

Compressive and Flexural Strength of Foamed Concrete Containing Polyolefin Fibers

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Abstract: Foam concrete is a lightweight concrete which is produced relatively inexpensively. However, due to its low strength and brittleness the application in building construction is rather limited. A study has been undertaken to investigate the effects of polyolefin fibers at a relatively low volume fraction (0 %, 0.2 %, 0.4 % and 0.6 %) on the compressive and flexural properties of foamed concrete. The foamed concrete was designed to achieve a target strength of 8-10 MPa with a density of 1600 kg/m³ at the age of 28 days. For each mixture, nine 100x100x100 mm cubes and three 100x100x500 mm beam were prepared. The compressive test was performed on cubes and three points loading flexural test on the beams was carried out in accordance to MS 26:Part 2:1991. Test results showed that polyolefin fibers only slightly improved the compressive strength and flexural strength of foamed concrete by 4.3% and 9.3% respectively.

Introduction

Using foamed concrete as a construction material not only reduced the self-weight of a structure, it also offers better thermal insulation and better fire protection than ordinary concrete. Conventional foamed concrete is typically proportioned to achieve only low compressive strength, suitable for its use in void fill and trench reinstatement and thus, the material is largely disregarded for use in structural sections[1]. Yasser [2] studied the contribution of foamed concrete to the strength of cross sections of composite members and found that foamed concrete was not satisfactory in resisting squash load and bending due to the brittle properties of the materials.

The addition of fibers in normal concrete to enhance the strength has been widely studied. Banthia and Sheng [3] reported that the addition of steel, polypropylene and carbon fibers can overcome the brittle properties of concrete. In order to overcome the brittle nature of foamed concrete, Gao *et al.* [4] has investigated the properties of fiber reinforced lightweight concrete. Kayali *et al.* [5] reported that polypropylene fiber addition of 0.56 % by volume of the lightweight aggregate concrete caused a 90 % increase in indirect tensile strength and 20 % increase in the modulus of rupture. Chen and Liu [6] also reported that the addition of steel fiber can significantly increase the split tensile strength of expanded polystyrene concrete and improve its shrinkage resistance properties. The use of polyolefin fiber in a precast concrete box was reported by Mindess *et al.* [7]. The addition of 1.5% volume fraction of this fiber has resulted in the optimum behavior of the element. In this study, the influence of polyolefin fiber at a low volume fraction on strength of foamed concrete was investigated. The use of this fiber in foamed concrete has the advantage in term of cost since the fiber is cheaper compared to other artificial fibers and it is readily available.

An Experimental Program

Polyolefin fibers. The characteristic of Polyolefin fiber is shown in Table 1. The table shows that, the specific gravity of this fiber is 0.91 with 0.64mm diameter and 50.4 mm in length. The advantages of this fiber are resistance to alkaline environment, high melting point and easy to work with.

Table 1 Polyolefin fiber characteristics [8]

Characteristics	Unit	Value
Specific Gravity	-	0.91
Tensile strength	MPa	275
Elastic modulus (E)	GPa	2.6
Strain failure (lengthening)	%	15
Inflammation point	°C	593
Plasticizing point	°C	160

Other Materials

The basic mixed ingredients used were: Cement, fine aggregate, water, foam and polyolefin fibers. No coarse aggregate was used in foamed concrete since it is heavier and will cause segregation. The cement used in all concrete mixes was ordinary Portland cement specified by MS 522: Part 1 [9]. Meanwhile, the fine aggregate used was local natural sand with specific gravity of 2.60 and the maximum size was 3 mm. The foam was produced by a foam generator in which a foaming agent diluted with water and air. The foaming agents were based on hydrolysed natural protein. The density of the foam was 50 g/liter. They were formulated to produce air bubbles that were stable and able to resist the physical and chemical forces imposed during mixing, placing and hardening of the concrete.

