International Journal of Structural Analysis & Design– IJSAD
Volume 2: Issue 1 [ISSN : 2372-4102]

Publication Date : 30 April, 2015

Flexural Strength Behavior Of The Profiled Steel Sheeting Half Board Floor System With Geopolymer Concrete Infill

MOHD ISA JAFFAR*,WAN HAMIDON WAN BADARUZZAMAN, SHAHRIZAN BAHAROM

***Abstract*— Profiled steel sheeting dry board (PSSDB) system is a structure that is composed of a profiled steel sheeting connected to a dry board by self-drilling and self-tapping screws. System failure in PSSDB has been traced to profiled steel sheeting, particularly on the top flange, which local buckling with compressive stress when load is applied. Previous research has only focused on infill, such as normal concrete, to study its fire resistance, floor frequency with regard to users, and membrane action. The application of infill other than normal concrete and the changes in the size of the board have not been discussed in studies on PSSDB. The current research aims to investigate the flexural behavior of the PSSDB full and half board panels with normal and geopolymer concrete infill under a simply supported. A model using finite element modeling is developed and its accuracy is verified against the results of laboratory experiments.**

Keywords—geopolymer concrete, local buckling, full board, half board, simply supported

I. Introduction

Profiled steel sheeting dry board (PSSDB) system is a lightweight composite structure that has been introduced [1] as composite flooring in place of timber flooring. Previous research has found that the PSSDB floor system could bear the load of wet concrete, workers, and construction equipment to a maximum of 4 kN/m^2. This load exceeds the service load that has a live load between 1.5 kN/m^2 to 2.5 kN/m^2 [2]. These findings gave birth to the idea of connecting the dry board to the profiled steel sheeting with self-drilling and self-tapping screws to create a stiffer PSSDB composite flooring structure. Utilizing dry board can also save on materials, such as concrete, and can overcome the weakening of concrete under tensile forces [3].

Dry Board of the PRIMAflex variety have a higher flexural strength of 16 MPa compared with the 9 MPa of the Cemboard variety [3]. Preliminary studies performed on the infill for PSSDB structures [4,5] have found that infills, such as normal concrete, could reduce the deflection at the mid-span by as much as 20.2%. This result clearly shows that the stiffness of the structure increases when the PSSDB system uses normal concrete infill.

Further studies related to the membrane action of the PSSDB using normal concrete as the infill with pinned–pinned boundary conditions show that partial development of the compressive membrane action increases by up to 27.38% [6]. High strength and low ductility, as well as low specified yield strength of 550 MPa, are some of the drawbacks of profiled steel sheeting [7]. Applying a load to the PSSDB structure triggers local buckling, particularly on the top flange, causing the profiled steel sheeting to fail before the ultimate load is reached. Therefore, the PSSDB system fails because of local buckling in the profiled steel sheeting before the structure reaches its maximum load.

Previous studies on infill have only focused on normal concrete, and the dry board utilized were full-sized boards. Geopolymer concrete is a green concrete that does not use cement as its main ingredient [8]. The concrete is prepared from materials such as fly ash, sand, and aggregates that react with alkaline liquids, such as silicon and aluminum [9]. Infill like geopolymer concrete have never been utilized in the PSSDB system. Geopolymer concrete (12 Molarity) can affect the stiffness of the system because its compressive strength is capable of reaching 68.48 MPa [10–12].

The current study hypothesizes that the use of profiled steel sheeting Peva 50, with an infill like geopolymer concrete and half dry board of the PRIMA*flex* variety will increase the stiffness of the PSSDB floor structure. This study investigates the flexural behavior of the PSSDB floor system, which is tested under flexural loads with different parameters. Finite element modelling (FEM) is employed to verify the accuracy of the findings.

II. Experimental Programmed

Table I presents the specifications and properties of the materials for the PSSDB components. The profiled steel sheeting used was of Peva 50 with a thickness of 1 mm (Figure 1) and the dry board was of PRIMA*flex* variety with a thickness of 12 mm. The DS-FH 432 connector used had a

---

*Mohd Isa Jaffar is a PhD student at the Department of Civil and Structural Engineering, National University of Malaysia (UKM), 43600 Bangi, Selangor, Malaysia,

Wan Hamidon Wan Badaruzzaman is a Professor of Civil and Structural Engineering at the Department of Civil and Structural Engineering, National University of Malaysia (UKM), 43600 Bangi, Selangor, Malaysia,

Shahrizan Baharom is a Senior Lecturer of Civil and Structural Engineering at the Department of Civil and Structural Engineering, National University of Malaysia (UKM), 43600 Bangi, Selangor, Malaysia,

diameter of 4.2 mm and a length of 30 mm. Figure 2 illustrates the structural components of the PSSDB with infill.

