Lightweight Concrete Reinforced with Polypropylene Fibers

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ABSTRACT

This research study the mechanical properties of lightweight concrete reinforced with polypropylene fibers. Foam agent used to produce lightweight foamed concrete. The aim of this study to investigate the effect of polypropylene fibers on mechanical properties of lightweight foamed concrete. The volume fractions of the polypropylene fibers (PPF) used are: 0.0%, 0.1%, 0.2%, 0.3%, 0.4%, and 0.5% total volume of concrete. The flowability, dry density, compressive strength and splitting tensile strength, were measured. The results shows, the flowability of lightweight foamed concrete reduced by addition polypropylene fibers. The compressive strength and splitting tensile strength increased with rising the percentages of polypropylene fibers.

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1. INTRODUCTION

Lightweight concretes can be defined as a concrete have an oven-dry density range 300 to not more 2000 kg/m3, with compressive strength for cube about 1 to more than 60 MPa, thermal conductivities of 0.2 to 1.0 W/mK. These values can be compared with those for normal weight concrete of approximately 2100–2500 kg/m3, 15 to greater than 100 MPa and 1.6-1.9 W/mK (Owens, et al., 2003). The types of lightweight concrete can be classified according to method of production. These types according to Neville and Brooks (2010) are produced as follows : a) Using lightweight aggregate of low specific gravity in place of normal weight aggregate , specific gravity for lightweight aggregate is lower than 2.6. This type of concrete is well-known as lightweight aggregate concrete. b) Inducing bubble voids within the concrete or mortar mass. This type of concrete is known as aerated, cellular, foamed, or gas concrete. c) Elimination the fine aggregate from the mix so the coarse aggregate of ordinary weight is generally used. This concrete is known as no-fines concrete.

Aerated concrete is produced by introducing or generating bubbles voids within the concrete (cement matrix), the voids or cell structure having a homogeneous distribution in cement matrix when formed of voids inside the fresh cement mixture, density range from 300 to 1600 kg/m3 Fouad (2006); Neville (2000). Aerated concrete is known as foamed concrete, foamed concrete is classified in two types according to method producing i. pre-foaming method include preformed foamed (foam agent with water) and mixed with cement slurry (cement paste or mortar), ii. mixing foaming method is mixed of foam agent with cement slurry , foam will produced voids inside the concrete Gelim (2011); (Ramamurthy et al. 2009); (Byun et al. 1998). Density of foam concrete about (400 to 1600 kg/m3) depending on proportion of foam agent and water, foam concrete can be used for structural application, partition, insulation and filling grades (Ramamurthy, et al., 2009). There are two types of preformed foam wet or dry foam. Wet foam is produced by using mesh (bubbles of 2-5 mm in size) and then spraying a solution of foaming agent over a fine mesh.

Dry foam is produced by forcing the foaming agent solution through a series of high-density restrictions and simultaneously forcing compressed air into the mixing chamber.

Dry foam is extremely stable compare with wet foam (less stable) and has a size smaller than 1 mm. This makes it suitable for easier application in base materials required in producing pump able foamed concrete Sulaiman (2011); (Nambiar, et al., 2007); Aldridge (2005). Compressive strength for foam concrete decreases exponentially with a reduction in density of foam concrete (Kearsley, et al., 1996).

Polypropylene fibers are the most popular of the synthetics. They are chemically inert, hydrophobic and lightweight. Polypropylene fibers can help reduce spalling of high strength, low-permeability concrete exposed to fire in a moist condition (Kosmatka, et al., 2003). Na Ayudhya (2011) studied the compressive and splitting tensile strength of autoclaved aerated concrete (AAC) containing perlite aggregate and polypropylene fiber subjected to high temperatures. The results showed that the unheated compressive and splitting tensile strength of AAC containing PP fiber was not significantly higher than those containing no PP fiber. Furthermore, the presence of PP fiber was not more effective for residual compressive strength than splitting tensile strength. (Gencel, et al., 2011) found that the adding of PP fibers to concrete has decreased the unit weight of concrete and increased the compressive strength of concrete. Splitting tensile strength, flexural strength and modulus of elasticity have been increased by PP fiber inclusion.

2. MATERIALS

The materials used in the present work are: cement, sand, water, and foam agent. Ordinary Portland cement (OPC) type (I) from Badoosh manufacture of Iraq was used in concrete mixtures. The physical characteristics of ordinary Portland cement is showed in Table 1, whereas conformed to ASTM C150.

