International Journal of Engineering & Technology, 7 (3.4) (2018) 209-212

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Computational Analysis on Flexural Behavior of Precast Aerated Concrete Panel Incorporating Polypropylene Fiber

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Abstract

Precast system has great advantages in terms of its speed of construction, strength and durability. In this research, Precast Lightweight Aerated Concrete Panel, PACP, incorporating polypropylene fibers were utilized and tested to analyze its structural behavior under flexural load. Finite element analysis (FEA) using LUSAS software was utilized to simulate the PACP models under flexure load adopting nonlinear and transient analysis. The dimension of PACP panel was 200mm thickness, 500mm breadth, 1400 mm length. The FEA results were com-pared to theoretical results in terms of the panel's ultimate load. Different thicknesses and reinforcement diameters were utilized in the FEM simulations to determine the optimum values for both parameters which confirm the stability of the panel. The outcomes demonstrated that 300 mm thickness is the optimum thickness while 12 mm diameter was the optimum size of reinforcement in the PACP panel.

Keywords: *component; Precast Aerated Concrete Panel, LUSAS, FEM, Flexural Load, Polypropylene*

1. Introduction

Nowadays large number of people are moving towards urban areas for better education, economy and life standard [1]. Due to this, some of the urban's residence areas are turning to slum area. This has become a serious issue in the society, where one way to minimize the slum is by using alternative in construction industry such as precast system to provide for the affordable houses [2]. Precast system offers the speed of construction, strength and durability which fulfill the requirements of affordable housing [3]. Light weight foamed concrete has less density compared to the conventional concrete [4, 5]. Foamed concrete is identified as light weight concrete where the air bubbles are created by utilizing the foaming agent which reduces the density of concrete relative to normal or conventional concrete [6-8]. It is about 87% lighter by weight than the conventional concrete [9] where its density varies upon the dosage of foam [10-11]. Low density foamed concrete enacts low stress on the substructures.

The coarse aggregate is not present in the foamed and named as aerated concrete [12]. Aerated concrete consists of binder, sand, water and foaming agent. It contains more than 25% air [13]. The foam manages to expand the concrete, rise the volume of mixture, self-compatibility and light weight [14-15]. In general, foam concrete is chosen as innovative construction material for its advantages mentioned above. However, the absence of coarse aggregate in foamed concrete is susceptible to shrinkage cracks. Cracks perform a great role in concrete which make concrete permeable, low strength and effect the durability of concrete [16-17].

Therefore, this paper investigated the performance of concrete incorporating polypropylene fibers (PP). PP is a synthetic carbon-based fiber, produced from polymerization method where monomer polymers are transformed to elongated restraints of polypropylene. Different scholars have performed their work to check the structural performance of foamed concrete. The conclusion was, 0.8% of PP fibers are optimum consisting percentage to improve characteristics also behavior of concrete [18]. Though foamed concrete has been utilized used for ages, its gap of research still exists in terms of its structural behavior under flexural load.

Fibrous aerated lightweight concrete has high potential to be developed further as construction material. It can be utilized in the small and high-rise projects due to its durability, adaptability and reliability [19-20]. Moreover, the merits of utilizing PP fibers in concrete have been increasing rapidly because it improves the strength performance, toughness, impact strength and also failure mode of concrete [21].

At present, experimental work is usually time and energy consuming, where lots of materials need to be utilized and large numbers of specimens need to be tested in order to analyze the performance. Meanwhile, finite element method is the numerical analysis used to analyze structural performance, thermal conductivity, lubrication, electric and magnetic fields [22].

The flexural performance of PACP is analyzed under four-point bending load by means of FEA. The flexural performance was studied in terms of its ultimate load, flexural stress, crack profile and load-deflection pattern.

2. Methods and Analysis

Nonlinear finite element three dimensional, 3-D model was established by utilizing LUSAS software to examine the PACP's performance underneath flexure load. The nonlinear and transient analysis was used for PACP's investigation. The information collected from previous experiments work results and hypothetical calculation were adopted as given figures in the FEM [9-10]. The outcomes were analysed in the terms of its ultimate load, load-deflection pattern and crack profile. Computational study was accompanied by means of developing sequence of simulations on PACP with different heights, thicknesses, and thicknesses of reinforcement. The aim of this parametric study was to examine the impact of various dimensions of PACP and to determine the optimum dimensions of reinforcement confirms constancy of PACP in context of its ultimate strength attained. The dimension of PACP panel is 1400 mm span length, 500 mm breadth with different values of thickness.

The total four specimens of PACP specimen with different thicknesses and diameter of reinforcement was simulated under flexural load. All the PACP specimen were modelled as foamed aerated concrete incorporating PP fibers. Concrete cover of 25 mm and link of 6 mm diameter were utilized for all specimen. Differences of overall wall thicknesses were in the limit of 150 mm to 300 mm and diameter of reinforcement is 6mm to 12mm. Each panel was selected as PACP-S1 to PACP-S4. Table 1 shows the PACP-S1 to PACP-S2 panels with 12 mm diameter of reinforcement, modelled and simulated under flexure load to determine the optimum thickness. Meanwhile, Table 2 shows the PACP-S1(a) to PACP-S1(d), modelled and simulated under the same load to conclude the optimum diameter of reinforcement bar in the panel.

