Journal of Constructional Steel Research 138 (2017) 79–92

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

The two-way flexural performance of the PSSDB floor system with infill material

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ARTICLE INFO

Article history:
Received 3 November 2016
Received in revised form 30 May 2017
Accepted 19 June 2017
Available online xxxx

Keywords:
Profiled steel sheeting
Dry board
Infill material
Two-way
PSSDB

ABSTRACT

This paper investigates the structural performance of the Profiled Steel Sheeting Dry Board (PSSDB) system; a lightweight composite structure which is made by binding a Profiled Steel Sheeting (PSS) to a Dry Board (DB) by mechanical screws. Many studies indicated that it can be used as flooring units. However, most of them focused on utilizing the system as a one-way floor panel. It's rare to find studies that consider the two-way position, and so far none has ever considered the effect of the infill material in that situation. Therefore, the purpose of this paper is to investigate the flexural performance of the two-way PSSDB floor panel with the presence of the infill material. An Experimental (EXP) and Finite Element (FE) approaches were employed. For the EXP tests, it was found that applying a steel plate (SP) can enhance the stiffness and strength of the PSSDB system by approximately 31% and 15%. The results were used to compare with the ones of a previous study, and it was shown that applying infill material can improve the strength by 13.2%. Applying both Steel Plate (SP) and infill material instead of SP alone can enhance it by 13.6%. As for the FE approach, it was demonstrated that changing the thickness of the DB and SP has a minor effect by no more than 5%, while changing the PSS's thickness can affect the performance by up to 18.3%. And finally, the effect of changing the type of infill material is less than 1%.

1. Introduction

Over the years, many researches and studies were conducted by the construction industry with the aim of producing structures that meet the cost-effective criteria. These studies can be divided into two groups; the first is combining different materials together to produce a new one called "composite material", which has better characteristics than that of its constituent utilized individually. The second one is about connecting two or more materials together that they act as a single unit and where the utilization of each material will be applied by its specified position. This one is called "composite structure". This paper deals with the latter type. Composite structures have various advantages; it has greater stiffness and strength, and presents a practical and economical solution for construction.

Up until now, various types of composite structure have been introduced. One of those in 1986 by Wright and Evans is called the Profiled Steel Sheeting Dry Board (PSSDB) system: a light-weight composite structure which consists of a Profiled Steel Sheeting (PSS) tied to a Dry Board (DB) by mechanical screws [1]. At the beginning, it was designed to replace the timber joist floor panels which are exposed to insects attack, moisture and other elements that affect the age of a building. Later in 1989, another study by Wright et al. [2] has demonstrated that the stiffness of the PSSDB system is greater than PSS alone by up to 70%. In addition, the system has other advantages; it does neither require temporary propping, skilled labors, nor a lot of construction time, and renovations can be easily handled (Fig. 1).

A lot of studies have focused on using the PSSDB panels as flooring system [3–10]. However, only few of them have considered the two-way action. Investigating the structural performance of the PSSDB system as two-way floor panels was first conducted by Ahmed et al. in 2002, in which small-scale PSSDB samples were used [11]. Based on the previous study, a recent one was conducted in 2015 using Finite Element (FE) analysis in order to inspect the behavior of the system under various factors [12]. Another study in 2016 was carried out, where in addition to using larger Experimental (EXP) specimens and different materials, an optimization method was suggested by applying a mild steel plate at the bottom flange of the PSS by using self-tapping & self-drilling screws, and which has proved to be an efficient one [13].

However the effect of infill material on the two-way bending behavior of the PSSDB floor system is yet to be inspected. Therefore, this paper aims to investigate the flexural performance of the two-way PSSDB floor panel with the presence of the infill material. The study will be done in three steps: the first is conducting EXP tests using PSSDB specimens, whereas the second is creating FE models and checking their accuracy by comparing them with the EXP results. The final step is conducting

Abbreviations: CS, Control sample; CONS, Concrete sample; CONPS, Concrete-plate sample; DB, Dry board; EPS, Expanded polystyrene; EXP, Experimental; FE, Finite element; LVDT, Linear variable differential transformer; PS, Plate sample; PSSDB, Profiled steel sheeting dry board; ST, Strain gauge; SP, Steel plate.

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http://dx.doi.org/10.1016/j.jcsr.2017.06.039
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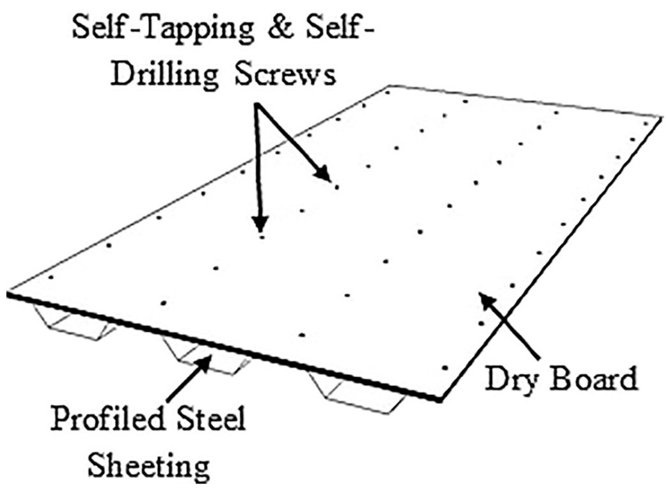

Fig. 1. Typical PSSDB panel.

