Fibre Reinforced Modulus of Elasticity and Compressive Strength of Foamed Concrete

R. Suzila, M. S. Hamidah, A. Anizahyati and M. R. Ahmad Ruslan

Abstract The influence of fibres in various level of density of foamed concrete to improve the performance characteristics has been investigated. Fibres used are in two different types which are synthetic (polypropylene fibre) and natural (kenaf fibre). Those fibres were cut into same length which is 15 mm with proportion of 3 % by volume in the design mix. The effects on modulus of elasticity and compressive strength are reported. Compared to plain foamed concrete, specimens filled with polypropylene (PP) fibre at 1,800 kg/m^3 density of foamed concrete, caused about 40 % increase in modulus of elasticity and a 18 % increase in the compressive strength. However, kenaf fibre specimens at 1,800 kg/m^3 density of foamed concrete caused a decrease in modulus of elasticity by about 29 % and decrease in compressive strength by about 21 %. These indicate a vital gain in the ductility and strength when foamed concrete incorporating with polypropylene (PP) fibre as compared to kenaf fibre reinforced foamed concrete.

Keywords Compressive strength · Modulus of elasticity · Kenaf fibre · Polypropylene fibre · Foamed concrete

1 Introduction

Foamed concrete is an innovative approach of concrete technology that is inherent in term of cost and constructive over conventional concrete. It is produced using less material than regular concrete, thus making it a green alternative for typical heavy concrete. This surety less environment impact by using less cement, much less sand and eliminated function of gravel in conventional concrete, which all require large amount of energy to be produced. Owing to this noteworthy,

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structural concrete has been widely manufactured by using foamed concrete in many applications such as insulating wall panels, thermally insulating foundation plates, precast and many more.

However, innovation has always been met with resistance. Foamed concrete, other than its lower strength, its mechanical characteristics also were lacking in some aspects [1] such as prone to low in elasticity, shrinkage and creep. This conundrum where influenced by the elimination of coarse aggregate function as a stronger matrix bond in the concrete.

One of the crucial characteristic of foamed concrete is the low elasticity and compressive strength due to its high porosity and the probability of high permeability [1, 2]. This could lead to increase in brittleness nature of foamed concrete and some disadvantage such as poor deformability [3]. The decisive problems of foamed concrete become the vital problems when these contribute to reduction of the strength and then affected performance and durability of the concrete.

Therefore, improving ductility and brittleness of foamed concrete is the key point to make them suitable as structural material with an endeavor to seek a superior mechanical property of foamed concrete. The vast attractions on the production of structural foamed concrete in many applications have become awareness for concrete industry to implement to greener environment and sustainable construction. These have renewed the interest in using fibres as a reinforcement that possess greater mechanical properties in term of elasticity and compressive strength.

There is now ample evidence that the application of discrete fibre has been proposed by many researchers in enhancement of foamed concrete mechanical properties such as Bagherzadeh et al. [3], Boghossian and Wedger [4] and Jones and McCarthy [5]. Conversely, review on the works of Libre et al. [6] and Rashdi et al. [7] has revealed that addition of fibre did not significantly affect the mechanical properties of foamed concrete.

Nevertheless, in spite of advantages that have been reported in this area [3–5], much more research is still needed. This is especially so because of the diversity of fibre types and various level of density may be obtained by foamed concrete.

The effect of two different types of fibre reinforcement on foamed concrete is reported in this paper. There are polypropylene (PP) and kenaf fibre. The paper reports and discusses the different effect from those sample incorporation with synthetic and natural fibre and the effect of various level of density on the modulus of elasticity and compressive strength of foamed concrete.

2 Experimental Work

2.1 Preparation of Foamed Concrete Specimens

Five series of foamed concrete with density ranging from 1,000 to 1,800 kg/m^3 were cast. There were 90 number of specimens, which consist of 45 cylinders (100Ø × 200) mm and 45 cubes (100 × 100 × 100) mm for modulus of elasticity test and compressive strength test respectively. For each series, the specimens were adopted with three batches of different fibre content. In this work, two types of fibre have been cut into 15 mm length to be incorporated at level of 3 % (by volume) of kenaf fibre and polypropylene fibre. For each series, 2.0: 1.0 sand cement ratio and 0.5 of water content were integrated. The polypropylene fibre used in this research is monofilament type whereas kenaf fibre used is bast type and was obtained from Lembaga Tembakau Negara (LTN). The Ordinary Portland Cement (OPC), river sand, tap water and foaming agent of synthetic type based (Finefoam 707) were used to generate foamed concrete mix.

