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Development of a New Composite Flooring System Based on Improved Profiled Steel Sheet Dry Board (PSSDB) System

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Abstract
This paper presents an experimental study on the behaviour of a double skinned 'Profiled Steel Sheet Dry Board (PSSDB)' composite panel system. This newly proposed system is basically an extended structural system based on a previously developed single skinned PSSDB system. The basic components forming the system consist of a single profiled steel sheet attached to a double-skinned dry board layers, also by self-drilling and self-tapping screws. The experimental structural stiffness of the proposed floor system is compared with simple theoretical prediction. The experiment is also performed to identify the behaviour of the system until failure using full-scale model in the laboratory. Two samples using different types of Profiled steel sheeting (Peva 45 and Bondek II, both having 1 mm thickness) were tested with the distance between screws of 200 mm for each sample. The dry board is 9 mm thick Prima*flex*. Prima*flex* is a newly introduced dry board as an alternative to an earlier widely used Cemboard. The dimensions of the simple supported models are 2000 mm (span) x 850 mm (width). It can be concluded that the use of double layer Prima*flex* with Bondek II is able to increase the stiffness and load bearing capacity of the system compared to that using Peva 45. It was found that the maximum load of Peva 45 and Bondek II were 24.1 kN and 41.6 kN respectively. The value of theoretical stiffness was found to be higher than the experimental stiffness; for Peva 45, the values were 229.0 kNm² and 196.6 kNm² respectively, and for Bondek II, the values were 536.6 kNm² and 304.7 kNm² respectively. These discrepancies are due to the simplification made in the theoretical prediction by assuming that the system is acting in a full interaction mode, whereas in reality, it is behaving in partial interaction behaviour. Therefore, it can be concluded that the PSSDB floor system comprising Bondek II does has great potential to be used as load-bearing structural floor system.

Keywords
Double-skinned flooring system, Profiled sheeting, Dry board

1. Introduction

The idea of using PSSDB system as a structural component was first introduced by Wright and Evans (1986) as a replacement to existing timber joist floor. Studies on the behaviour of the PSSDB system as floor panels have been reported in earlier publications by Ahmed (1999), Ahmed and Wan Badaruzzaman (2002, 2006), Akhand (2001), Wan Badaruzzaman *et al*., (2001a) and Wan Badaruzzaman and Wright (1998). The above reported studies include structural and non-structural performance of the system. Most of the previous research works studied PSSDB floor panels with single-skinned dry board utilising other types of dry board. This paper, however, deals with the effect of using double-skinned dry boards on two different types of profiled steel sheet, namely Peva 45 and Bondek II. A new type of dry board, namely Prima*flex* was introduced here to form a more rigid load bearing panels. The deflection and stiffness values of the PSSDB panels are compared. In an earlier research works, Wright *et al*., (1989) have proposed two types of boards to be used in their PSSDB system, namely plywood and chipboard. However, a study done by Wan Badaruzzaman *et al*., (2001b) on a type of cement bonded board, Cemboard, manufactured locally in Malaysia indicates that this board is good in weather, fungal and insect resistance. Even though the three types of dry boards were usually used in the PSSDB system, the authors found that Prima*flex* performed better as will be shown in this paper. Prima*flex* is also manufactured locally in Malaysia by Hume Cemboard Berhad (Hume, 2007).

2. Component of Materials

Profiled Steel Sheet Dry Board composite panel system consists of three main components, namely profiled steel sheet, dry boards and connectors, which are available as individual item from the local market.

2.1 Profiled Steel Sheeting

The profiled steel sheeting is the principal load bearing component in a PSSDB floor system. The yield strength of profiled steel sheet is between 350 MPa to 550 MPa. Even though the strength is high, the stiffness characteristic is low. The thickness of the sheeting for wall and roof applications is relatively thin (0.4 mm –0.6 mm). Based on the studies of over hundreds of different steel sheets, the sheets could be sorted into several groups based on their shape and depth (Wright *et al.,* 1989). The difference in shape and depth will greatly influence the performance of the PSSDB system. The stiffness of the sheeting increases with the depth of the profile.

