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Structural Behaviour of Precast Lightweight Foamed Concrete Sandwich panel (PLFP) with Double Shear Truss Connectors under Eccentric Load: Preliminary Result

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Abstract. Recent years in Malaysia, precast concrete sandwich panel gained its popularity in building industries due to its economic advantages, superior thermal and structural efficiency. This paper studied the structural behaviour of precast lightweight foamed concrete sandwich panel (PLFP) with double shear truss connectors under eccentric load. Preliminary results were analysed and studied to obtain the ultimate load carrying capacity, load-deflection profiles and strain distribution across the panel thickness at mid depth. The achieved ultimate load carrying capacity of PLFP due to eccentric load from the experimental work was compared with values calculated from classical formulas (if it is more than 1 comparison) developed by previous researchers. Preliminary results showed that, the use of double shear truss connectors in PLFP was able to improve its ultimate load carrying capacity to sustain eccentric load and achieve certain compositeness reaction in between the wythes.

Introduction

More than 60 years ago, Lightweight Construction Methods (LCM) were developed and used globally for diverse construction applications. LCM was used in the building industry for applications such as houses, apartments, schools, hospitals, and commercial buildings [1]. The world is witnessing a revolution in construction practices with a new phase of development fuelled by the rapid economic growth and the high rate of urbanization. Construction provides direct mean for the development, expansion, improvement and maintenance of urban settlements [2].

The development and construction of lightweight precast sandwich structural elements in building construction is a growing trend in construction industry all over the world. Construction industry uses the precast concrete sandwich panel because of its economic advantages, superior thermal and structural efficiency. At the same time it will contribute to green building ideology by producing a cleaner and neater environment at project site through quality control, lower total construction time and cost [3].

Design of PLFP with Double Shear Truss Connectors

In this study, a small scale PLFP was casted to study its structural behaviour and determine its ultimate load carrying capacity due to eccentric load effect by using Magnus frame until it failed. Foamed concrete with wet density of 1,700 kg/m^3 was used as PLFP outer wythes and expanded polystyrene (EPS) as its insulation core layer. It is strengthened by using 9mm diameter steel bar as double shear truss connector as illustrated in Figure 1.

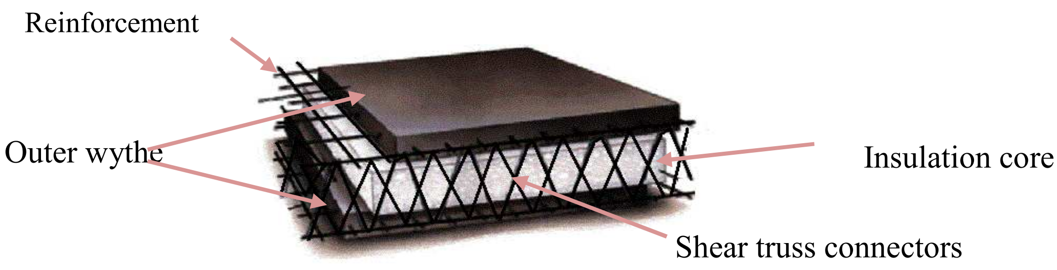
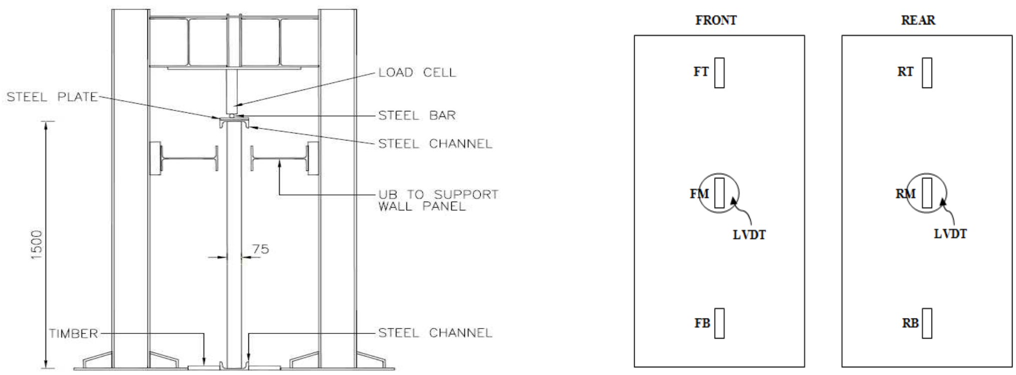


