International Journal of Civil & Structural Engineering– IJCSE
Volume 1: Issue 2 *[ISSN: 2372-3971]*
Publication Date : 25 June 2014

Parametric Design of Profiled Steel Sheeting Dry Board (PSSDB)

Maryam Vafa, Wan Hamidon Wan Badaruzzaman and Mahmood Seraji

***Abstract*—This paper presents the parametric finite element modelling of a lightweight composite system known as Profiled Steel Sheet Dry Board (PSSDB) composed of cold-formed profiled steel sheet (PSS) and dry board (DB) connected together by self-tapping and self-drilling screws. The process of parametric modelling with regard to achieving optimised design of the PSS is explained. Three dimensional non-linear finite element PSSDB model has been parametrically developed using Ansys Parametric Design Language (APDL). It is revealed that this approach can speed up the optimisation process considerably and acts as a very effective tool to the optimisation processes.**

Keywords— ***PSSDB, profiled steel sheet, dry board, composite panels, floor, parametric design, FEM***

I. Introduction

Profiled steel sheeting dry board known as (PSSDB) is an innovative lightweight composite system initiated by Wright and Evans [1] in the United Kingdom. This system is a product of profiled steel sheeting (PSS) and dry board (DB) attached together by self-tapping and self-drilling screws. Several advantages of this system over traditional ones are: light weight, easily transported, environmentally friendly, less dependency on skilled labours, and reducing construction time and waste materials. Among earlier studies on the PSSDB system are reported in Ahmed et al. [2], Ahmed and Wan Badaruzzaman [3], Shodiq [4], Awang and Wan Badaruzzaman [5], Gandomkar et al [6], Vafa et al. [7,8]. Fig. 1 shows the profiled steel sheeting dry board system.

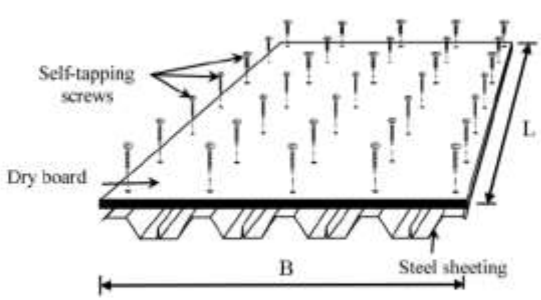

Figure 1. Profiled Steel Sheeting Dry Board (PSSDB) system [5]

The flexibility in design regarding the geometries and material properties is one of the main merits of the composite PSSDB system. Therefore, finding the optimum geometries and materials will result in more efficient composite system. Yet, this system is currently fabricated from available PSS and DB in local markets. In order to come up with an optimum PSSDB which can carry higher load along with less material usage (i.e. lighter but effective system), an optimisation method is strongly desired.

Concerning the design optimisation of PSSDB system, an efficient and hybrid optimisation technique on the basis of Genetic Algorithms (GAs) as a global search algorithms and non-linear finite element model (ANSYS) [9] as a fitness function evaluator has been considered. As the GA demands large computational time depending on the evaluation of each individual in ANSYS, Artificial Neural network (ANN) as an alternative and approximate fitness evaluator may resolve this difficulty. The schematic representation of this method is shown in Fig. 2.

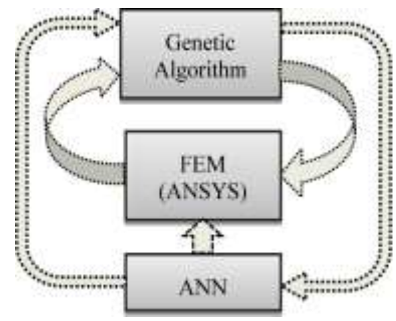

Figure 2. Schematic representation of the iterative procedure between FEM & ANN & GA.

In order to follow the introduced optimisation technique, it is required to simulate PSSDB system frequently as a finite element model. Consequently, a parameterised fully three dimensional non-linear finite element modelling of the profiled steel sheeting dry board system is required. This paper presents the procedures of the parameterised non-linear FEM of PSSDB system as a floor unit, implementing Ansys Parametric Design Language (APDL).

Maryam Vafa, Wan Hamidon Wan Badaruzzaman and Mahmood Seraj
Department of Civil and Structural Engineering /Universiti Kebangsaan Malaysia, UKM Malaysia

II. Description of the model

In structural modelling of the PSSDB system, various types of continuous and discrete parameters are defined. Considering this system as a floor unit, a simply supported PSSDB system under uniformly distributed load (UDL) is parametrically simulated. The three different components, PSS, DB and screws concerning the geometries and materials are defined clearly in ANSYS.