Mix Proportions

Table 2 shows the details of typical mixes used for foamed concrete and polyolefin fiber reinforced foamed concrete with a density of 1600 kg/m³. A total of four types of mixtures was cast with 0 %, 0.2 %, 0.4 % and 0.6% polyolefin fiber volume fractions. An indication of batch weights was given because the characteristics of the foam would influence the weight required. The high w/c ratio of the mix would provide a mixture with a high workability. If the mixture was too dry and stiff, it was liable to extract water from the foam and caused it to collapse.

Table 2: Mix proportions

Concrete	FC plain	PFC 0.2	PFC 0.4	PFC 0.6
Ordinary Portland cement (kg/m ³)	390	390	390	390
Water (kg/m ³)	175	175	175	175
Foam (kg/m ³)	235	235	235	235
Fibers (kg/m ³)	0	1.6	3.2	4.8
Sand (kg/m ³)	800	800	800	800

Test Procedures

The Compressive and flexural strength test were carried out using Universal Testing Machine (UTM) according to MS 26: Part 2 [10]. The compressive strength test was performed on 100 x 100 x 100 mm cubes. For each mixture, 9 specimens were prepared and tested at 3, 7 and 28 days. The load-displacement curves were monitored throughout the test using a computer-based data acquisition system. The flexural strength was performed on specimens with dimensions of 100 × 100 × 500 mm using the third point loading procedure of MS 26: Part 2 [10]. For each mixture, 3

specimens were prepared. The test was conducted in a displacement-controlled manner, and deflections were measured at the center of the specimen using the dial gauge, and a loading rate of 0.5 mm/min. The load-displacement curves in flexural tests were obtained using a computer-based data acquisition system.

Results and Discussion

Density. Figure 1 shows the relationship between the concrete density and polyolefin fiber volume fraction. It clearly demonstrates that the concrete density decreased with the increasing of polyolefin fiber volume fraction. The concrete density decreases from 1600 kg/m^3 to 1579 kg/m^3 at 0.6 % fiber volume fraction. These values can represent a percentage of 0.9 %, 1.2 % and 1.3 % for PFC 0.2, PFC 0.4 and PFC 0.6 mixes respectively. Kayali *et al* [5] also reported a similar result for the concrete density of polypropylene fiber reinforced lightweight aggregate concrete with the about 1.5% decrease at 1 % fiber volume fraction.

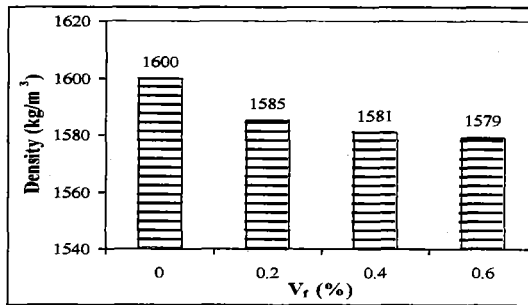


Fig 1: Effect of fiber volume fraction on density.

Compressive Strength. Polyolefin fiber in foamed concrete mixes has only a minor effect on the compressive strength. The presence of polyolefin fiber appears to increase slightly with additional fiber volume fraction from 0.2 % to 0.6 % as shown in Figure 2. The effect of fiber volume fraction in compressive strength is insignificant and inconsistent cause by the decreasing value at 0.2 % fiber volume fraction. In term of percentage, the difference in the compressive strength compared to plain concrete for PFC 0.2, PFC 0.4 and PFC 0.6 mixes is -13.8 %, 5.4 % and 4.3 % respectively.

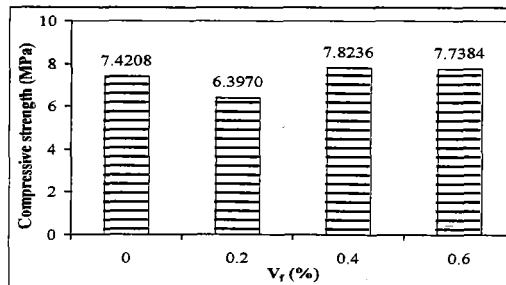


Fig 2: Effect of polyolefin fiber volume fraction on 28-day compressive strength.

