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Connector Stiffness of 'Peva-Cemboard' Screwed Connection in Profiled Steel Sheet Dry Board (PSSDB) Panel

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Abstract
The Profiled Steel Sheet Dry Board (PSSDB) composite panel consists of profiled steel sheet connected to dry board by self-drilling and self-tapping screws. The mechanical connectors, namely the screws, serve to transfer the shear force between the two layers. When a PSSDB floor panel is loaded, the connectors, dry board and profiled steel sheet around the connectors deform, thus inducing slip between the layers. The amount of slip, which reflects the stiffness of the connection, determines the degree of composite action and the overall performance of the floor panel. The actual connector stiffness is thus a very important parameter in the finite element analysis of the floor. The stiffness varies according to the type of screw and spacing between screws, dry board and profiled steel sheet used and needs to be determined empirically for each new combination. This paper describes a series of experiments to determine the connector stiffness, known as the push-out tests for three combinations of profiled steel sheets and dry boards. It is basically a compression test to determine the load versus slip curves. Nine samples were tested; the ultimate loads and modes of failure were observed. The stiffness values were determined from the slope of the graphs. The results showed that the Peva-Cemboard combination has a higher stiffness than that of the Peva-Plywood, but the latter recorded a higher ultimate load. The failure modes consist of a mixture of sheared or pull-out of screws (inclination failure), tearing of profiled sheeting and crushing of dry boards. All the stiffness values are within the range of previous findings and can be used in the finite element analysis of the floor model.

Keywords
Composite panel, Shear connectors, Push-out test, Stiffness, Profiled steel sheeting

1. Introduction

The Profiled Steel Sheet Dry Board (PSSDB) composite panel consists of profiled steel sheet connected to dry board by self-drilling and self-tapping screws. The system can be used for a variety of structural purposes such as flooring, roofing, and walling panels. The structural behaviour of the basic PSSDB system depends on the properties of the basic components forming the system and the degree of interaction between them. The degree of interaction can be either full or partial, depending on the connector modulus and spacing. Studies on the behaviour of the PSSDB system as floor panels have been reported in earlier publications (Wright *et al.,*1989; Ahmed, 1996; Ahmed *et al.,*2002; Wan Badaruzzaman *et al.,* 2003). When a PSSDB floor is loaded, the connectors are subject to shear forces and as they deform, they allow a considerable relative displacement between the profiled steel sheeting and dry board layers to occur, resulting in partial or incomplete interaction between layers. To develop an analytical model of a composite for this partial interaction, it is required to input the shear properties of the connection and the most convenient way is through laboratory test called push-out test, on small size specimens (Akhand, 2001).

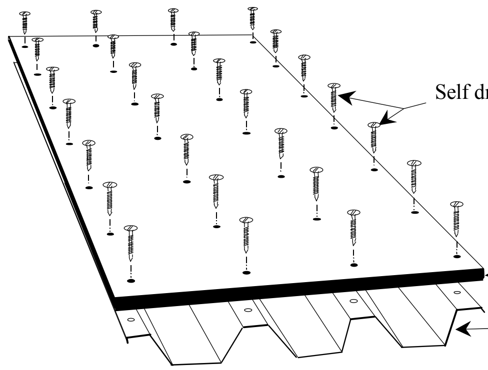

Figure 1: A Typical PSSDB Composite Panel

The push-out test is a standard procedure in steel-concrete composite member's construction such as reported by Ellobody *et al*. (2007), Jeong *et al.* (2005). The test is to investigate the capacity of the shear connection and load-slip behaviour of the shear connector between concrete and profiles steel sheeting. However, for PSSDB system, push-out test is carried out mainly to determine the shear connector stiffness needed in the finite element analysis of a floor, roof or wall model. The stiffness varies according to the type of screw and spacing between screws, dry board and profiled steel sheet used and needs to be determined empirically for each new combination. Although previous PSSDB push-out test data are available (Ahmed, 1996; Akhand, 2001; Harsoyo, 2004; Awang, 2008), the present study uses different material, quality and combination, thus, requires a new push-out test to be performed. In the typical PSSDB push-out test, profiled steel sheeting is connected to two pieces of dry board by means of shear connectors which are the self tap, self drill screws. Compression is applied and the load versus slip curve is plotted. The stiffness value is determined from the linear rising slope of the graph.