A. *Geometry*

1) Panel

At the beginning of the programming, the span length L and the cover width of the panel B are stipulated (see Fig. 1).

2) PSS

Two different cross sectional views of PSS have been shown in Fig. 3. It is obvious that top flange width f_t, the horizontal space between consecutive top and bottom flanges l_θ in relation to web inclination angle θ, bottom flange width f_b, depth h, edge lip e, the angle between edge lip and top flange width θ_{lip}, thickness of steel t_s and pitch size p are the main PSS parameters would be changed in order to shape assorted PSS cross sections.

However, there are some limitations of choice to fulfil some specified conditions stipulated in the Codes of Practice as follows:

The limiting value of width-to-thickness ratio (b/t) for compression elements according to the BS5950 [10] needs to be considered for the top flange width f_t.. Considering the definition of cold-formed thin gauge members in ENV [11]

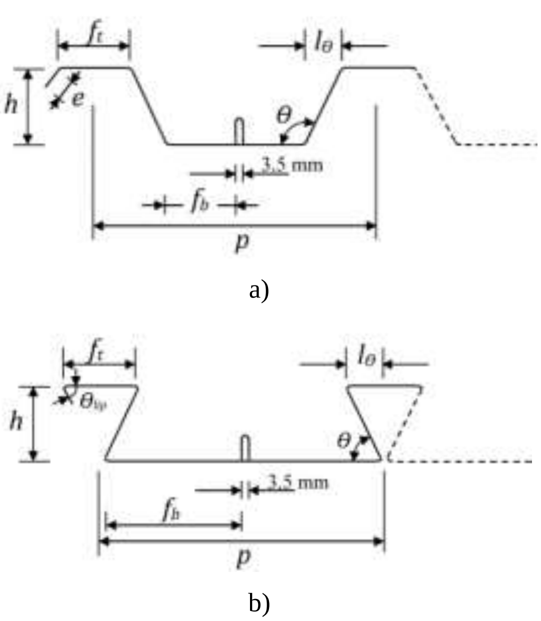

Figure 3. Cross section of typical PSS a- $l_\theta > 0$ b- $l_\theta < 0$

, θ is restricted between 45 and 135 degrees and accordingly l_θ is defined as Eq. (1) and Eq. (2). In addition, θ_{lip} is considered to be equal to θ but greater than 70 degrees as detailed in [10].

$$-\frac{h}{\tan 45} \le l_\theta \le -\frac{h}{\tan 135} \tag{1}$$

while

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

The edge lip will maintain its straightness under load if its second moment of area with regard to the axis crossing the mid-thickness of top flange is greater than I_{min} as shown in Eq. (4) [10]. Therefore, the minimum lip length e can be calculated from Eq. (3).

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

where, b is the width of the element to be stiffened and t is the thickness of the lip.

The real value of cover width B, for the stipulated PSS cross section is then calculated based on the number of pitches and the initial value of B defined at the beginning of the program. So the values of B for varying cross sections will be close to its initial value and the panel sizes would be close to each other in term of comparison of the results. Afterwards the three dimensional PSS according to the defined span length L is drawn.

3) DB

The thickness of dry board t_{db} is the only parameter that needs to be defined in DB modelling. The width and length of dry board will follow the values of B and L accordingly.

4) Screws

The spaces between centres of screws s is an essential parameter in the modelling of screws.

B. *Material Properties*

Young's modulus E, Poisson's ratio ν, and yield strength p_y are the main input material parameters of steel and dry board. Elastic-perfectly plastic behaviour for steel is considered for PSS. Manufacturers' manuals or experimental test can be used to define the material properties of DB. In addition, the stiffness of screws must be defined in the simulating of partial interaction between PSS and DB. The stiffness of screws can be achieved through push-out test.

C. *Modelling*

It is clear that implementing appropriate elements in finite element modelling of structures highly affects the accuracy of the model. In the modelling of PSSDB, SHELL281 is employed for modelling of PSS and DB considering its large strain non-linear application. Moreover, COMBIN14 with longitudinal capabilities is chosen in ANSYS for the modelling of screws. The stiffness of this element is defined in three orthogonal directions separately.

In addition, surface to surface contact elements between PSS and DB are needed to constitute the contact and sliding between these two elements. To take this fact into account, the three dimensional 8 nodes surface element CONTA174, appropriate for shell elements, is adopted. This element, associated with target segment elements TARGE170, is applied on the interfaces between profiled steel sheeting and dry board.