The compressive strength increased with the increasing of age of concrete for all mixes (Figure 3). Mixes with plain foamed concrete gain strength, expressed as a percentage of 28-day strength, more rapidly than mixes with fiber reinforced foamed concrete. According to Gambhir [11], this is because the cement grains are closer to one another and a continuous system of gel is established

more rapidly for the plain foamed concrete. For fiber reinforced foamed concrete, the interruption of fiber presence is the factor of decreasing value.

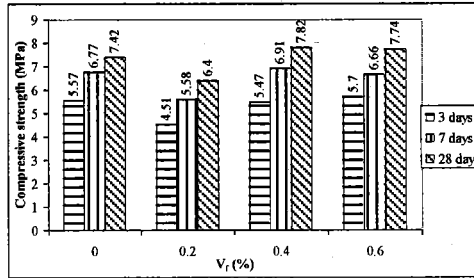


Fig 3: Relative compressive strength with different fibre volume fraction with time of concrete.

Flexural Strength

The presence of polyolefin fibers appears to increase marginally the flexural strength from 1.40 MPa to 1.53 MPa for 0.6 % fiber volume fraction as shown in Figure 4. These values represent a percentage of 0.7 %, -2.9 % and 9.3 % for PFC 0.2, PFC 0.4 and PFC 0.6 mixes. Kayali *et al.* [5] also founded that increasing about 20 % in flexural strength for polypropylene fiber reinforced lightweight aggregate concrete at 0.56 % by volume fraction. The reason for the increase of flexural strength is the fracture process of polyolefin fiber reinforced foamed concrete consists of progressive debonding of fiber have slowed down the crack propagation.

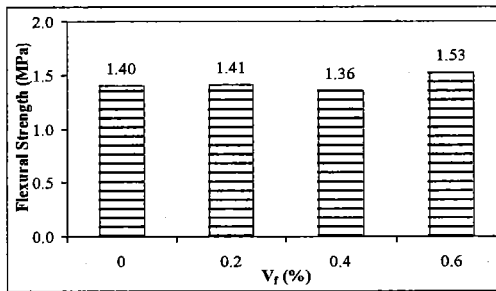


Fig 4: Flexural strength test results of concrete at different volume fractions.

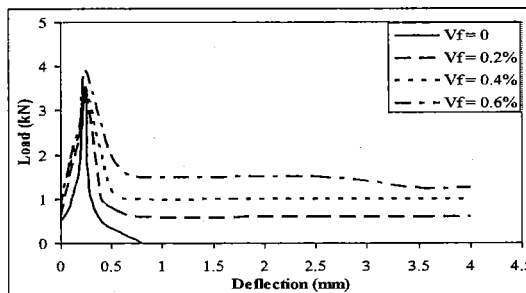


Fig 5: Flexural load-deflection curves at different volume fractions

The typical flexural load-deflection curves of polyolefin fiber reinforced foamed concrete with fiber volume fractions of 0.2 %, 0.4 % and 0.6 % are shown in Figure 5. The test results show that the load-deflections curve for polyolefin fiber reinforced foamed concrete are similar to the curves for polyolefin fiber reinforced concrete described by 3M Corp [8]. It observed that the linear elastic part of the curves appear before the ultimate load.

Conclusion

The effect of polyolefin fibers at volume fraction ranging from 0.2 % to 0.6 % on the compressive and flexural strength of foamed concrete materials were investigated experimentally. Sufficient replicated test data were produced in order to confirm the validity of the following conclusions:

- (i) The compressive strength of foamed concrete improved only slightly with the addition of polyolefin fiber. The non-improvement in compressive strength do not have much effect on the applications of the fiber reinforced foamed concrete in general. This is due to the fact that the main objective of incorporating polyolefin fibers into the foamed concrete is not to increase its compressive strength but rather to delay the propagation of cracks.
- (ii) The compressive strength of polyolefin fiber reinforced foamed concrete increased with the age of curing and independent of volume fraction.
- (iii) The flexural strength of foamed concrete is only marginally increased with the addition of polyolefin fiber.

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