The cylinder 100Ø × 200 mm and cubes 100 × 100 × 100 mm were prepared for three replicate test specimens for both modulus of elasticity test and compressive strength test. The specimens were demoulded after 48 h casting in order to ensure a sufficient hardening for handling. Then, all the test specimens were subjected to water cured for 28 days.

2.2 Testing Method

2.2.1 Compressive Strength Test

Foamed concrete with density ranging from 1,000 to 1,800 kg/m^3 were cast in 100 × 100 × 100 mm cubes. The cubes were conducted by using the compressive machine at the pace rates of 3.00 kN/s as recommended by BS 1881: Part 4: 1997. The stress readings were recorded and analyzed to determine the effect of additional fibres to the compressive strength at the age of 28 days.

2.2.2 Modulus of Elasticity Test

The modulus of elasticity test was performed at the age of 28 days according to ASTM C469-02. Two linear variable differential transformers were connected to a digital transducer and the data were fed into a data logger. The load was applied at constant rate within the range 35 ± 5 psi per second. The data from both linear variable differential transformers (LVDTs) were averaged and plotted as stress–strain relationship graph. To obtain the elastic zone, the data were recorded when the data points starting at strain value of 50 million, up to 40 % of the ultimate load.

3 Results and Discussions

The results of 28-day modulus of elasticity and compressive strength of foamed concrete are presented in Table 1 with respect to the specimen level of densities and fibre type of each series. The series consist of plain foamed concrete (NLWC),

Table 1 Results of modulus of elasticity and compressive strength

Density (kg/m^3)	Modulus of elasticity (GPa)			Compressive strength (MPa)		
	NLWC	LWCK	LWCP	NLWC	LWCK	LWCP
1,000	3.88	3.21	5.87	1.91	1.23	1.82
1,200	5.18	4.59	7.78	2.37	1.44	7.01
1,400	7.95	7.10	11.54	3.69	4.68	13.44
1,600	10.69	9.54	16.35	13.25	10.87	16.93
1,800	16.36	11.59	22.96	16.16	12.84	19.04

PP reinforced foamed concrete (LWCP) and kenaf reinforced foamed concrete (LWCK).

3.1 Effects of Various Level of Density to Modulus of Elasticity and Compressive Strength

To study the effect of various level of density on elastic modulus and compressive strength of foamed concrete, five series of specimens were performed ranging between 1,000 to 1,800 kg/m^3 for group addition of polypropylene fibre (LWCP), kenaf fibre (LWCK) and plain foamed concrete (NLWC). Figures 1 and 2 presents the modulus of elasticity and compressive strength of the series of unreinforced, reinforced with polypropylene fibre and kenaf fibre.

Obviously, the elastic modulus of foamed concrete incorporated with polypropylene fibre (LWCP) uptakes proportionally with increment of foamed concrete density. However, the compressive strength values shown abruptly increased between 1,200 and 1,600 kg/m^3.

On the other hand, for both specimens with kenaf fibre (LWCK) and plain foamed concrete (NLWC) clearly shown a symmetrical trend or achieved almost the same values up to 1,600 kg/m^3. But there is an overlapping results of compressive strength between kenaf reinforced foamed concrete (LWCK) and plain foamed concrete (NLWC) at the density ranging between 1,200 and 1,400 kg/m^3. Nevertheless, at the end as of 1,800 kg/m^3 lightweight concrete filled with PP fibre (LWCP) gives the highest value for both elastic modulus and compressive strength.

From Figs. 1 and 2, it shows that the value of elastic modulus and compressive strength increasing as the density level was increased for all foamed concrete specimens. It was observed that PP reinforced foamed concrete (LWCP) with the highest density of 1,800 kg/m^3 gives the maximum elastic modulus value of 22.96 GPa as compared to kenaf reinforced foamed concrete (LWCK) and plain foamed concrete (NLWC) which are 11.59 and 16.36 GPa, respectively. Same goes to compressive strength, the highest strength of 19.035 MPa was given by PP reinforced foamed concrete (LWCP), whereas, 12.838 and 16.157 MPa for kenaf

