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The effect of profiled steel sheet's cross section on the strength-to-weight ratio of profiled steel sheet dry board floor system: A parametric study

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***Abstract*— Composite system of Profiled Steel Sheet Dry Board (PSSDB) is a system composed of profiled steel sheet (PSS) and dry board (DB), attached together by self-tapping or self-drilling screws. PSS, the most significant structural component of this system is currently sourced from the available profiles in local markets. Yet, it is apparent that manufacturing specific PSS for this system can result in a more economical system. This paper investigates the effect of varying cross-sections of PSS on the PSSDB system regarding ultimate load carrying capacity (strength) and (weight) of the system.**

***Keywords*—PSSDB, profiled steel sheet, dry board, strength, composite panels, floor, ultimate strength-to-weight ratio.**

I. Introduction

Profiled Steel Sheet Dry Board (PSSDB) system comprises of profiled steel sheet (PSS) and dry board (DB) joined together as a composite system via self-tapping or self-drilling screws, see Fig. 1. Compared to the traditional composite slabs, PSSDB floor system would bring about a lighter and thinner slab. Other advantages include: easily transported, less dependent on skilled labour, environmentally friendly and reduced construction wastage.

This system was originally introduced by Wright and Evans in 1986 [1] in the United Kingdom. In 1989, Wright et al. [2] published the first paper regarding this system. Following that, extensive studies on this system are carried out by researchers mostly at Universiti Kebangsaan Malaysia (UKM) [3-10].

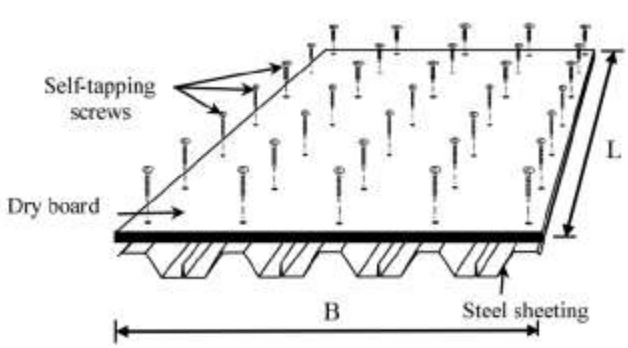


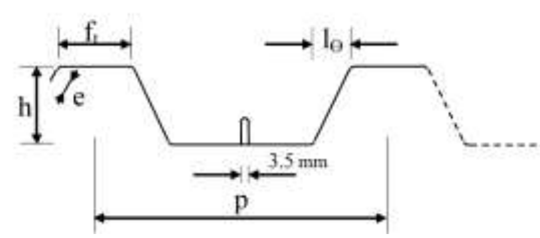
Figure 1. Profiled Steel Sheet Dry Board (PSSDB) system [7]

Currently the PSSDB system is fabricated from PSS available in local markets. However, since the PSS is a significant structural component of the PSSDB system, using such profiles in this system is not economical and the need for more appropriate and optimised PSS in this system is apparent.

One of the main merits of cold-formed steels is the flexibility of their sections for a given condition. However, finding the optimum section size and shape among the vast possible sections that will fulfil all the requirements is demanding. The objective of this paper is to study the influence of PSS section with various sizes and shapes on the ultimate load carrying capacity-to-weight ratio of PSSDB system.

II. Description of the model

In this paper, ANSYS [11] finite element commercial package is employed to simulate the PSSDB floor system. The verification of the model is carried out with the experimental test done by Shodiq [8].



(a)

(b)

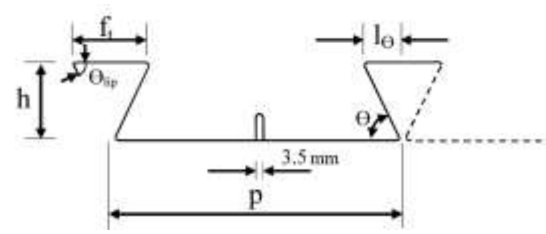


Figure 2. Cross sectional view of typical PSS: (a), $l_\Theta > 0$; (b), $l_\Theta < 0$

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TABLE I.