2.1.1 Peva 45 profiled steel sheeting

Figure 1 shows the cross-section Peva 45 profiled steel sheeting. Table 1 shows the characteristics of 1 mm thick Peva 45. The minimum specified yield strength of Peva 45 is 350 MPa. The Young's modulus of Peva 45 is 210×10^3 MPa.

Table 1: Peva Section Properties

Nominal Thickness (mm)	Cover-width (mm)	Depth of Sheeting (mm)	Height to Neutral Axis (mm)	Area of Steel (mm^2/m)
1.0	750	45	17.83	1422

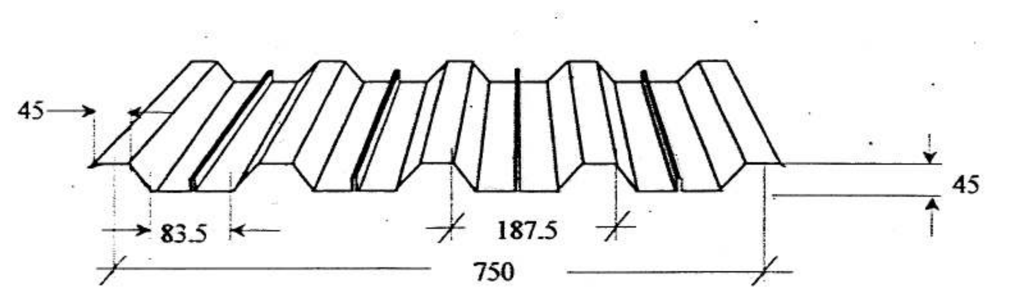

Figure 1: Cross Section of Peva 45 (units in mm)

2.1.2 Bondek II profiled steel sheeting

Bondek II has two internal dovetail ribs and a male and a female lap ribs to enable lap joint between modules 600 mm cover-width. The minimum specified yield strength of Bondek II profiled steel sheeting is 550 MPa. The Young's modulus of Peva 45 is 210×10^3 MPa. Table 2 shows the characteristics of 1.0 mm thick Bondek II while Figure 2 shows the cross-sectional view.

Table 2: Peva Section Properties

Nominal Thickness (mm)	Cover-width (mm)	Depth of Sheeting (mm)	Height to Neutral Axis (mm)	Area of Steel (mm^2/m)	Moment of Inertia (cm^4/m)
1.0	600	54	14.43	1634	63.68

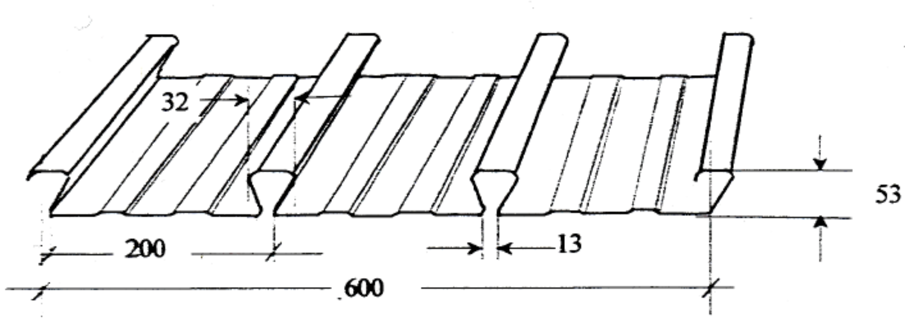

Figure 2: Cross Section of Bondek II (units in mm)

2.2 Prima*flex*

The Young's modulus of Prima*flex* is 8000 MPa, which is higher than the usual dry boards used by other researchers such as Cemboard (4800 MPa). Prima*flex* is made from top grade cellulose fibres, Portland cement and finely ground sand. It will not deteriorate when exposed to sun, rain, wind, dampness and dryness. Whilst on the aspect of fire resistance, Prima*flex* is classified as highly fire-resistant in relevant Australian and British Standards. Table 3 shows the structural properties of Prima*flex*, 9 mm.