Table 1. Physical characteristics of cement.

Test	Results	ASTM C 150 limits
Initial setting time (minutes)	225	Not less than 45 min. Not more than 375 min.
Fineness (Blaine m^2/kg)	310	Min. 280 m^2/kg
Compressive strength of 50 mm cubic mortar specimen (MPa)		
3 days	22	Min. 12 MPa
7 days	29	Min. 19 MPa

The fine aggregate was natural river sand was supplied from the Kanhash region; the grading limit is according to ASTMC 33 as shown in Table 2. The specific gravity and fineness modulus of sand are 2.61 and 2.7, respectively. Foam agent was used to obtain lightweight foamed concrete. The type of foam agent (NEOPOR) (leycoChem LEYDE GmbH Germany) is an organic material, which has no chemical reaction but serves solely as wrapping material for the air to be induced in the concrete. The foaming agent has to be diluted in 40 parts of water before using it according to the manufacturer. Polypropylene fibers (GF) were added to the lightweight foamed concrete, the properties of polypropylene fibers are shown in Table 3.

Table 2. Grading of fine aggregate.

Sieve No. (mm)	Passing (%)	ASTM C 33 limits
No.4 (4.75)	100	95-100
No.8 (2.36)	81	80-100
No.16 (1.18)	66	50-85
No.30 (0.6)	52	25-60
No.50 (0.3)	25	5-30
No.100 (0.15)	7	0-10

Table 3. Properties of polypropylene fibers

Fibre properties	Polypropylene fibers
Fibre length	45 mm
Aspect ratio	45
Specific gravity	0.9 g/cm^3
Modulus of elasticity	6 GPa
Tensile Strength	650 MPa
Chemical Resistance	Excellent resistance to Acid Alkali
Shape	Crimped

3. MIX PROPORTION

The proportion of the mixture with was 1:2.25 (cement: sand). The amount of cement 485 kg/m^3 and water cement ratio was 0.48 with foam agent 1 kg/m^3. Initially cement and sand were mixed according to the mix proportion. Then, water was added to prepare mortar. Before adding foam agent, foam agent was diluted in 40 parts of water according to manufacturer (leyco Chem LEYDE GmbH Germany), his water is considered as a part of total water of the mix. Foam produced by using a mixer, which forming the foam according to the pre-foaming method. Lastly, the foam was added to the mortar and the flow of the batch was measured by using flow table according to ASTM C 1437 and ASTM C 230. Gradually added the polypropylene fibers to the mix. Polypropylene fibers are incorporated in different proportions of volume fraction as shown in Table 4. The mix should have a uniform dispersion of the fibers in order to prevent segregation or balling of the fibers during mixing. Most balling occurs during the fiber addition process. Increase of aspect ratio, volume percentage of fiber, and size and quantity of coarse aggregate will intensify the balling tendencies and decrease the workability Hassan (2012); Wafa, (1990).

Table 4. Volumetric fractions of polypropylene fibers*.

Mix No.	M0	M1	M2	M3	M4	M5
PPF (%)	0.0	0.1	0.2	0.3	0.4	0.5

*Percentages of polypropylene fibers taken by total volume of concrete

4. EXPERIMENTAL WORK

The moulds of 100 mm cubes were used for testing the compressive strength of lightweight foamed concrete according to BS EN 12390-3. The average of three cubes are used to determine the compressive strength. Besides, the cylinder moulds (100 mm diameter and 200 mm height) used to determine the splitting tensile strength according to ASTM C 496. The average of three cylinders used to determine the splitting tensile strength. The fresh density for all mixes measured and recorded as shown in Table 5. The dry density of hardened lightweight foamed concrete was done according to ASTM C 642.

5. RESULTS AND DISCUSSION

5.1. Flowablity

The flowability was measured according to ASTM C 1437, the flow for mixes of lightweight foamed concrete reinforced with reinforced with polypropylene fibers were varied depending on volume fraction of fibers. The flow varied between (128-119%), as shown in Figure 1. This relationship illustrates that the flowability reduces with the increase of fibers Neville and Brooks (2010). the flow was about 128% for mix M0, and flow reduced with the increase of polypropylene fibers. Thus, the use of 0.5% of polypropylene fibers reduced the flow to 119%.

