending of the screw and bulging of the dry board surfaces in the area surrounding the head of the screw. This type of failure was observed in specimens with 8 mm thick. of DB. The second mode happened when the thickness of dry board was 16 mm. These specimens failed by the shearing of the screw.

For push-out specimens connected by epoxy adhesive resin, the failure started by the buckling of the PSS and ended by separation of the dry board from the PSS. Therefore, this type of connection can be represented as a rigid connection with small resistance to separation.

For the specimens connected by screw, when the thickness of dry board is doubled, the strength of the specimens increases by about 20% for the both cases where the dry boards are attached to the trough or rib sides of PSS. While for the specimens connected by epoxy adhesive material, the ultimate load increases by 14% with the increase in dryboard thickness to double.

The results of the experimental show that, the epoxy adhesive resin is a good alternative connection for use in PSSDB system as well as being alternative building material in construction building.

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