TABLE I. Details of specification and material properties.

Material Properties	**Thickness /diameter (mm)**	**Width & Length (mm)**	**Modulus of Elasticity E, (N/mm^2)**	**Ultimate strength N/mm2**	**Weight of covered area (N/m^2)**
Profiled Steel Sheeting (Peva 50)	1.0	1000 x 2600	275 x 103	350	100.00
Self-drilling and self-tapping screw	4.2	30.0	-	-	-
Dry board (PRIMA*flex*) Full Board & Half Board	12.0	1000 x 2600 & 1000 x 1200	8030	22	172
Concrete (Grade 30)	Infill	Infill	25000	30	598
Geopolymer Concrete (12 Molarity)	Infill	Infill	29000	68.48	575

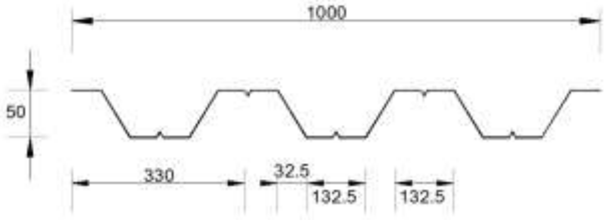


Figure 1. Profiled steel sheeting (Peva 50)
(Note: All dimensions are in mm)

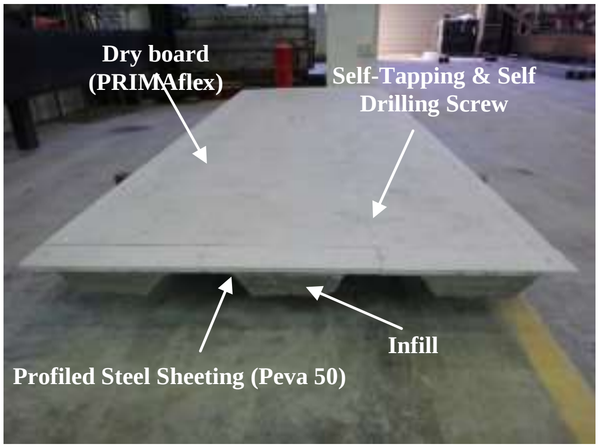


Figure 2. Structural components of PSSDB system

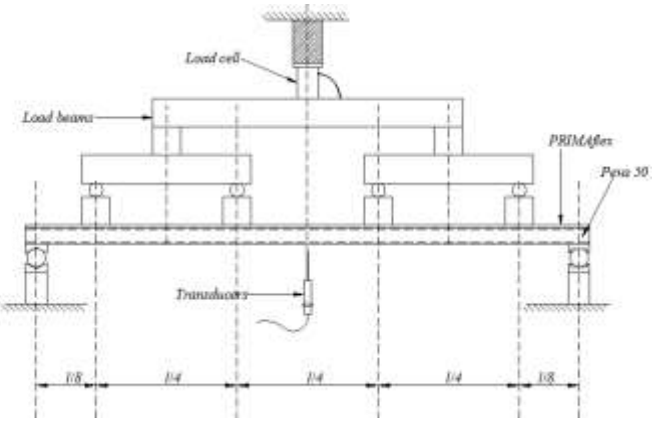
Five PSSDB samples were prepared, as shown in Table II

TABLE II. Experimental samples

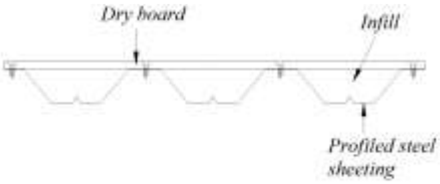
Name of Model	**Description**	**Dimension Peva 50 (mm)**	**Dimension PRIMA*flex* (mm)**	**Method**
CS	Control Sample	2600 x1000	2600 x1000	Experimental
FBNC	Full Board with Normal Concrete Infill	2600 x1000	2600 x1000	Experimental & Finite Element Modeling
HBNC	Half Board with Normal Concrete Infill	2600 x1000	1300 x1000	Experimental
FBGPC	Full Board with Geopolymer Concrete Infill	2600 x1000	2600 x1000	Experimental
HBGPC	Half Board with Geopolymer Concrete Infill	2600 x1000	1300 x1000	Experimental