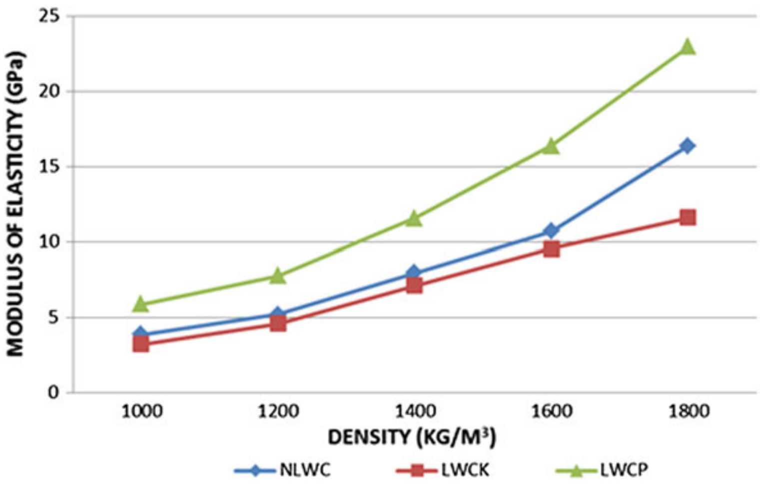

Fig. 1 Modulus of elasticity of lightweight concrete

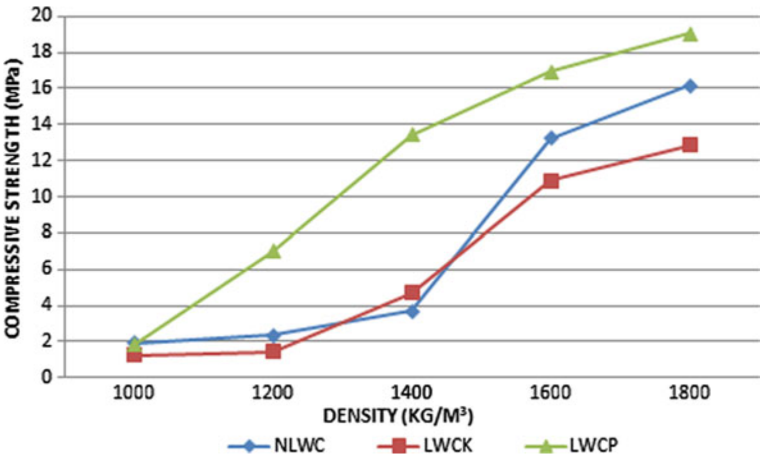

Fig. 2 Compressive strength of lightweight concrete

reinforced foamed concrete (LWCK) and plain foamed concrete (NLWC) respectively.

Owing to the high porosity, foamed concrete is more prone to deform. Apparently, the absence of coarse aggregate in foamed concrete leads to lower elasticity due to its lower density [5]. Consequently, this would affect the ductility of the foamed concrete and become more brittle [8]. Moreover, the size of voids in the foamed concrete will govern its compressive strength. The higher the compressive strength will indicate the lower void size. Foamed concrete which contain a lot of voids, the compressive strength will reduce according to the reduce of

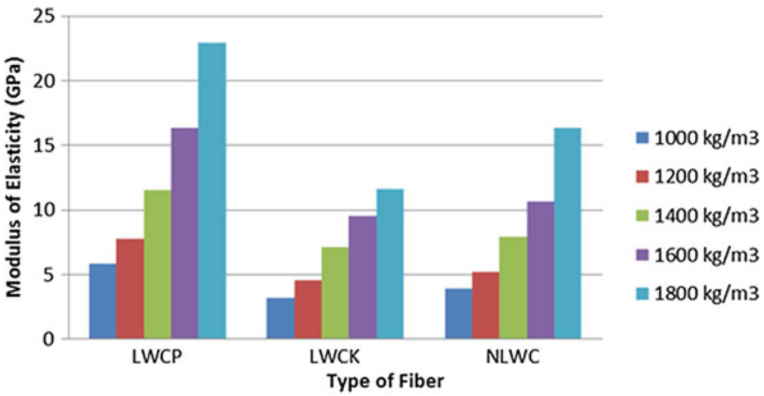

Fig. 3 Modulus of elasticity of lightweight concrete

density. This revealed that the elasticity and compressive strength of lightweight concrete is affected by the volumetric proportion of aggregate in the concrete in order to perform the stronger matrix bond [8].