TABLE II. CHOSEN VARIABLES FOR PARAMETRIC STUDY

P (mm)	**f_t (mm)**	**Θ (degrees)**									
		66	72	77	84	96	103	114	124	132	135
		l_Θ (mm)									
173.5	30	-	-	-10	-5	5	10	20	30	40	45
	40	-	-15	-10	-5	5	10	20	30	40	45
	45	-	-15	-10	-5	5	10	20	30	-	-
	55	-20	-15	-10	-5	5	10	20	30	-	-
183.5	30	-	-	-10	-5	5	10	20	30	40	45
	40	-	-15	-10	-5	5	10	20	30	40	45
	45	-	-15	-10	-5	5	10	20	30	40	45
	55	-20	-15	-10	-5	5	10	20	30	-	-
193.5	30	-	-	-10	-5	5	10	20	30	40	45
	40	-	-15	-10	-5	5	10	20	30	40	45
	45	-	-15	-10	-5	5	10	20	30	40	45
	55	-20	-15	-10	-5	5	10	20	30	40	-
223.5	30	-	-	-10	-5	5	10	20	30	40	45
	40	-	-15	-10	-5	5	10	20	30	40	45
	45	-	-15	-10	-5	5	10	20	30	40	45
	55	-20	-15	-10	-5	5	10	20	30	40	45

A simply supported PSSDB system under uniformly distributed load with a typical span length, L of 2400 mm and initial width, B of 1000 mm is considered. The depth, h of the PSS section is fixed at 45 mm. The thickness, t_s of the PSS is 1 mm, and its Young's modulus, E_s = 210000 MPa. The DB adopted is a type of cement bonded rubber wood DB, known as Cemboard, with a thickness of 16 mm and Young's modulus, E_{db} = 4500 MPa. Yield strength of 350 MPa and 15 MPa are assigned to PSS and DB respectively. Self-tapping and self-drilling screws of 200 mm spacing centre to centre are assumed for the connections.

The effect of 3 design variables - top flange width, f_t, web inclination angle, Θ and pitch size, p of the PSS cross section are examined on ultimate load carrying capacity-to-weight ratio of the system, see Fig. 2. A total number of 137 nonlinear analyses of the PSSDB system with varying parameters are conducted. The chosen variable sizes of PSS cross sections have been listed in Table I.

The PSS cross sectional pitch sizes, p of 173.5, 183.5, 193.5 and 223.5 mm are selected. Four various top flange widths, f_t of 30, 40, 45 and 55 mm are chosen considering the maximum value of width-to-thickness ratio, b/t for compression elements specified in BS5950 [12]. In order to have practical sizes for the bottom flange widths of the PSS cross sections , they are tended to be greater than 53.5 mm as well. For the purpose of maintaining the straightness of edge lips under load, the size of edge lips are changed in the cross section. Therefore, the minimum second moment of area of the lip about the axis through the mid-thickness of top flange width are considered to be greater than I_{min} (1) [12]. In this study the minimum of edge lip is 10 mm.

$$I_{min} = \frac{tb^3}{375} \tag{1}$$

where

b is the width of the element to be stiffened;

t is the thickness of the lip

In accordance with [12], the angle between edge lip and top flange width, Θ_{lip} is considered to be greater than 70 degrees. Table II shows the values of e and Θ_{lip} for PSS cross sections.

The web inclination angle, Θ is bounded between 45 and 135 degrees and consequently the dimension of each horizontal space between top and bottom flange, l_Θ is calculated as follow [13]:

$$-\frac{h}{\tan 45} \le l_\theta \le -\frac{h}{\tan 135} \tag{2}$$

while

$$l_\theta > -\frac{f_t}{2} + 5 \tag{3}$$

TABLE III. THE VALUES OF THE ANGLE BETWEEN EDGE LIP AND TOP FLANGE WIDTH FOR PSS CROSS SECTIONS

P (mm)	l_Θ (mm)	f_t (mm)							
		30		40		45		55	
		e^a	$\Theta_{lip}{}^o$	e^a	$\Theta_{lip}{}^o$	e^a	$\Theta_{lip}{}^o$	e^a	$\Theta_{lip}{}^o$
173.5 183.5 193.5 223.5	-20	-	-	-	-	-	-	12	70
	-15	-	-	10	72	10	72	11	72
	-10	10	77	10	77	10	77	11	77
	-5	10	84	10	84	10	84	11	84
	5	10	96	10	96	10	96	11	96
	10	10	103	10	103	10	103	11	103
	20	10	114	10	114	10	114	12	114
	30	10	124	10	124	10	124	13	124
	40	10	132	10	132	11	132	14	132
	45	10	135	10	135	12	135	14	135