2. Test Specimens

Nine specimens were prepared for three sets of experiments and the details are given in Table 1 below.

Table 1: Specimen Details for the Push-out Experiment

Specimen	Profiled steel sheeting	Dry board	Quantity
Peva-Cemboard	Peva 45 (0.8 mm thick)	Cemboard (18 mm thick)	3
Peva-Plywood	Peva 45 (0.8 mm thick)	Plywood (18 mm thick)	3
Cemboard-Timber	none	Cemboard (18 mm thick) Timber (45 mm thick)	3

For the Peva- Cemboard and Peva-Plywood specimens, the profiled steel sheeting (Peva 45) is connected to two pieces of dry board (Cemboard or Plywood) by means of six mechanical connectors (screws) as shown in Figure 2 below.

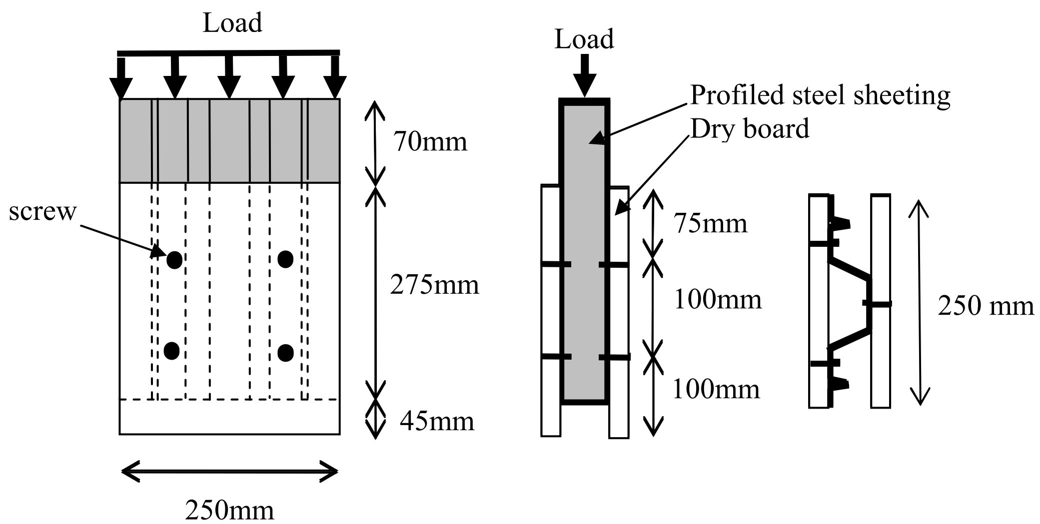

Figure 2: Schematic Drawing of Peva-Cemboard and Peva-Plywood Specimens; Starting from the Left – Elevation, Side and Cross Sectional Views.

However, for Cemboard-Timber specimens, the dry board (Cemboard) is connected to three identical timber blocks instead, by means of six similar connectors. The schematic drawing is given by Figure 3.