Table 3: Structural Properties of Dry Boards (Prima*flex* 9 mm)

Characteristics	Dry	Wet
Modulus of Elasticity (MPa)	8000	7000
Shear strength (perpendicular to the plane of the sheet) (MPa)	18	14
Compressive strength (MPa)		
- In plane of the sheet	20	15
- Perpendicular to the plane	>50 MPa	>50
Flexural strength (mean)	≥ 16 MPa	≥ 10

Source: Hume Cemboard (2007)

2.3 Connectors: Self-Tapping, Self-Drilling Screws

The connection between components (profiled steel sheet and dry board) is very important in the composite PSSDB system. The self-drilling and self-tapping screws were found to be the most suitable connectors for the system. These types of screws are also locally produced in various sizes and shapes. The screws in the system will transfer the horizontal shear force between the dry board and the profiled steel sheeting.

3. The Specimens

Two samples were prepared; one was the specimen using 1 mm thick Peva 45 (Figure 3), whilst the second specimen used 1 mm thick Bondek II (Figure 4). Table 4 shows the detail information for the samples. The screw spacing was fixed at 200 mm for practicality purposes, and the panel overall dimensions were 2000 mm x 850 mm.

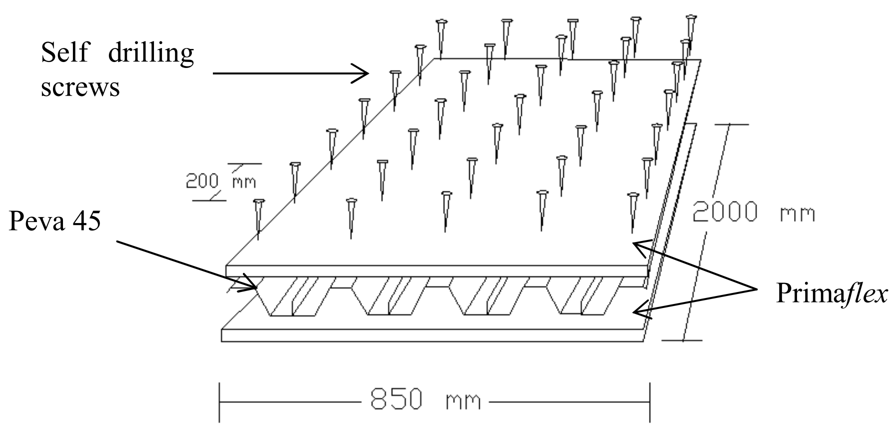

Figure 3: Sample 1

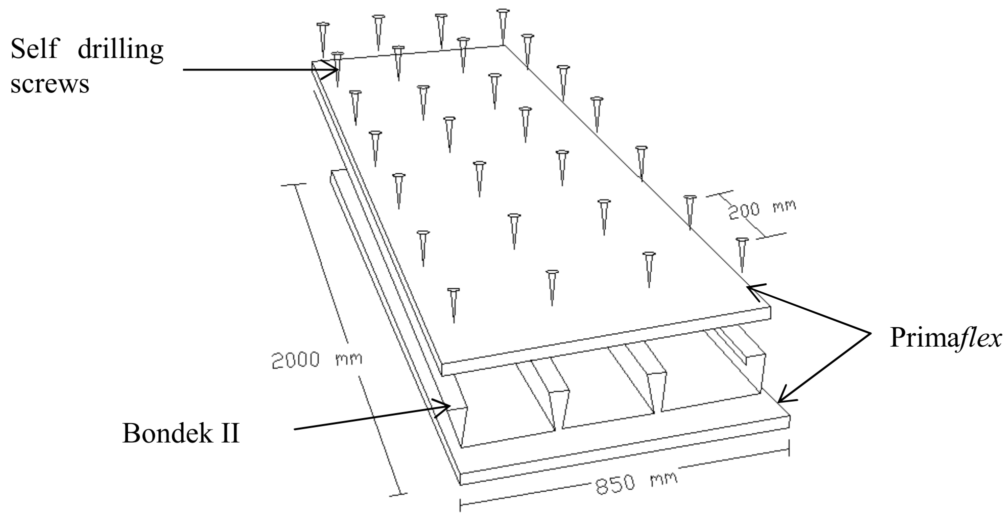

Figure 4: Sample 2

Table 4: Samples for the Flexural Tests

Sample	Profiled Steel Sheet (PSS)	Dry Board (DB)	Screws
1	Peva 45, 1 mm thick	Prima*flex* 9 mm thick	DX-345 BO 30 mm length at 200 mm c/c on each bottom PSS flange
2	Bondek II, 1 mm thick	Prima*flex* 9 mm thick	DX-345 BO 30 mm length at 200 mm c/c on each bottom PSS flange

4. Experimental Works