a.unit in mm

III. Results and discussions

A. *Correlation between ultimate load carrying capacity-to-weight ratio and Θ for various pitch sizes*

Since the span length is constant, the total PSSDB cross section weight, W_{cs} (4) with regard to the density of steel, D_s of 7850 kg/m^3 and dry board, D_{db} of 1250 kg/m^3 can represent the weight of PSS in the calculation of the ultimate load carrying capacity-to-weight ratio.

$$W_{cs} = D_{db}\,(n * l_s * t_s + l_{db} * t_{db}) \qquad (4)$$

$$n = \frac{D_s}{D_{db}} \qquad (5)$$

where

l_s is the total length of profiled steel sheet (PSS);

t_s is the thickness of profiled steel sheet (PSS);

l_{db} is the length of dry board (DB);

t_{db} is the thickness of dry board (DB);

D_s is the density of profiled steel sheet(PSS);

D_{db} is the density of dry board (DB).

The horizontal space between consecutive top and bottom flanges, l_Θ is considered alternatively as web inclination angle, Θ as well.

The trend of non-dimensional ultimate load carrying capacity-to-weight ratio, P_u/W_{cs} with respect to angle length for various f_t is revealed in Figs. 3-6. As seen in the graphs, the sections with top flange width, f_t of 40 mm has the highest ultimate load carrying capacity-to-weight ratio. For p value of 173.5 and 183.5 mm, the best value of P_u/W_{cs} is when the value of l_Θ is around 20 mm. The trend of P_u/W_{cs} goes down when the value of l_Θ is greater than 20 mm . The value of non-dimensional P_u/W_{cs} in relation to PSS pitch size of 193.5 and 223.5 mm tend to increase as the web inclination angle, raises up to 30 and 40 mm respectively.

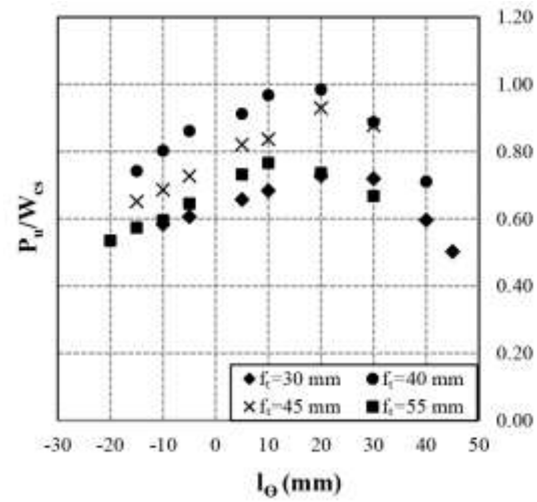

Figure 3. Non-dimensional ultimate load-to-weight ratio versus horizontal space between top and bottom flange for p = 173.5 mm

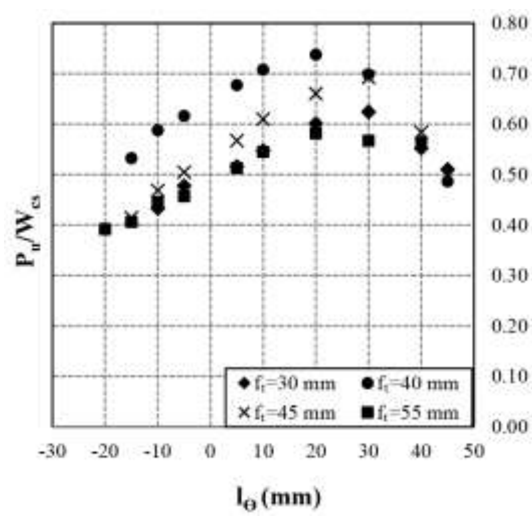

Figure 4. Non-dimensional ultimate load-to-weight ratio versus horizontal space between top and bottom flange for p = 183.5 mm

