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Experimental Study on the Compressive Membrane Action in Profiled Steel Sheet Dry Board (PSSDB) Floor System

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***Abstract*— This paper describes the experimental work conducted at Universiti Kebangsaan Malaysia to examine the capability of the profiled steel sheet dry board (PSSDB) system to develop the compressive membrane action (CMA) in the floor. The development of the CMA inside the floor is strictly associated with the horizontal movement of the slab end under the vertical loading. Therefore, the simply supported PSSDB floor was tested under vertical uniformly distributed load. Study of results revealed that the recorded horizontal movement at the roller support of the slab is 0.81 mm in the pin- roller supported case. This proves that the PSSDB floor has the potential to develop the CMA under the pin-pin support condition.**

***Keywords*— Compressive membrane action; horizontal movement; flexural capacity; experimental work.**

I. Introduction

The profiled steel sheet dry board (PSSDB) roofing system, an alternative for traditional roofing, is a lightweight composite structural system that consists of the profiled steel sheeting (PSS) and dry board (DB) connected to each other by self- tapping and self-drilling screws (Fig. 1). The concrete could be used as an infill material. The system can be used for the variety of applications such as floor, roof, and wall. Easy handling and installation are some advantages of this system in addition to its lightweight. Review of literature provides a long list of experiments and analytical studies in PSSDB system [1-3] however, none of the previous works dealt with the CMA.

This paper presents the results of an experimental test conducted by the authors in the case of horizontal movements at the supports which provide a valuable insight into the potential of developing the CMA by the PSSDB system.

Flexural deformation of unrestrained slabs can be associated with the in-plane movements at the supports which are compatible with the vertical deflections of the slab at mid-span. Restricting the horizontal movement of the slab at the end supports causes the slab strips to behave similar to arch action from boundary to boundary, which is known as the CMA at first stages of the loading. The first part of the Fig. 2 [4], between points A and B, demonstrates the CMA in load-deflection relationship for a one-way slab with restrained ends.

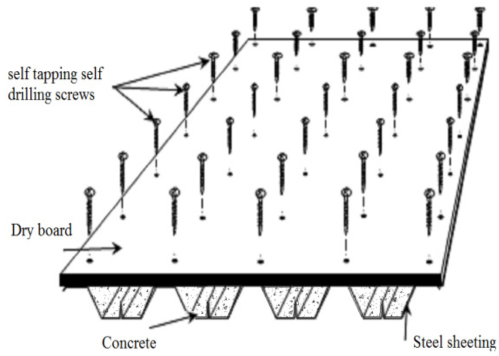


Fig. 1 Typical PSSDB floor system

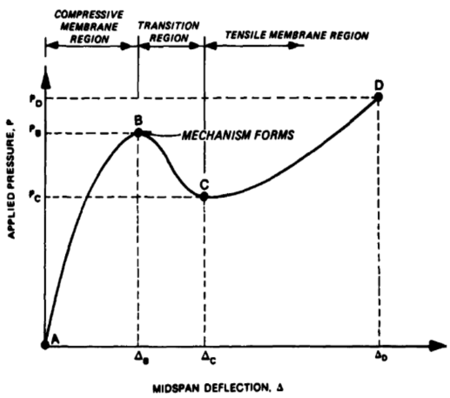


Fig. 2 Load-deflection relationship for a one-way slab with restrained ends

II. Membrane Action

The membrane action is inclusive of two stages; compressive membrane action (CMA) and tensile membrane action (TMA). CMA develops at small deflections and carries the load in an arching action from boundary to boundary. Taking the CMA into account cause the expected load-carrying capacity of the slab to increase dramatically compared to the predicted capacity by the yield line theory. As the deflection at the centre of the slab increases, or in other words, the depth of the arch pressure line decreases, the compressive forces in that area switches to tensile forces, and the TMA comes into the picture. The ultimate tensile membrane capacity occurs when the stress at the central region of the profiled steel sheet approaches the yield point.

Owing to some vague points in the theory of the CMA, most of the codes are not considering the effect of the CMA in enhancing the flexural capacity. The most significant obstacle to the routine consideration of membrane action in the work related to concrete slab strength analysis and design is the lack of information on the levels of restraint stiffness of the various structural components that would sustain membrane action [5-8].