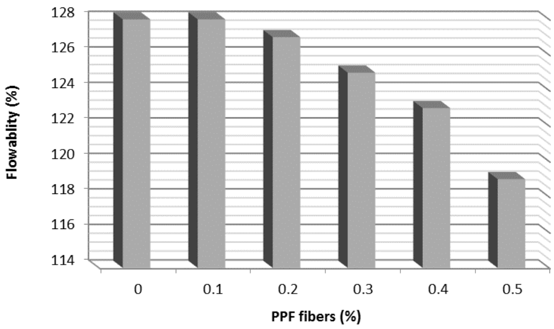

Figure 1. Effect of polypropylene fibers on the flowability of lightweight foamed concrete

5.2. Dry Density

The dry density increased with polypropylene fibers content. The dry density of reference mix (M0) was 1690 kg/m^3, and the dry density for mixes with addition 0.1%, 0.2%, 0.3%, 0.4 and 0.5% polypropylene fibers were 1690, 1695, 1700 and 1702 kg/m^3.

5.3. Compressive Strength

The compressive strength of lightweight foamed concrete incorporated with different percentage of polypropylene fibers as 0.0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5% volume fraction. Compressive strength increases with the increase of polypropylene fibers, while the compressive strength decreased at 0.5% polypropylene fibers but not less than reference mix. Fig. 2 shows the relationship between the compressive strength at age 28 days and percentage of polypropylene fibers. It can be observed 0.2% polypropylene fibers gives the highest compressive strength 21.7 MPa.

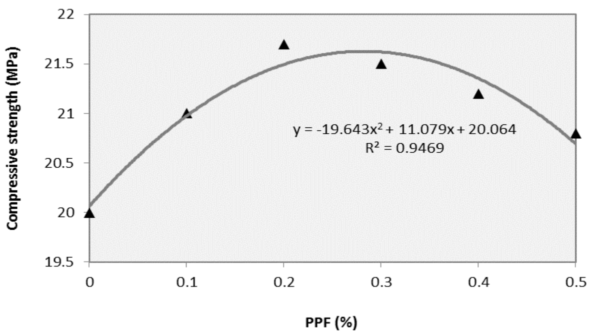

Figure 2. Relationship between the compressive strength at 28 days and percentage of polypropylene fibers

5.4. Splitting Tensile Strength

The splitting tensile strength increased with the percentage increase of polypropylene fibers. The highest splitting tensile value obtained by the maximum volume fraction of polypropylene fibers (0.5%) added to the lightweight foamed concrete. The increase of splitting tensile strength of the lightweight foamed concrete reinforced with polypropylene fibers at 28 days was up to 26% with 0.5% polypropylene fibers (M5) compared with the reference mix (M0). The incorporation of 0.1%, 0.2%, 0.3% and 0.4% polypropylene fibers increases the splitting tensile strength by about 5%, 14%, 19% and 23%, respectively, compared with reference mix (M0). Figure 3 shows the relationship between polypropylene fibers percentages with splitting tensile strength at age 28 days.

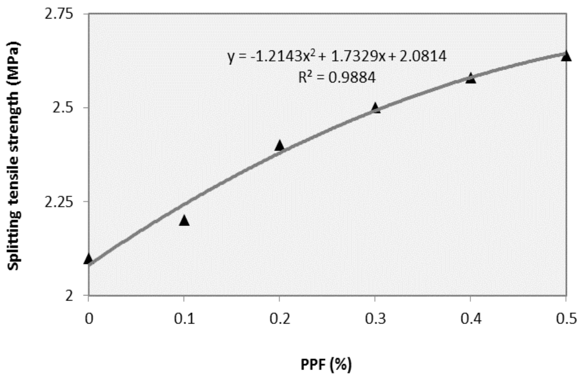

Figure 3. Relationship between percentage of polypropylene fibers with splitting tensile strength

6. CONCLUSION

From the data in this study, some conclusions can be drawn as follows:

1. The flowability of lightweight foamed concrete significantly reduces with the increase of polypropylene fibers percentages. The least value of flow is 119% with the use of 0.5% of polypropylene fibers.
2. The dry density of lightweight foamed concrete increased with addition polypropylene fibers.

3. The addition of polypropylene fibers into the lightweight foamed concrete enhanced compressive strength.

4. The splitting tensile strength of lightweight foamed concrete increased with the increase of polypropylene fibers percentages in the mixes. The highest percentage increase in splitting tensile strength was 26% for 0.5% polypropylene fibers.

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