Fig. 1 : The Components of PLFP

Experimental Procedure

PLFP was tested using Magnus Frame with 1000kN loading capacity. Load applied gradually until failure occurred. Figure 2(a) shows the experimental set-up, where the PLFP was clamped to reaction frame correctly in the position to get the targeted end condition. The eccentricity loading was carried out by applying the load at an eccentricity $t_w/6$ along top edge of the panel length during the experimental programme. A total of six strain gauges were used for surface strain measurement and two Linear Voltage Displacement Transducers (LVDTs) were placed in the middle on each side of the panel as shown in figure 2(b).



(a) (b)

Fig. 2 : (a) The Experimental Set- and (b) the arrangement of strain gauges d LVDTs

Result and Analysis

The PLFP specimen details with its designation, mechanical properties and slenderness ratio are tabulated in Table 1.

Table 1 : Dimension and Properties of PLFP Specimen

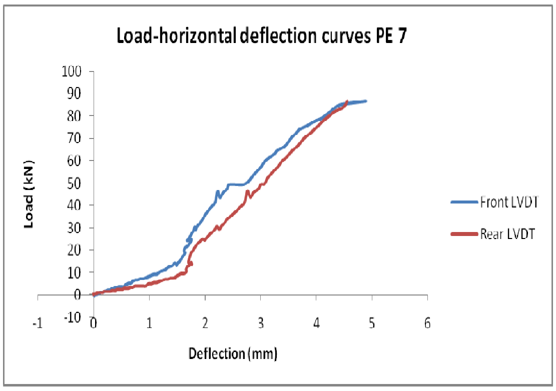
Dimension [mm] h x b x t	**Wet Density [kg/m^3]**	**Dry Density [kg/m^3]**	**Compre-ssive Strength [N/mm^2]**	**Polysty-rene Thickness [mm]**	**Slender-ness Ratio [h/t]**	**Reinforcement (Vertical & Horizontal) [mm]**	**Truss Connector [mm]**
1100x370x50	1700	1619	8.47	10	22	4	3

Ultimate Load Carrying Capacity Table 2 presents the ultimate load carrying capacity of PLFP. The load bearing capacity was observed by measuring the ultimate failure load. Cracks were observed in both concrete wythes and marked on the panel as they occurred at every load increment until the PLFP failed by crushing of concrete wythes at mid depth.

Table 2 : Ultimate Failure Load and Deflection for PLFP

First Crack (kN)	Maximum Load (kN)	Maximum Deflection (mm)
64.5	86.5	4.89

Load Deflection Profile The horizontal load deflection of PLFP was recorded at the mid-height because the maximum deflection was expected at this critical area. As shown in figure 3(a), the PLFP reacted as partial composite panel with high compositeness reaction in between the wythes. The load-deflection curves tend to move in same direction since the early stage of loading until the ultimate load carrying capacity was achieved. The similar trend of curves on both faces proved that both wythes in PLFP deflected together in the same direction and reacted as partially composite panel.



(a)

(b)

Fig. 3 : (a) Deflection curves at mid-height and (b) deflection occurred at mid depth

Surface Strain Distribution. In load-strain relationship measurement, strains on both surfaces of the foamed concrete wythes and strains across the mid-depth of panel were recorded. Figure 4(a) to 4(c) shown that strains recorded were very small. The middle zone experienced tensile strain on front surface and compressive strain on rear surface, while the upper and lower parts of the panel experienced compressive strain.