III. Experimental work

In order to quantify the amount of horizontal movements of the PSSDB floor under the vertical loading, an experimental test is conducted. The test is one-bay PSSDB floor composed of Peva45, Prima*flex*, with concrete infill. The characteristic of the used material can be found in table 1. Prima*flex* is composite material flat sheet composed of top grade cellulose fibre, Portland cement, and finely ground sand that is produced under the intense pressure [9].

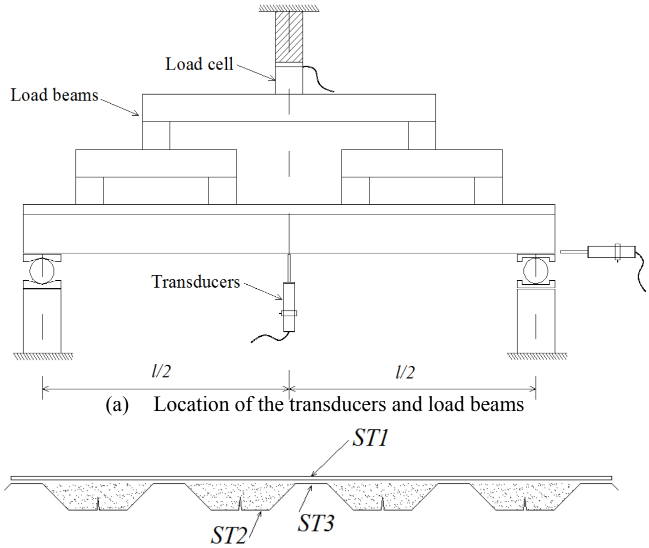
TABLE 1
Details of the specimen

	Thickness / diameter (mm)	**Width & Length (mm)**	**Modulus of Elasticity E, N/mm2**
Peva45	1.0	795×1750	203.4×10³
Screw DS-FH 432	4.2	30.0	----
Prima*flex*	12.0	795×1750	8030

The corrugations in the Peva45 were filled with concrete of grade 30 and after the curing period, the Prima*flex* board was installed on the Peva45 by self-tapping and self-drilling screws. Simply supported condition is applied in the test with the purpose of measuring the horizontal movement of the specimen at the roller end. Six transducers and three strain gauges were used to measure the movement and the strains at important areas. Three transducers were placed to detect the vertical movements of the mid-span of the specimen, while three transducers were positioned to detect the horizontal movement at the roller support. To model the uniformly distributed load in the test, an equivalent line load with an equal amount idea was employed (Fig. 3).

Monotonic static load was applied in small increments of load until either onset of the local buckling or 80% of predicted ultimate load each of them happens sooner. The loading would be based on the deflection changes after this point.

Proper considerations have been made during preparing the specimen and performing the test in order to maximize the accuracy of the obtained results. Therefore, the recorded results of the transducers and the strain gauges by the data logger are reliable.



(a) Location of the transducers and load beams

(b) Strain gauges positions at mid-span

Fig. 3 Test setup details

IV. Experimental results

As it can be seen in the load-deflection curve obtained from the recorded results (Fig. 5) the initial part of the curve is approximately linear before the appearance of the local buckling and material nonlinearity at profiled steel. In spite of occurred local buckling, the load increases to reach the ultimate capacity point and then reduces to show the ductile failure of the specimen.

The failure of the specimen is due to the local buckling near the mid-span that appears at the top flange and the sides of webs (Fig. 4). Larger plastic buckling happens, as expected, at interior top flanges compared to the exterior flanges.