The models described above were constructed and tested in the laboratory. The models were tested on a simple span via a whiffle tree loading to simulate a uniformly distributed load. The loading system was designed to produce a uniform line load along the mid-span of the panels. Load cell and hydraulic hand pump jacks were used for the loading purpose. Deflections at mid and quarter span of the specimens were measured using transducers. Figure 5 shows a typical test arrangement. All the transducers and load cell were connected to a data logger. The transducers were located at the middle and quarter span along the mid span line. The transducers were also located at both ends of the mid width line to detect any unintentional unsymmetrical eccentricity of loading.

Five transducers (T1 to T5) were attached to the specimen surface as shown in the schematic drawing of Figure 5 to measure the deflections. Some of the transducers were meant for checking the symmetrical behaviour of the specimens, which is very important to confirm the reliability of the test results. All the measuring devices were connected to a digital portable electronic data logger. The initial values were zeroed prior to the testing. These conditions were considered to represent the initial unloaded state of the panel. Loads were then applied incrementally as shown in Figure 6, starting from zero until the samples failed.

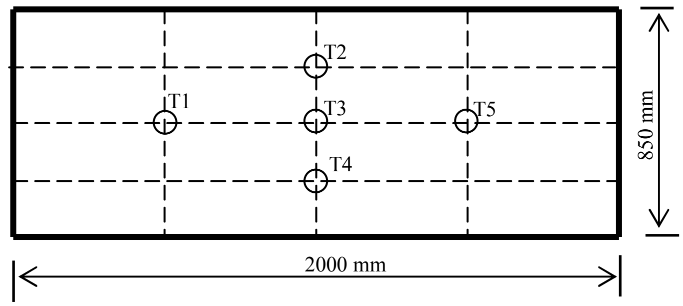

Figure 5: Schematic Drawing of the Transducers Location

Figure 6: The Panel Deflects Under Loading in the Laboratory

5. Experimental Test Results and Discussions

Figure 7 and Table 5 show the maximum load, flexural stiffness and load-deflection behaviour of the test models based on the mid-span, mid-width deflection values for the various load intervals. At the initial stage, the load-deflection curves obtained from the experiment exhibits similar characteristics. The curves show a linear elastic relationship. This linear elastic response continued until a non-linear stage and plastic stage are reached before failure of the models. From the results, the sample using Bondek II (Sample 2) is obviously performing much better than sample with Peva 45 (Sample 1).