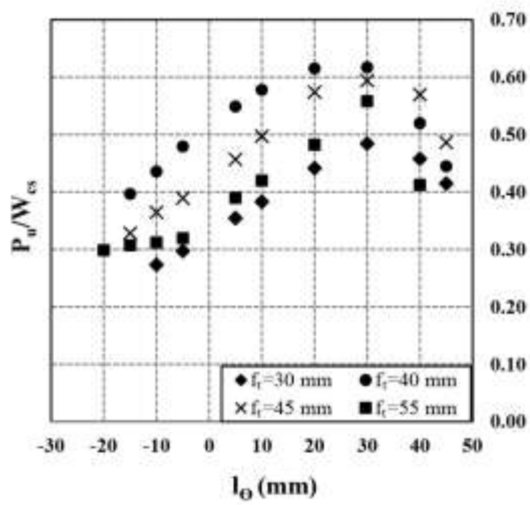

Figure 5. Non-dimensional ultimate load-to-weight ratio versus horizontal space between top and bottom flange for p = 193.5 mm

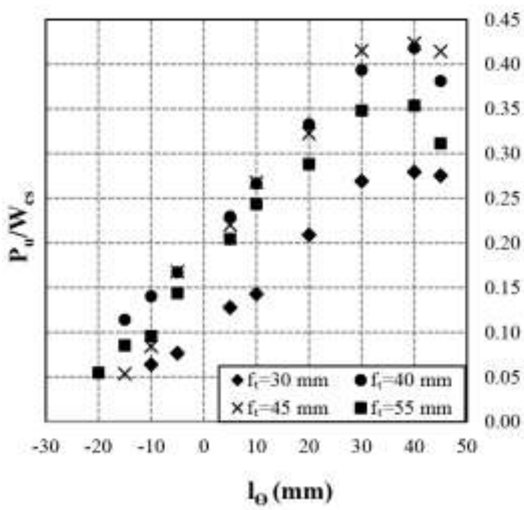

Figure 6. Non-dimensional ultimate load-to-weight ratio versus horizontal space between top and bottom flange for p = 223.5 mm

B. *Correlation between ultimate load carrying capacity-to-weight ratio and ϴ for various top flange widths*

As it mentioned earlier, the cross sectional weight of PSSDB, W_{cs} and the horizontal space between top and bottom flange, l_Θ is considered alternatively as replacement of weight and web inclination angle, ϴ in Figs. 7-10 as well. Figs. 7-10, show results of non-dimensional P_u/W_{cs} ratio with respect to l_Θ for various pitch sizes. For pitch size less than 223.5 mm the trends of P_u/W_{cs} for the sections with l_Θ less than 20 mm is almost linear and generally tend upward with an increase in l_Θ. As can be seen from the figures the PSS sections with pitch size of 173.5 mm and top flange width of 40 mm play the highest role in term of the ultimate load carrying capacity-to-weight ratio. Also the graphs show that as the PSS pitch size increases P_u/W_{cs} ratio decreases.

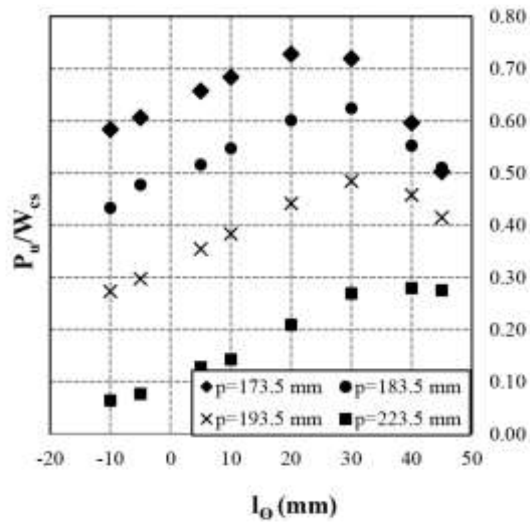

Figure 7. Non-dimensional ultimate load-to-weight ratio versus horizontal space between top and bottom flange for f_t = 30 mm