3.2 Effects of Fiber Content

Foamed concrete is expected to manifest a low mechanical behaviour such as elastic modulus and compressive strength. In this work, two types of fibre were chosen which are polypropylene fibre (PP) and kenaf fibre to represent the enhancement in mechanical of different density of foamed concrete.

Results of elastic modulus and compressive strength of foamed concrete with different types of fibre were performed. The mean of elastic modulus and compressive strength from three identical specimens are expressed as depicted in Figs. 3 and 4 for group of five different levels of density of foamed concrete.

According to the results illustrated in Fig. 3, it can be seen that the modulus of elasticity for kenaf reinforced foamed concrete (LWCK) is lower than that of PP reinforced foamed concrete (LWCP) and plain foamed concrete (NLWC). This is predictable since the compressive strength as depicted in Fig. 4 also shows that kenaf reinforced foamed concrete (LWCK) records the lowest value as compared to the other two PP reinforced foamed concrete (LWCP) and plain foamed concrete (NLWC).

The elasticity and compressive strength increase as the density of foamed concrete increase. The foamed concrete specimens with addition of PP fibre (LWCP) attain the highest elasticity and compressive strength as compared to plain foamed concrete (NLWC). This proved that, inclusion of PP fibre in the foamed concrete mix improves the elastic modulus and compressive strength of the resulted foamed concrete. This finding is also in line with that reported by Jones and McCarthy [5].

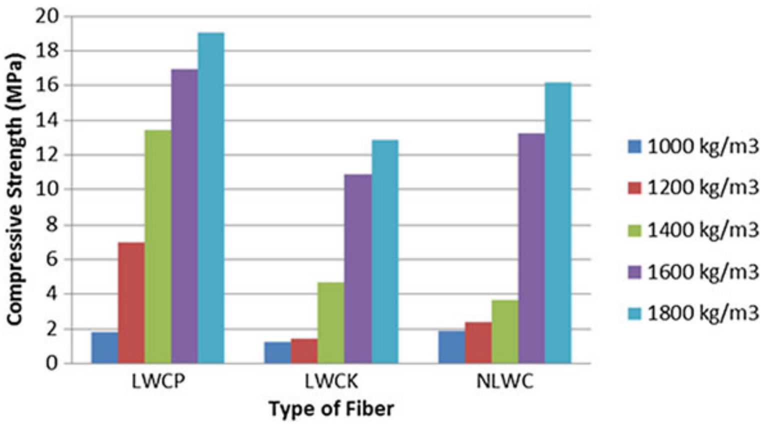

Fig. 4 Compressive strength of lightweight concrete

However, inclusion of kenaf fibre (LWCK) gives lesser impact to the modulus of elasticity and compressive strength of foamed concrete. In fact, the modulus of elasticity and compressive strength of kenaf reinforced foamed concrete (LWCK) is lower than those of plain foamed concrete (NLWC). This could be due to its high cellulose content that attribute to high absorption of moisture which negatively affects the mechanical properties of the resulted concrete [7]. High amount of absorbed water causes swelling of fibre. This could fill the gap between fibre and the matrix bond and eventually could lead to reduction in the elasticity and compressive strength [8].

These observations emphasize the importance of the matrix bond of foamed concrete to improve the performance of foamed concrete. The advantage that the polypropylene fibre contributes to the ductility of foamed concrete is obvious.

4 Conclusion

This study investigates the influence of incorporating fibre into the foamed concrete mix made of varies on the compressive strength and modulus of elasticity properties of the resulted foamed. The following conclusions can be drawn from the investigation:

1. Addition of polypropylene (PP) fibre appreciably increased the ductility and strength of foamed concrete. However, addition of kenaf fiber did not significantly enhance the modulus of elasticity and compressive strength. This could be due to kenaf high cellulose content that attribute to high absorption of moisture which affects these properties. Thus, polypropylene fibre (synthetic) contributes more to ductility and strength compared to kenaf fibre (natural) in this study.

2. Addition of polypropylene (PP) fibre (LWCP) to 1,800 kg/m^3 density of foamed concrete caused a 40 % increase in modulus of elasticity and a 18 % increase in the compressive strength. However, kenaf reinforced foamed concrete (LWCK) at 1,800 kg/m^3 density of foamed concrete caused a decrease in modulus of elasticity by about 29 % and decrease in compressive strength by about 21 %.
3. Modulus of elasticity and compressive strength of the foamed concrete increases as the density of foamed concrete increases. In other words, the elasticity and compressive strength of foamed concrete is affected by its density.

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