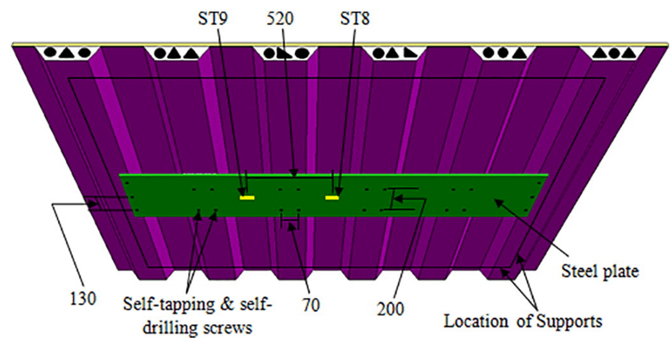

Fig. 3. The PSSDB concrete-plate sample (all dimensions are in millimeters).

parametric studies in order to understand more of the factors that might affect the two-way bending performance.

2. Experimental approach

The purpose of the EXP tests as previously mentioned is to inspect the effect of the infill material on the flexural behavior of the PSSDB system as two-way floor panel. The preparation of the specimens, test rig, measurement devices will be explained below.

2.1. PSSDB samples

Two square samples were prepared for the tests; the first is called the concrete sample (CONS). It has dimensions of 2 m by 2 m, and it consists of Peva 50 (as PSS) with 1 mm thickness and Prima*flex* (as DB) with 12 mm thickness. Both of the components were bonded together using self-tapping and self-drilling screws with 200 mm spacing between the screws. Also the grooves of the PSS have been filled with a light-weight Expanded Polystyrene (EPS) concrete which can be seen in Fig. 2 below.

The second specimen, which is called the concrete-plate sample (CONPS) has the same components and properties as the previous one; however, a mild steel plate (SP) of 5 mm thickness was pinned at the bottom flange of the PSS at the center using self-tapping and self-drilling screws as displayed in Fig. 3. The properties of each material will be expounded below.

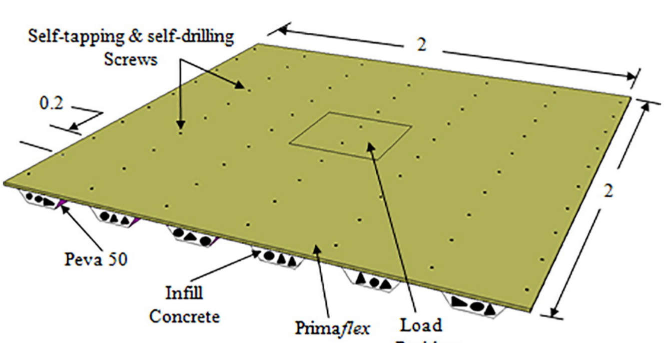

Fig. 2. The PSSDB concrete sample (all dimensions are in meters).

2.2. The properties of the PSSDB components

Each PSSDB component has its own role; the DB provides a flat surface and enhances the strength and stiffness of the composite structure. Therefore it's considered an important element in the PSSDB system. Prima*flex* DB was employed in this paper as stated earlier. It's basically a fiber cement board that is manufactured from portland cement, finely ground sand, top grade cellulous fiber and water. Prima*flex* is lightweight, highly fire resistant, durable and has great weather resistance. Furthermore, it has higher Young's modulus (8000 MPa) than the Cemboard (4800 MPa) which was used by Ahmed et al. [11]. The properties of Prima*flex* are illustrated in Table 1.

The PSS's role on the other hand is to provide tensile reinforcement and permanent formwork. It's made from cold forming a steel strip in a rolling mill. The steel is coated with zinc or zinc/aluminum alloy in order to obtain a galvanic protection and a resistance to corrosion. Peva 50 was applied as PSS in this study and its properties are presented in Table 1.

The screw connection role is to ensure the composite action between PSSDB components. In this case, DS-FH 423 self-drilling and self-tapping screws were used. It has a diameter and length of 4.2 mm and 30 mm respectively. The presence of the SP can enhance the two-way action. It has dimensions of 1650 mm by 400 mm and has 5 mm thickness. Also, it has the same Young's modulus, Poisson's ratio and yield strength as the PSS.

The infill material can be used for non-structural purposes (sound proofing and fire resistance) and structural purposes (stiffness and strength). For this paper, it was employed for the latter. A light-weight Expanded Polystyrene (EPS) concrete was used as infill material. It's made from normal portland cement, fine sand, coarse aggregate with a maximum size of 10 mm, silica fume, water, and EPS beads with a diameter and density of 6.3 mm and 9.5 kg/m^3 respectively. The coarse aggregate was partially replaced with the EPS beads by 30%. The details

Table 1
Properties of the materials used.

Material	Thickness (mm)	Young's modulus (MPa)	Poisson's Ratio	Bending strength (MPa)
Prima*flex*	12	8000	0.25	22
Peva50	1	21,000	0.3	350

Table 2
Mix properties of the concrete per 1 m^3.

Cement (kg/m^3)	Sand (kg/m^3)	10 mm aggregate (kg/m^3)	Water (kg/m^3)	Silica fume (kg/m^3)	EPS beads (kg/m^3)
400.5	690	716.8	215	44.5	1.82