A simply supported tool held by a rig and composed of a pin and roller was specially designed for the experiments conducted on the samples. The load imposed on the samples comprised four concentrated line loads that closely resembled the distributed load method, as shown in Figure 3. The loading beams of the mild steel box section with dimensions of 100 mm x 100 mm and thickness of 4 mm were arranged according to the 'Whiffle Tree' method, wherein the load from the load cell was distributed symmetrically on the samples through the four concentrated line loads, as presented in Figure 3. This approach commonly used in structural tests was employed to evaluate the profiled steel sheeting [13]. The value of the generated load can be obtained through a load cell, with a capacity of 1000 kN, which is connected to a data logger and a computer.

The generation of loads by hydraulic jacks was performed carefully to avoid sudden loading on the sample. The average value of each load was 0.075 kN/m^2. The load was applied continuously until maximum reading was reached. The load value reading began to decrease, whereas the deflection gauge reading increased when the sample failed (Figure 4). The Control Sample (without infill) locally buckled (Figure 5) before the ultimate load was received. In contrast to the samples that used an infill (Figure 6), local buckling occurred after the sample received the ultimate load, followed by sample failure.



(a) Testing Rig



(b) PSSDB side elevation

Figure 3 Sample test set-up

Figure 4 Testing of a PSSDB floor under bending loads

Figure 5 Local buckling for CS sample

Figure 6 Local buckling for FBNC sample

III. Finite Element Modeling (FEM) Of the FBNC Model

Theoretical models produced by FEM software are important in predicting the behavior of a structure and enabling it to be designed safely. The choice of elements for each material component is vital in ensuring accurate analysis. ABAQUS 6.9 EFI software was employed for this model. The PSSDB floor system was selected to develop the FEM model, given that the system is based on the FBNC model. The thin and thick shell elements are the two types of elements in this software. The 1 mm-thick profiled steel sheeting and 12-mm thick PRIMAflex dry board made use of the thin shell S4R element. The 3D spring model in the X, Y, and Z directions used in the analysis was linked by self-tapping and self-drilling screws. The Cartesian type of spring element, wherein two elements were combined using three local Cartesian directions through two nodes, was employed. The infill applied for the floor structure comprised grade 30 normal concrete and geopolymer concrete (12 Molarity). Concrete has high compressive strength but low tensile strength. The C3D8R element, a 3D element with an eight-node linear brick, was used for the infill. The boundary conditions of this model were simulated by using the supported pins and rollers at both ends. A distributed load is generally imposed on the floor in real situations, and the imposed load is synchronized through four concentrated line loads for finite element analysis. Convergence study is important in FEM to ensure that the total mesh accurately selected results during analysis. The analysis employs trial and error by changing the value of the mesh element until the deflection values converge [14].

IV. Result and Discussion

a. Experimental Analysis

Figure 7 shows the results of the flexural experiments performed on the PSSDB samples using the full board, half board with normal concrete infill, and the control sample. All three samples showed an almost linear relationship at the beginning of the curve. The curve displayed a nonlinear relationship when the load continuously increased. Local buckling on the top flange of the profiled steel sheeting caused the failures that were recorded. Such local buckling caused the bottom flange to bend and undergo significant deformation.

The floor will generally bear a safely distributed load, wherein the maximum deflection does not exceed the L/350 range when subjected to loads [15]. The serviceability limit of the stated deflection was 7.4 mm in this experiment. The FBNC sample showed 66% increase in stiffness compared with that in the control sample. The HBNC sample also showed 20% increase in stiffness compared with the FBNC sample and 100% increase in stiffness compared with the control sample. The results clearly showed that the presence of concrete in the half board sample increased the stiffness compared with those in the FBNC and control samples.