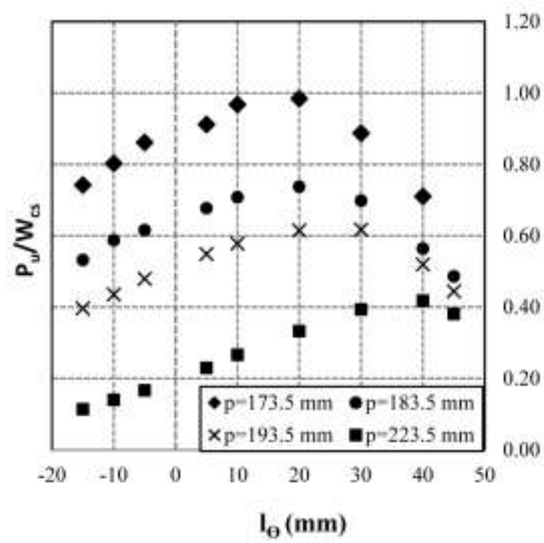

Figure 8. Non-dimensional ultimate load-to-weight ratio versus horizontal space between top and bottom flange for f_t = 40 mm

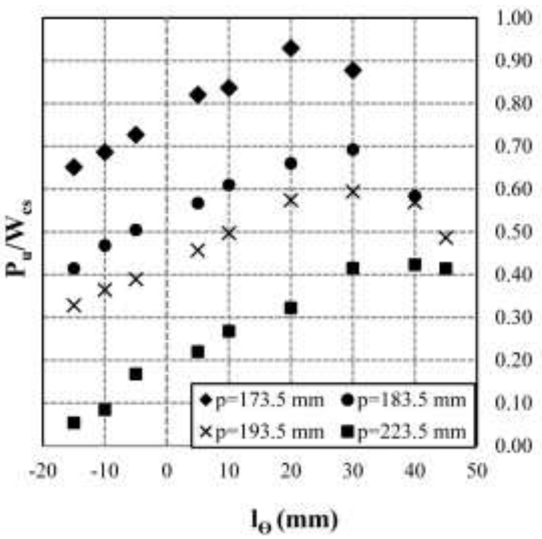

Figure 9. Non-dimensional ultimate load-to-weight ratio versus horizontal space between top and bottom flange for f_t = 45 mm

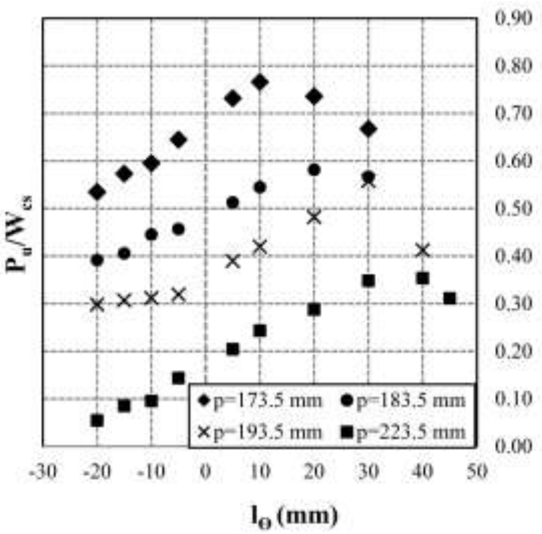

Figure 10. Non-dimensional ultimate load-to-weight ratio versus horizontal space between top and bottom flange for f_t = 55 mm

IV. Conclusions

To conclude, this paper investigates numerically the effect of PSS cross section on the strength-to-weight ratio of profiled steel sheet dry board as a floor system. The results of 137 parametric studies regarding the ultimate load carrying capacity-to-weight ratio of the panels are presented in term of charts. Three different variables, top flange width, f_t, web inclination angle, Θ and pitch size, p in the PSS cross section are changed in order to come up with different PSS cross sections. The results show that cross section with pitch size of 173.5 mm and l_Θ of 20 mm along with top flange width of 40 mm demonstrates the best value considering the ultimate load carrying capacity-to-weight ratio of PSSDB system.

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