Fig. 4 Failure due to local buckling

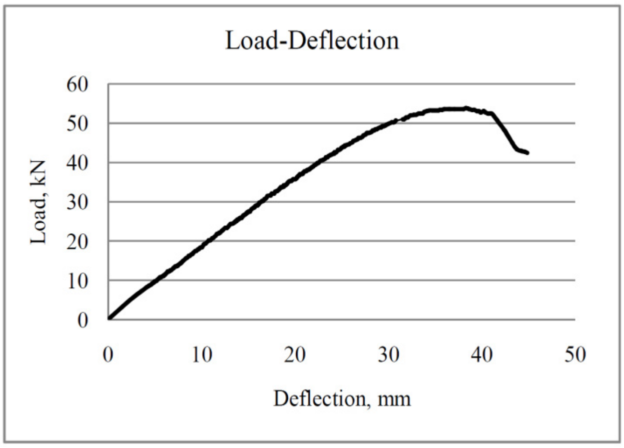


Fig. 5 Load-deflection behavior of a PSSDB floor on simple span

The objective of this test was to determine the horizontal movement of the specimen with the simply supported condition under the vertical loading to explore the potential of the PSSDB floor in development of CMA. Load-horizontal movement curve as seen in Figure 6 depicts the membrane movement of specimen end at the roller support. The horizontal movement increases until the vertical load hit 52.73 kN and while the load increases further, the horizontal movement decreases.

Restricting the movement at the supports, cause the CMA to develop at first stages of loading until the point that there is no more tendency for outward movement of the specimen ends. The TMA then initiates from the point that the increase of the loading cause the inward movement of the ends.

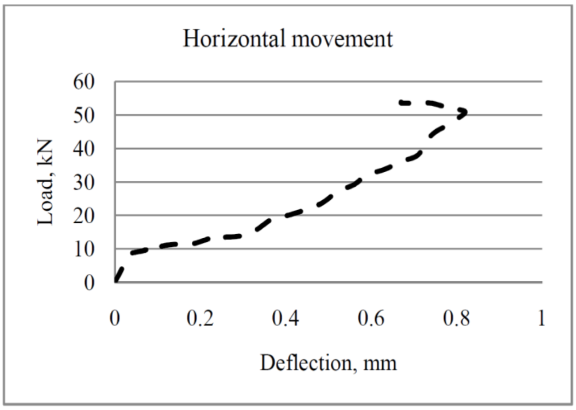


Fig. 6 Relative lateral displacement of slab ends

Figure 7 demonstrates the strains recorded at various strain gauge locations against the load. The figure is inclusive of the theoretical yield line of steel in tension and compression indicated by the dotted lines. While the stress at location of well-attached strain gauges under the lower flange (ST2) reaches the theoretical yield stress (550 N/ mm²) the stress at top flange (ST3) is only 232 N/mm² (strain 0.001132). The results obtained from the strain gauge at the top of Prima*flex* (ST1) reveals that the developed stress at that point is far below the yield stress of the material according to the provided by the manufacturer.

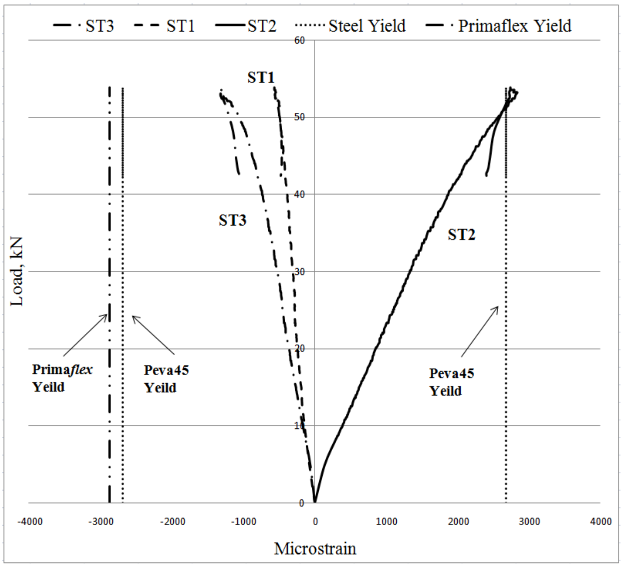


Fig. 7 Distribution of the strain in profiled steel sheeting and Prima*flex* under distributed load

V. Conclusion

The demonstrated graphs proved that the PSSDB floor have potential to develop the CMA and hence enhance the flexural capacity of the system. Fixing the supports (either against translation and/or rotation) apart from developing the CMA, improves the capability of the PSSDB system in large displacement (TMA) for the case of fire condition.

VI. Acknowledgement

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