D. *Meshing*

Concerning the convergence study, element edge length of 20 mm is found to be appropriate for meshing of the PSS and DB components.

E. *Loading and Boundary Conditions*

A close simulation of uniformly distributed loading (UDL) defined in BS5950 [12] has been considered in modelling of UDL in PSSDB system as it is shown in Fig. 4. In order to derive the load-deflection curve of the structure, loading is applied using displacement control method. Furthermore, to reduce the computational time and required computer resources a quarter of the actual PSSDB panel is modelled.

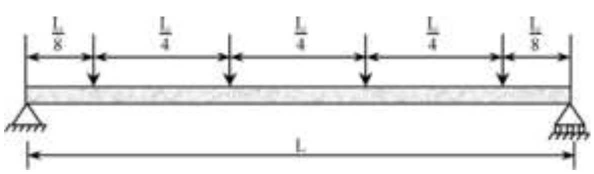

Figure 4. Uniformly distributed loading simulation

F. *Getting the Results*

As the strength-to-weight ratio is one of the important aspects in optimisation of this structure, the maximum load carrying capacity of the system W as well as the cross-sectional area of steel A_s is calculated. Also idealising the PSSDB panel as a beam, allow us to compute the minimum flexural stiffness required for PSSDB panel by employing the beam elastic theory. Considering the minimum 70% contribution of profiled steel sheeting in the total flexural stiffness of PSSDB section according to Wan Badaruzzaman et al. [13], the least required second moment of area of PSS $I_{s.min}$ may be anticipated from elastic beam theory as well.

III. Verification of Numerical Model

The verification of the non-linear finite element modelling of PSSDB has been performed considering the experimental

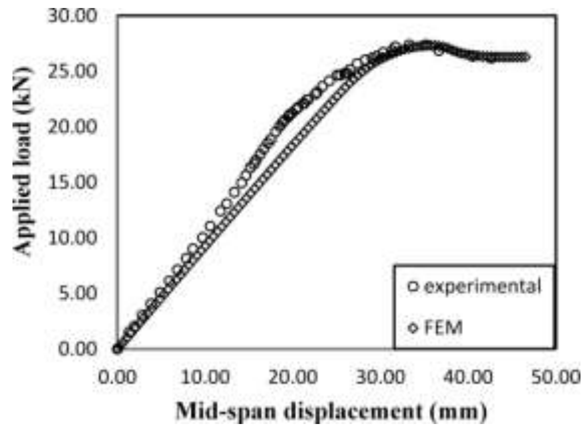

Figure 5. Comparison of load-deflection curve (experimental test vs. FEM)

test done by Shodiq [4]. Fig. 5 compares the load-deflection curve between experimental test and its finite element model. Good agreement is demonstrated between the plotted curves of results.

IV. Parametric Study and Discussion

Table 2 demonstrates the characteristics and the results of the different PSSDB systems under UDL which are modelled parametrically in ANSYS. All the specimens have the span length of 2400 mm with the initial B of 1000 mm. t_s and t_{db} are also considered 1 mm and 16 mm respectively. In addition, a type of cement bonded rubber wood dry board, known as Cemboard is considered for the DB. Table 1 shows the material properties of PSS and DB.

TABLE I. MATERIAL PROPERTIES

Specimen	*E* (MPa)	*D* (kg/m³)	P_y (MPa)
PSS	210000	7850	350
DB	4500	1250	15

Due to utilising APDL, all PSSDBs are modelled effortlessly in a few seconds. It is obvious that a large number of analyses should be run for the optimisation algorithm. As a result, the use of the parameterised finite element modelling simulates PSSDB system properly and gives the accurate results automatically. Therefore it helps the optimisation process accelerate tremendously.

V. Conclusions

Various phases of the parametric FE modelling of the PSSDB system, as a floor unit, applying APDL were described. All the boundaries and stipulations were clarified. A number of non-linear analyses were conducted. The input parameters and output results were displayed in term of table as well. The achieved results revealed that, the parameterised finite element modelling of PSSDB system enhances the