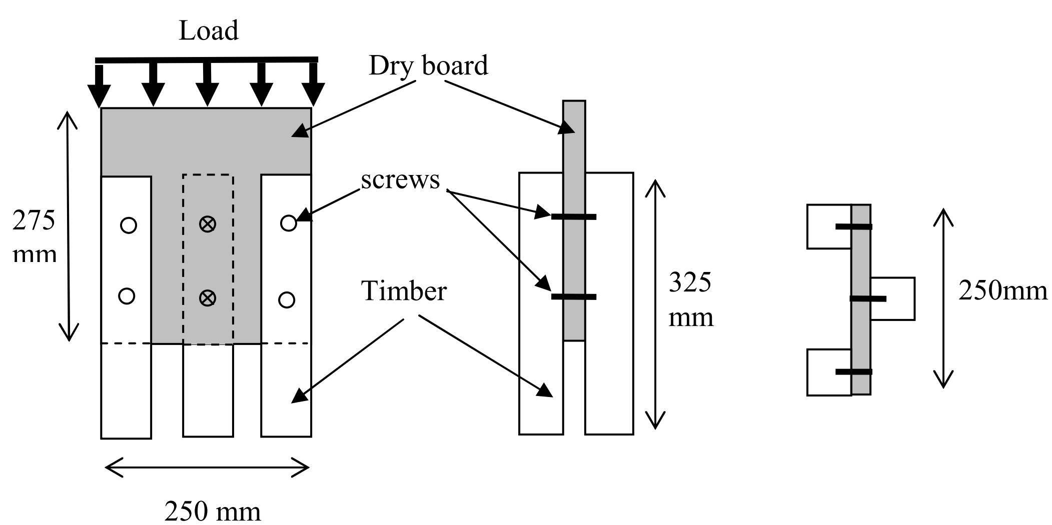

Figure 3: Schematic Drawing of Cemboard-Timber Specimen; Starting from the Left -Elevation, Side and Cross Sectional Views

The materials and the combination selected are based on the actual ones used in the PSSDB floor being investigated. The self tapping, self-drilling screws are all 3.2 mm (1.25 inch) in length, and 3 mm in diameter.

3. Testing and Observation

All the specimens were then mounted vertically in the *Enerpac* frame and a uniform load was applied via a hand pump to the upper protruding end of the profiled steel sheeting (for the Peva- Cemboard and Peva-Plywood specimens) or dry board (for the Cemboard-Timber samples) as shown in Figure 4.

Figure 4: Specimens Testing of -(Left) Profiled Steel Sheeting and Dryboard, (Right) Dry Board and Timber

Two transducers were placed at equal distance from the centre of the samples and the average reading was taken as the displacement or slip, corresponding to the gradually applied load. The Peva-Cemboard samples recorded an average of 3.13 kN for ultimate load. All of the samples displayed some tearing of profiled sheeting prior to failure by sudden fracture of the screw near the head. Crushing and spalling of the Cemboard were also observed in the vicinity as shown in Figure 5.

Figure 5: Sample Failure of Specimens – Spalling of Cemboard Dry Board (B)

The Peva-Plywood, however, reached an ultimate load of 3.82 kN, 22% higher than that of Peva-Cemboard. The samples failed by the screws being completely pulled through the plywood whilst still being attached to the profiled steel sheeting as evident in Figure 6. The screws were slightly bent but still left intact. The Cemboard-Timber samples have the lowest ultimate load of 1.33 kN. They failed either due to screw fracture or total screw pull-out from the timber.

Figure 6: Sample Failure of Specimens - Slanted Screws

Figure 7 shows the condition of the screws recovered from the experiment. In general, the sample material combination determines the manner the screws failed or deformed. The screws were either severed at different parts of the screw shaft, or bent under the shearing load.

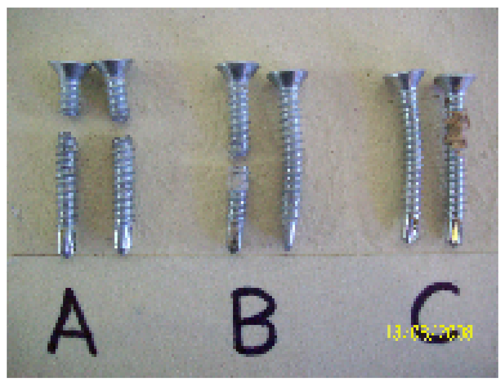

Figure 7: Failed Screws Condition from –
(A) Peva-Cemboard (B) Cemboard-Timber (C) Peva-Plywood samples

4. Test Results and Analysis

Figure 8 shows the load-slip curve for all the three specimens. The load is expressed in terms of average load per connector. The tests show that the initial load-slip response for the entire specimen for up to 1 kN/mm is linear and elastic.