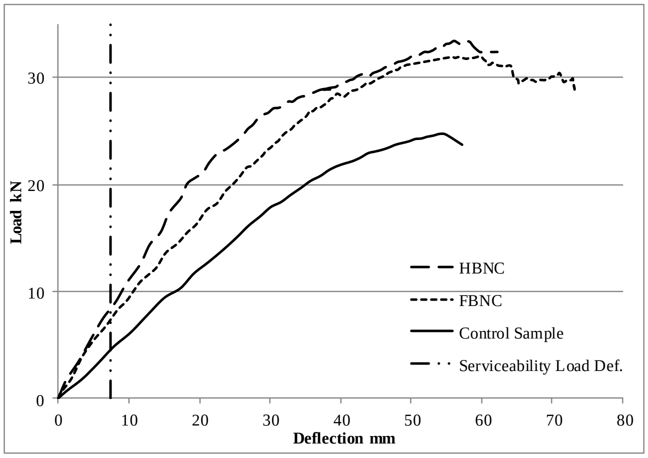


Figure 6 Load-Deflection Curve for normal concrete infill

Figure 8 shows that the curves in the graphs were almost similar, but higher ultimate loads were obtained when the samples used an infill composed of geopolymer concrete with a molarity of 12. The FBGPC sample showed 77% increase in stiffness compared with that in the control sample. The stiffness of the HBGPC sample increased by 34% compared with the FBGPC and by 144% compared with the control sample.

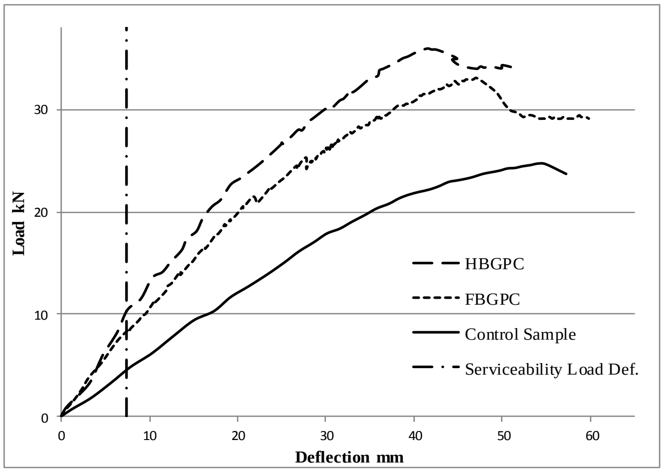


Figure 8 Load-Deflection Curve for Geopolymer Concrete infill

b. Verification of FEM

Figure 9 shows the experimental results of the FBNC sample under flexural load and the results of the FEM analysis. The experimental results indicated a linear curve in the elastic range until the sample reached the maximum load. The curve then became nonlinear when a sudden increase in the load occurred until the sample reached the level of failure. FEM analysis using the ABAQUS 6.9 software verified the results when the graph that was plotted was almost precise. Within this range, the sample underwent plastic behavior, wherein the strain continuously increased although the load did not. The difference between the FEM and the experimental model curves was less than 10%. The difference was within the permissible variation limit of below 15% [16,17]. The model is valid and can be used for parametric studies based on the evidence provided by FEM.

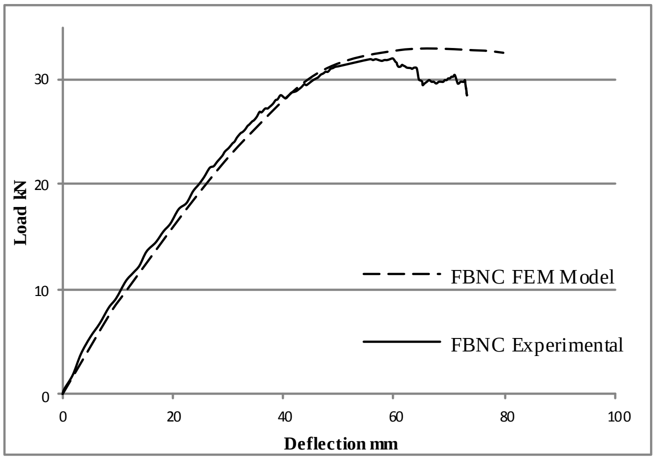


Figure 9 Load-Deflection Curve for FBNC (experimental and FEM)

V. Conclusion

This study aimed to investigate the flexural behavior of the PSSDB floor system, which was tested under flexural loads with different parameters. Experiments were performed on two different cases. The first case involved samples using a full board and the second case involved samples using a half board, wherein each sample used normal concrete (grade 30) and geopolymer concrete (12 molarity) infill. The results showed that the mid-span deflection could be reduced by using the half board and the geopolymer concrete infill. Local buckling because of compression, particularly at the top flange of the profiled steel sheeting, could also be reduced. The geopolymer concrete infill increased the stiffness of the floor structure between 32% and 42% compared with normal concrete. This finding was observed in the lower mid-span deflection of the floor system using geopolymer concrete infill compared with that using normal concrete infill. The samples using the half board also showed an increase in stiffness of 10% to 18% compared with the samples using the full board. The reason for this phenomenon was the half board PSSDB system, which used 68% more concrete than the full board PSSDB system. In addition, the interlocking mechanism between the half board and the concrete enabled the structure to bear a high load while reducing the deflection at the mid-span. The objective of this study was achieved when the use of half board with the geopolymer concrete infill, namely, the HBGPC sample, reduced the deflection at the mid-span by up to 20% compared with the FBNC sample.