THE CHARACTERISTICS AND RESULTS OF THE SPECIMENS

Specimen	B (mm)	f_t (mm)	l_θ (mm)	f_b (mm)	θ (Degree)	θ_{lip} (Degree)	p (mm)	e (mm)	h (mm)	I_s (mm^4/m)	$I_{s.min}$ (mm^4/m)	W (kN/m^2)	A_s (mm^2/m)
B1	982.5	45	28	42	121.89	121.89	188.5	10	45	468313	502837	12.47	1476.2
B2	999.5	50	15	55	106.7	106.7	193.5	10	50	639898	488012	14.93	1582.4
B3	1007.5	65	-20	80	66.95	70	188.5	14	47	724330	492855	15.30	1931.1
B4	1147.5	55	10	70	100.89	100.89	218.5	11	52	694835	432725	14.27	1568
B5	1117.5	42	-10	80	77.47	77.47	185.5	10	45	549798	512173	14.35	1802.7
B6	1007.5	52	-5	70	84.17	84.17	185.5	10	49	693509	506944	15.82	1779.4
B7	1097.5	60	30	42	119.51	119.51	207.5	13	53	684886	452439	14.28	1487.9
B8	989.5	59	-18	80	71.24	71.24	186.5	12	53	910911	500809	18.39	1972.5
B9	1089.5	47	20	50	113.5	113.5	190.5	10	46	514928	496800	13.13	1521.9
B10	979.5	36	-5	80	84.17	84.17	189.5	10	49	608212	504882	15.53	1769.8
B11	1047.5	63	25	40	116.57	116.57	196.5	14	50	630145	474942	13.68	1512.2
B12	1127	40	-11	82	76.55	76.55	185.5	10	46	570285	513232	14.77	1826.4
B13	971.5	57	30	41	119.05	119.05	202.5	13	54	711796	464284	15.22	1507.8

optimisation process significantly and could be considered as appropriate tool in this regard.

Acknowledgment

Special thanks to the Malaysian Ministry of Higher Education for providing the funds to conduct this research work under the ERGS/1/2012/TK03/UKM/01/2 grant.

References

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

[2] E. Ahmed, W.H. Wan Badaruzzaman and H.D. Wright, "Two-Way Bending Behaviour of Profiled Steel Sheet Dry Board Composite Panel System," Thin-Walled Structures, vol. 40, pp. 971-990, 2002.

[3] E. Ahmed, and W.H. Wan Badaruzzaman, "Vibration Performance of Profiled Steel Sheet Dry Board Composite Floor Panel," KSCE Journal of Civil Engineering, vol. 17 : 1, pp. 133-138, 2013.

[4] H.M. Shodiq, "Performance Improvement of Profiled Steel Sheeting Dry Board Floor System by Concrete Infill," PhD Thesis, Department of Civil & Structural Engineering, Universiti Kebangsaan Malaysia, 2004.

[5] H. Awang and W.H. Wan Badaruzzaman, "Structural Performance and Applications of a Reversed Profiled Steel Sheeting Dry Board Roof Panel system," Asian Journal of Civil Engineering (Building and Housing), vol. 11, pp. 371-384, 2010.

[6] F.A. Gandomkar, W.H. Wan Badaruzzaman and S.A. Osman, "The Natural Frequencies of Composite Profiled Steel Sheet Dry Board (PSSDB) System, " vol. 8, pp. 351-372, 2013.

[7] M. Vafa, W.H. Wan Badaruzzaman and S.A. Osman, "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," International Journal of Advancements Civil Structural and Environmental Engineering-IJACSE, vol. 1: 1, 2013.

[8] Vafa M, Wan Badaruzzaman WH and Osman SA, "Cover Width Effect of Profiled Steel Sheet Dry Board (PSSDB) Panel on Strength-To-Weight Ratio," In Proceeding of International Conference on Civil And Architecture Engineering (ICCAE'2013). May 6-7, Kuala Lumpur, Malaysia. pp. 70-73, 2013.

[9] ANSYS Finite Element Commercial Package, Vol13.

[10] British Standards Institution. BS 5950: Part 6. Code of Practice for Design of Light Gauge Profiled Steel Sheeting, Structural Use of Steelwork In Building. UK, 1995.

[11] Eurocode 3: Design of Steel Structures-Part 1.3. DD ENV 1993-1-3. General Rules-Supplementary Rules for Cold Formed Thin Gauge Members and Sheeting, British Standards Institution, 2001.

[12] British Standards Institution. BS 5950: Part 4. Code of Practice for Design of Composite Slabs with Profiles Steel Sheeting. UK, 1994.

[13] W.H. Wan Badaruzzaman, E. Ahmed and A.R. Khalim, "Out Of Plane Bending Stiffness Along the Major Axis of Profiled Steel Sheet Dry Board Composite Floor Panels," Jurnal Kejuruteraan, vol.8, pp. 79-95, 1996.