Table 1: Dimensions and characteristics of specimen

Specimen	w x t x l (mm)	Diameter of reinforcement (mm)
PACP-S1	500x300x1400	12
PACP-S2	500x300x1400	12
PACP-S3	500x300x1400	12
PACP-S4	500x300x1400	12

Table 2:PACP-S1 panels with various diameter of reinforcement

Specimen	w x t x l (mm)	Diameter of reinforcement (mm)
PACP-S1(a	500x300x1400	12
PACP-S1(b	500x300x1400	10
PACP-S1(c	500x300x1400	8
PACP-S1(d	500x300x1400	6

The FEM modelled for PACP in this research was in a 3-D non-linear plane stress element. The support conditions were static at x and y direction at its left end and restrained in y-direction at its right end. Loading specifications were point loads acting alongside the aerated concrete surface. The physical model for PACP specimen exhibited in Figure 1 and Figure 2. The node was seen with each line and produces a surface and mesh to form the capacity to construct it 3-D. A 3-D plane stress model was established conferring to the sizes presented in Table 1. The dimensions of link and wire mesh were same as for entire PACP models, diameter of steel utilized as main bar was changed.

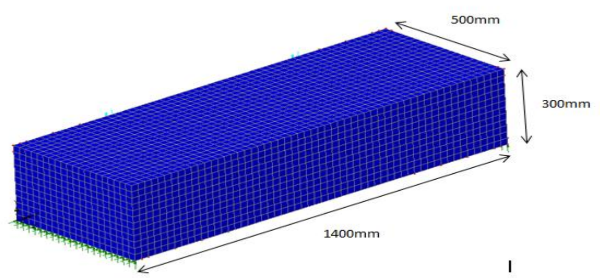

Fig. 1: 3-D Physical model of PACP panel

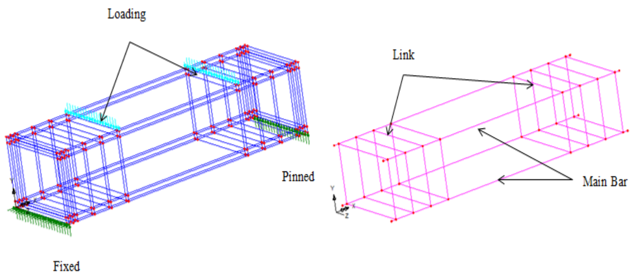

Fig. 2: Solid PACP loading and support condition

Table 3 presents the properties of foamed concrete utilized in the PACP finite element model. The characteristics were obtained from laboratory tests conducted on foamed concrete cubes and cylinders. Table 4 presents the properties of steel used as the main bar, link and wire mesh in the PACP.

Table 3: Properties of foamed concrete utilized in the PACP modal [8]

Panel	ρ_c(Mpa)	Ft (Mpa)	E (KN/mm^2)	Mass density, ρ (kg/m^3)	v
PACP	11.30	0.30	12	1600	0.20

Table 4: Properties of steel used for reinforcement bar, link and wire mesh [8]

Reinforcemen	σy (MPa)	Pt (MPa)	ε	Es (kN/mm^2)	ρ (kg/mm^3)	v
Bar	560	627	0.19	196	8x10^6	0.3
Link	519	545	0.05	210	8x10^{-9}	0.3
Wire Mesh	251	397	0.07	226	8x10^{-9}	0.3

3. Results and Discussions

The suggested FEM model was corroborated in terms of its strength capability and deflection. Table 5 and Figure 3 defines the ultimate potential of PACP panels from finite element analysis and hypothetical estimate rate, respectively, for panel PACP-S1 to PACP-S4. It was concluded that ultimate potential from FEM outcomes are greater than the hypothetical values for PACP-S1 and PACP-S2, lesser than the hypothetical limits for PACP-S3 and PACP-S4. Figure 2 represents the variance between the ultimate loads of PACP panels with different thicknesses as of FEM and hypothetical. The percentage difference among the two results are as shown in Table 5 and Figure 3.

Table 5: Ultimate load of PACP-S1 to PACP-S4 from FEA and Theoretical calculation.

Panel	Ultimate Load (kN)		Percentage Difference (%)
	F E M	Theoretical	
PACP-S1	26.50	25.2	4.86
PACP-S2	26	23	11.51
PACP-S3	16.80	18.8	10.60
PACP-S4	9.80	14.2	31.01

From Table 5 and Figure 3, PACP-S1 with 300 mm thick is noticed to have achieved highest the ultimate strength. It is visible from the table that when the thickness decrease, the strength increased. It expected because larger concrete cross section area could usually sustain higher load.