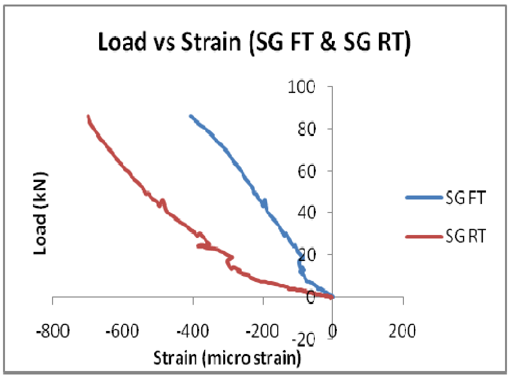


Fig. 4(a) : Front Top& Rear Top

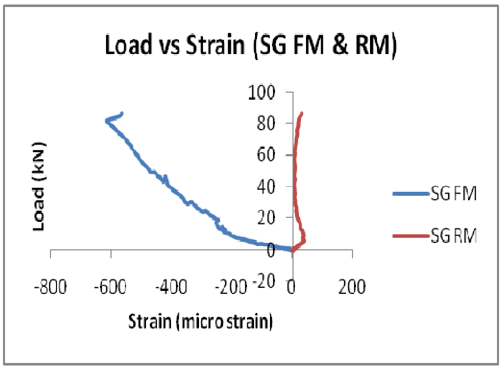


Fig. 4(b):Front Middle & Rear Middle

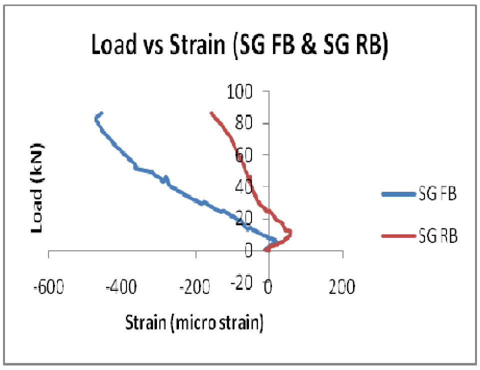


Fig. 4(c): Front Bottom & Rear Bottom

Comparison of the Ultimate Load Bearing Capacity of PLFP with Theoretical Values. Table 3 shows the ultimate load carrying capacities of PLFP obtained from classical formulas [4][5][6][7]. The result of the ultimate load carrying capacity showed that result from experimental work achieved adequate and higher strength than the value from classical formulas. The percentage differences from classical formulas ranged from 38.01% to 54.68%. Classical formulas obtained lower values compared to experimental result because it did not take into account the factor of double shear truss connectors. It showed that the use of Double shear truss connectors was able to increase the strength of PLFP and the system can be used as load bearing wall.

Table 3 : Comparison of the Load Bearing Capacity of PLFP with Classical Formula

Standard / Previous Researchers	Formula	Ultimate load , Pu(kN)	% Difference
Experiment PLFP	-	86.5	0
ACI 318-89	$P_u = 0.55\phi f_{cu} A[1-(kH/32t)^2]$	42.1	51.33
BS 8110 Part 1 (1997)	$K = \frac{N_{uz} - N}{N_{uz} - N_{bal}} \leq 1$	39.2	54.68
Benayoune	$P_u = 0.4 f_{cu} A_c[1-(kH/40t)^2] + 0.67 f_y A_{sc}$	53.6	38.01
Noridah Mohamad	$P_u = 0.4 f_{cu} A_c[1-kH/40[t-t/20])^2] + 0.6 f_y A_{sc}$	52	39.90

Conclusion

The use of double shear truss connectors in PLFP is able to improve ultimate load carrying capacity under eccentric load. The result of the ultimate load carrying capacity shows that PLFP with double shear truss connectors has ultimate load carrying capacities of 86.5kN which is higher than classical formulas. Therefore the targeted strength for PLFP was achieved.

The ultimate load achieved in PLFP is pending upon several factors which include its material strength, compressive strength, slenderness ratio, panel height, orientation of shear connectors and reinforcement. For the load deflection profile, the similar trend of curves on both faces proved that both wythes in PLFP deflected together in the same direction and reacted as partially composite panel. From the comparison of the ultimate load bearing capacity of PLFP with theoretical values, result from experimental work achieved adequate and higher strength than the value from classical formulas.

Based on the result and analysis, it is believed that by using the double shear truss connectors, two concrete wythes were held together as partially composite sandwich panel to act as single unit and improve its ultimate load carrying capacity.

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