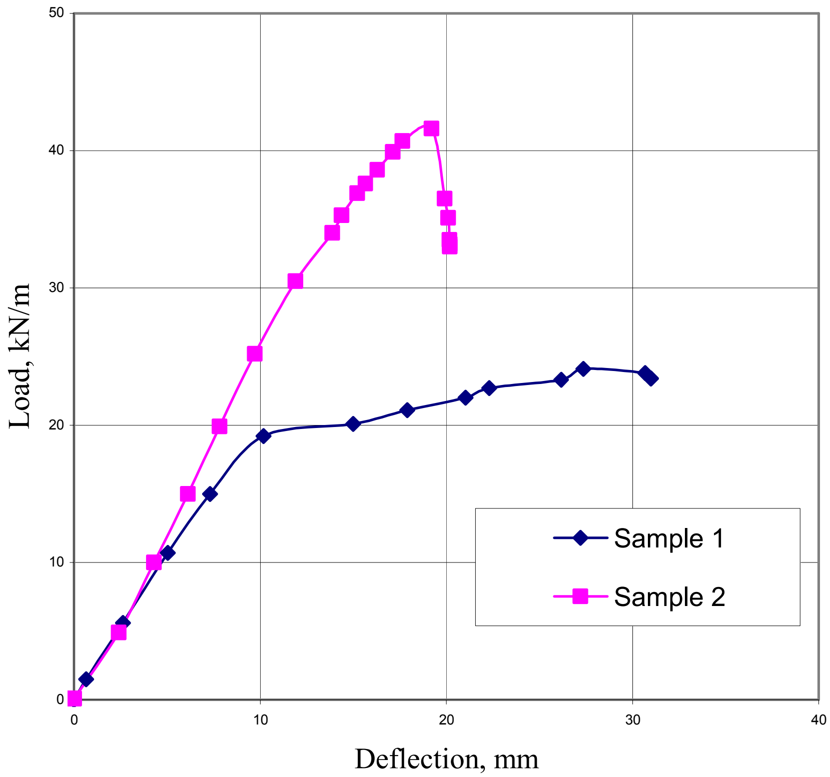

Figure 7: Comparison of Flexural Load-Deflection Behaviour of PSSDB Panel

From the load-deflection graph, the slope was ascertained to be 0.9436 for Peva 45 and 1.4623 for Bondek II. These values were substituted in the stiffness formula;

$$\text{Stiffness} = \frac{5wL^4}{\Delta 384}$$

where P/Δ is the slope of the load-deflection graph, and L represents the span of the specimen. Solving the formula yields the values for experimental stiffness for panels using Peva 45 and Bondek II to be 196.6 kNm² and 304.7 kNm² respectively. The theoretical stiffness (EI) is determined based on simple beam theory assuming full interaction between profiled steel sheeting and dry board converting all to steel unit via modular ratio concept. The stiffness, EI, for Sample 1 (using Peva 45) and Sample 2 (using Bondek II) are calculated to be 229.0 kNm² and 536.6 kNm² respectively.

Table 5: Stiffness of Samples

Sample	Maximum Load, (kN)	Mid-span, Mid-Width Deflection at Maximum Load (mm)	Flexural Stiffness, EI (kNm^2)	
			Experimental	Theory
1	24.1	83.6	196.6	229.0
2	41.6	45.9	304.7	536.6

Comparison of the stiffness values shows that there was a 35.5 % increase in stiffness of panel when using Bondek II as profiled steel sheeting. In fact, the maximum load that can be sustained by the connected panels was increased from 24.1 kN to 41.6 kN. This indicates that the dovetails cross section of Bondek II has helped increased the stiffness PSSDB floor panels. Therefore, for practical considerations, PSSDB floor panel adopting using Bondek II is recommended for cases that require a floor system of higher stiffness and strength.

6. Conclusions

This paper has described in detail experimental investigations of an innovative PSSDB double skin floor panel system. In terms of stiffness and load bearing capacity, the Bondek II system is 35.5% and 42% higher, respectively, compared to that of PSSDB system using Peva 45. However, the value of theoretical stiffness was found to be higher than the experimental stiffness. These discrepancies are due to the simplification made in the theoretical prediction by assuming that the system is acting in a full interaction mode, whereas in reality, it is behaving in partial interaction behaviour. The mode of failure was found to be local buckling of the upper flange of the profiled steel sheeting. It can be concluded that the PSSDB panel does have great potential to be used as load-bearing structural roof system and the used of Bondek II as profile steel sheeting in a PSSDB floor system is strongly recommended.

7. References

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