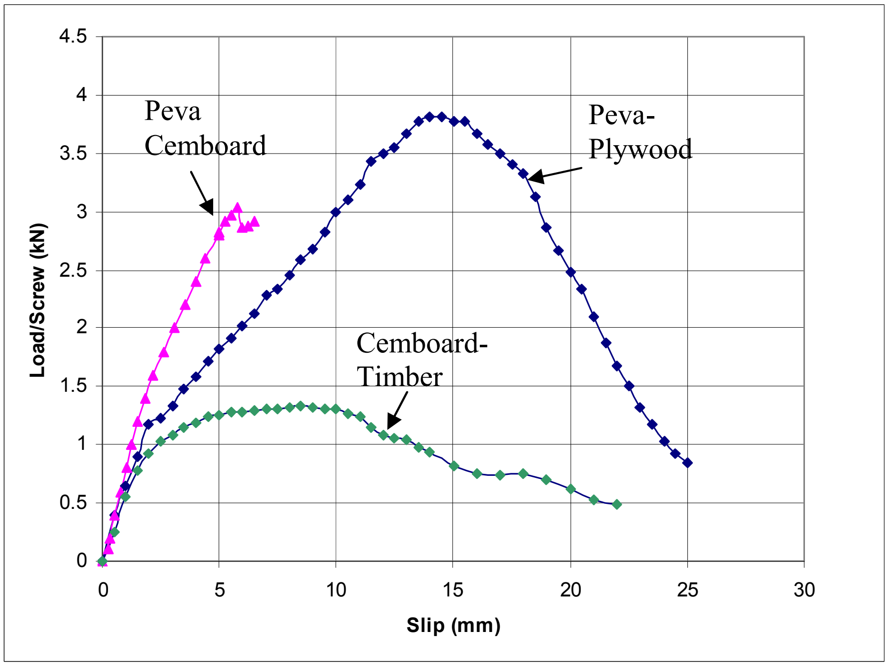

Figure 8: Push-out Tests Graph for the Respective Specimens

The stiffness values are determined by these slopes for the respective specimens. Peva-Cemboard marks the highest stiffness value of 0.77 kN/mm, followed by Peva-Plywood (0.61 kN/mm) and Cemboard-Timber (0.53 kN/mm). However, their performances at higher loads are remarkably distinct. Peva-Cemboard maintains the slope but falls short after it hits the 3 kN/mm mark. This can be attributed to the brittle nature of Cemboard which allows the screw to lean and bite through the board before finally snapped near the head. Cemboard is basically a cement bonded rubber-wood board with a modulus of elasticity of 4500 N/mm^2. Plywood, on the other hand, has a higher modulus of elasticity value of 8160 N/mm^2 and this factor has allowed the Peva-Plywood specimen to attain 22 % higher ultimate load. The plywood is made of layers of thin sheets of veneer, glued perpendicularly to each other. The concaving graph proves that these characteristics have better resistance to screw by prolonging the process of leaning and biting which results in an overall ductile behavior. The Cemboard-Timber specimen has the lowest stiffness and ultimate load values among all the rest. Its ultimate load is only 42% of that of Peva-Cemboard and 35% of that of Peva-Plywood specimens. Without the presence of a stronger material such as steel sheeting, the combination of Cemboard and timber maintains a ductile behavior but at a much lower load.

5. Conclusion

The stiffness and ultimate load of the push-out specimens analyzed are summarized in Table 2 below.

Table 2: Stiffness and Maximum Load Values for Push-out Test

Specimen	Stiffness (kN/mm)	Ultimate Load (kN)
Peva-Cemboard	0.77	3.13
Peva-Plywood	0.61	3.82
Cemboard-Timber	0.53	1.33

Peva-Cemboard ranks the highest in terms of stiffness and Cemboard-Timber has the lowest value in both the stiffness and ultimate load. However, in the linear region, Cemboard-Timber performance matches that of the rest of the specimens despite the absence of the stronger material, the profiled steel sheeting. This is clear from the values of the stiffness in Table 2. Nonetheless, this absence has drastically reduced the ability of the Cemboard-Timber in nonlinear region to resist the shearing load which results in a much lower ultimate value of 1.33 kN. Peva-Cemboard combination has a higher stiffness than that of the Peva-Plywood, but the latter recorded a higher ultimate load although both use the same profiled steel sheeting. This emphasizes the influence of dry board has on the performance of the specimen. The failure modes consist of a mixture of sheared or pull-out of screws (inclination failure), tearing of profiled sheeting and crushing of dry boards. All the stiffness values are within the range of previous findings and can be used in the finite element analysis of the floor model.

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