Acknowledgment

The research work support provided by Ministry of Education Malaysia and Universiti Kebangsaan Malaysia. The authors would like to express sincere gratitude for all the support provided.

References

[1] Wright, H.D. & Evans, H. R. & Burt, C. A. 1989. Profiled steel sheet/dry boarding composite floors. The Structural Engineer, 67 (7), 114-129.

[2] Wright, H.D. & Evans, H. R 1986. Profiled Steel Sheeting for the replacement of Timber Flooring in Building Renovation, SERC Grant GR/D/76875. United Kingdom.

[3] Hanizam Awang & Wan Hamidon Wan Badaruzzaman 2009. The Behaviour of a Reversed Profiled Steel Sheet Dry Board (PSSDB) Panel for Application in a Roofing System. Journal of Construction in Developing Countries, Vol 14(2), 2009, 21-35, 2009.

[4] Shodiq, H.B.M. (2004). Performance of new profiled steel sheeting dry board floor system with concrete infill. PhD. Thesis. Department of Civil and Structural Engineering, Universiti Kebangsaan Malaysia

[5] Wan Badaruzzaman, W. H., Shodiq H.M. and Khalim, A. R., 2002. The Effect of Cocrete Infill and Topping to the Structural Behaviour of Profiled Steel Sheeting Dryboard (PSSDB) Flooring System. Proceeding of 2nd World Engineering Congress: 245-247.

[6] A. M. Akhand, W.H. Wan Badaruzzaman, H.D. Wright. (2004). Combined flexure and web crippling strength of a low-ductility high strength steel decking: experiment and finite element model. Thin-Walled Structures 42 (2004) 1067-1082.

[7] A. M. Akhand, W.H. Wan Badaruzzaman, H.D. Wright. (2004). Combined flexure and web crippling strength of a low-ductility high strength steel decking: experiment and finite element model. Thin-Walled Structures 42 (2004) 1067-1082.

[8] MacCaffrey, R. 2002, Climate Change and the cement Industry, Global Cement Lime Journal (Environmental Special Issue), (2002). pp. 15-19.

[9] Davidovits, J., (1994). Geopolymers: Inorganic Polymeric New Materials Engineering, Vol. 16 (2&3), pp. 91-139

[10] M. M. A. Abdullah, H. Kamarudin, H. Mohammed, I Khairul Nizar, A. R. Rafiza & Y. Zarina 2011. The relationship of NaOH Molarity, Na2SiO3/NaOH Ratio, Fly Ash/Alkaline Activator Ratio and Curing Temperature to the Strength of Fly Ash-Based Geopolymer. Advanced Material Research Vols 328-330 (2011) pp 1475-1482

[11] Mohd Mustafa Al Bakri Abdullah, Kamarudin Hussin, Mohammed Bnhussain, Khairul Nizar Ismail, Rafiza Abd Razak, Zarina Yahya 2011 Microstructure Study On Optimization Of High Strength Fly Ash Based Geoplymer. LAP LAMBERT Academic Publishing GmbH & Co.KG

[12] Rangan, B.V. (2009), Engineering Properties of Geopolymer Concrete : Structures, Processing, Properties and Application. Woodhead Publishing Limited, London

[13] ECCS Publication 20. 984. Eropean Recommendations for Steel Construction: The testing of profiled metal sheets. London: Eropean Convention for Constructional Steel Work.

[14] Akhand, AM. 2001. Nonlinear finite element modeling and partial plastic analysis of composite profiled steel sheeting dry board continuous floor. Ph.D. Thesis Universiti Kebangsaan Malaysia.

[15] BS8110 Part 1 1997. Code for practice for design and construction. Structural use of concrete British Standard Institution.

[16] ASCE Standard 1984. Specifications for the Design and Construction of Composite Slabs. New York : American Society of Civil Engineers.

[17] AISI Specification. 1996. Specification of the design of cold formed steel structural members, 1996 Edition. Washington : American Iron and Steel Institute