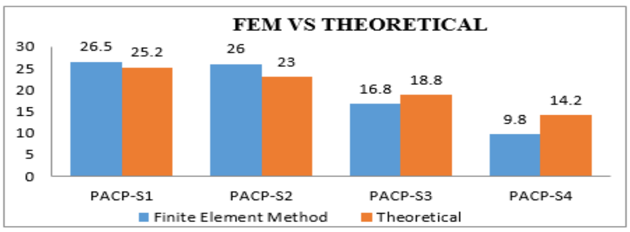

Fig. 3: Difference of Ultimate Load between FEM Analysis and Theoretical value

Figure 4 presents the crack profile on ultimate load for specimen PACP-S1. The crack was noticed near arise at the bottom of the middle span also on the support of PACP. It anticipated as the simply supported panel, crack happens on mid-span also on support of the specimen. All panels appear to consume proficient alike crack profile such as PACP-S1.

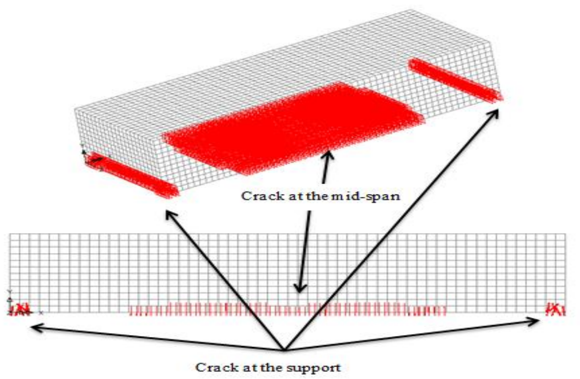

Fig. 4: Crack pattern at Ultimate Load of PACP-S1

Table 6 shows deflection of PACP-S1 to PACP-S4 panels as found from finite element method. It is seen that PACP-S4 panel with thickness of 150 mm deflected the most with maximum deflection of 0.52 mm. Meanwhile, PACP-S1 with the thickness of 300 mm presents the least deflection of 0.22mm. This indicates that panel's thickness has obviously influenced the value of deflection. Results also show that the more thickness the panel, the lower the deflection will be achieved. Figure 7 describes the lateral deflection of flexural loaded specimens PACP-S1 to PACP-S4 as acquired from finite element examined.

Table 6: Dimensions and characteristics of specimen

Panel	w x t x l (mm)	Max Deflection (mm)	Ultimate Load (KN)
PACP-S1	500x300x1400	0.22	26.5
PACP-S2	500x300x1400	0.35	26
PACP-S3	500x300x1400	0.41	16.8
PACP-S4	500x300x1400	0.53	9.8

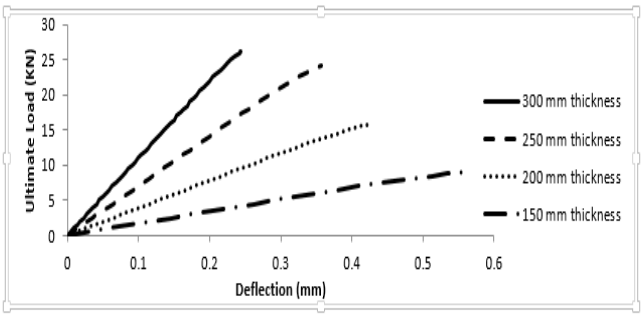

Fig. 4: Lateral deflection of flexural loaded specimen solid PACP-S1 to PACP-S4 found from FEA

Table 7 presents the values of maximum deflection achieved in all PACP-S1 panels with various diameter of bar reinforcement. It shows that panel PACP-S1(a) with largest diameter of reinforcement achieve the lowest maximum deflection which is 0.22 mm. It is also noticed that panels with lower diameter of reinforcement recorded higher deflection values. This is as expected that larger diameter of reinforcement contributes to larger cross section area of steel; thus, the panel is able to sustain the load more efficiently. This cause less deflection value.

Table 7: Maximum deflection in all pacp-s1 panels with various diameter of bar reinforcement.

Specimen	w x t x l (mm)	Diameter of reinforcement (mm)	Maximum deflection (mm)
PACP-S1(a)	500x300x1400	12	0.22
PACP-S1(b)	500x300x1400	10	0.24
PACP-S1(c)	500x300x1400	8	0.27
PACP-S1(d)	500x300x1400	6	0.32

4. Conclusion

The ultimate load, P_ult, rises with the rise of the thickness. Results demonstrated that the thicker the panel, the stronger it will get. Thickness of 300 mm gave the highest ultimate load of 26.5 KN. It is observed that the bigger the diameter of the reinforcement, the higher strength of panel will be attained. From the outcome, Results predicted that 12mm diameter of main bar gave the lowest deflection value of 0.22mm for the panel. Therefore, it is concluded that 300mm is the optimum thickness and 12mm is the optimum bar diameter for the PACP panel.

Acknowledgement

The authors would like to thank the UniversitiTun Hussein Onn Malaysia (UTHM) which provided the financial support for this project under Tier 1 grant (Volt-H122).

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