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Research Article

Evaluation of the lightweight foamed concrete characteristics

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ABSTRACT

The purpose of this paper is to assess the properties of light weight foamed concrete. In this research, two phases are investigated. The first stage explored the characteristics of fresh and hardened foamed concrete using a foaming agent. The following parameters were employed in this study: foaming agent used as a volume of concrete mix by 10, 20, and 40%, fly ash used as a replacement of cement content by 10, 25, and 50%, and polypropylene fiber used with varied volume fractions of 0.5, 0.75, and 1.0%. Slump values are applied to evaluate the fresh properties. To evaluate the hardened concrete, the dry density and compressive strength at 7 and 28 days are computed. Furthermore, the 28-day tensile splitting strength and flexural strength are studied. The effect of a high temperature was evaluated. The second stage investigated the effects of polypropylene fiber on both fresh and hardened concrete. It was observed that foaming agents improve fresh characteristics while decreasing compressive strengths and dry density. Furthermore, utilizing fly ash improves the characteristics of both fresh and hardened foamed concrete. The fiber reduces the fresh characteristics while enhancing the toughened properties. Because of its low density, foamed concrete is being used for structural applications because of this study. Such as those utilized for thermal insulation, acoustic impedance, and fire breaks. Also used to create road foundations for roads built on soft soil.

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1. Introduction

Foam concrete is a form of cement mortar containing cement, water, and foam brought using an appropriate foaming agent. Other research's describing this material as lightweight cell concrete, low-density foam concrete, or cell lightweight concrete, and many others. In applications, it offers pleasant answers to cope with various challenges and troubles faced in construction activities Fu et al. (2020). Mainly for lowering the dead load of structures and for heat preservation, damping, sound insulation, and pore filling. The researchers found that the chemical foaming approach is more suitable for ultra-lightweight FC than mechanical foaming. Shi et al. (2019) Used ultra-lightweight expanded polystyrene foamed concrete (EFC), and its thermal insulation property was measured. It was noticed EFC thermal conductivity declines as the temperature exceeds. In addition, the precise volume of EPS particles can't only reduce the EFC thermal conductivity however also decrease the influence of temperature at the thermal conductivity. FC can be produced through addition of pre-foam into mortar to produce FC without filler or FC with filler, consisting of fly ash, quarry dust.

Habsya et al. (2018) studied the influence of foaming agent and fly ash content material at the density, thermal conductivity, compressive strength, and water absorption of lightweight Foamed Concrete (LFC). The results indicated that the increasing of foam content decreases density, thermal conductivity, and compressive strength of LFC and increases water absorption. On the other hand, the increasing of FA content decreases water absorption, but it will increase density, thermal conductivity, and compressive energy.

Kearsley and Wainwright (2001) studied the porosity and permeability of replacing a large content of cement

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up to 75% with both classified and unclassified fly ash. Porosity was mainly dependent on the dry density now not on ash content or kind, which became more for foamed concrete. The permeability increased with growing porosity and ash content material.

Gopalakrishnan et al. (2020) investigated the impact of fly ash with the aid of partially changing in cement as much as 50% and replacing river sand by quarry dust as much as 50% for diverse mixes. It has been concluded that the changing partially 30% of first-rate sand b and quarry dust mixture produced higher first-class effects in par with the conventional foam concrete.

Kanagalakshmi et al. (2015) studied the effect of quarry dirt substitute (0-50%) with sand on compressive strength of foamed concrete. The results indicated the compressive strength of foam concrete product of quarry dust extra than the control foam concrete by 43%. So that, it was proposed that burnt clay bricks can be effectively replaced with foam concrete blocks. Many types of fibers have been used to observe the properties of foamed concrete.

Regarding natural fibers and synthetic such as, polypropylene fiber, steel; Raupit et al. (2017) discovered that the addition of polypropylene fiber to the lightweight foamed concrete does affect the tensile strength of the foamed concrete. However, Atoyebi et al. (2018) studied the steel fiber content material in specimens increases the splitting tensile strength decreases. While Hazlin et al. (2017) concluded that foamed concrete added by Polypropylene fibers gave better performance in tensile strength in comparison to foamed concrete without Polypropylene fibers. This study shows the mechanical properties of foamed concrete, and the influence of elevated temperatures on it.

2. Significance of the Research

With urban growth, there is a need to identify and produce sustainable materials that aid in long-term development. The necessity of the day is for a lightweight material with a low self-weight that uses by-products or wastes. Because of its light weight, foam concrete is becoming increasingly common. Therefore, the aims of this paper are:

- To investigate the influence of different percentages fly ash on foam concrete.
- Investigate the impact of different volume fraction of polypropylene fibers on foam concrete.
- To investigate the effect of high temperature of the properties of foam concrete.

3. Experimental Program

All tests in this paper were conducted in the Civil Engineering Department's Quality Control and Strength of Testing Materials Laboratory at the Higher Institute of Engineering and Technology, Menoufia, Egypt. The following sections detailed the materials used, as well as how to prepare, cast, cure, and test testing specimens.

3.1. Materials

3.1.1. Cement

The Lafarge Cement Factory manufactured Portland cement (CEM I 42.5 N) with specific gravity 3.15 in accordance with (E.S.S.47651-1/2013) and (E.P.C 203/2018).

3.1.2. Sand

Natural siliceous sand that satisfies the Egyptian standard specifications (E.S.S.1109/2008). It is practically impurity-free, with a specific gravity of 2.6 t/m^3 and a fineness modulus of 2.61.

3.1.3. Fly ash

Class (F) fly ash with a specific gravity of 2.3 was utilized to fulfill the requirements of (ASTM C618).

3.1.4. Water

Water per binder (fly ash+ cement) ratio (w/b) was 0.30. Tap water was used for mixing the concrete conformed to the requirements of (E.P.C 203/2018).

3.1.5. Foaming agent

Foaming agent type EUCO from Swiss Chemistry Factory is chloride free. It was used to produce lightweight concrete by entraining a controlled amount of air bubbles to concrete mix. Table 1 indicates the properties of the foaming agent used throughout this investigation.

3.1.6. Fiber

Polypropylene fibers were used (Table 2, Fig. 1). The fibers accounted of the total mix volume was utilized to fulfill the requirements of (ASTM C1116).

Table 1. Properties of the foaming agent.

Appearance	liquid
Color	transparent
Specific gravity	1,01
Viscosity	6,5 MPA
Chloride content	nil
Compatibility with cement	all types of Portland cement
Shelf life	up to 2 years
Surface tension ASTM C 233	41,9 N/cm^2

Table 2. Properties of the polypropylene fibers.

Length range (mm)	(12-20)
Average diameter (µm)	20
Aspect ratio (L/d)	800
Tensile Strength (MPa)	550-600
Fiber elongation (%)	14-25%
Specific gravity (kg/m^3)	0.9
Melting point	160° C
Burning point	590° C

Fig. 1. Polypropylene fibers used in this research.

3.2. Methodology

At the beginning, the start points of choosing the proportions of foamed concrete mixes was conducted firstly based on previous research as reported by Kanagalakshmi et al. (2015), Roslan et al. (2013), and Reddy et al. (2017). The methodology for producing foam concrete (Fig. 2, Table 3) with the required characteristics varies substantially. The concrete was mixed in the following method to achieve the target density of 1500-1800 kg/m^3.

To create the foam, the foam agent was diluted 1: 30 with water weight and blended with a mixer at 500 cycles per minute for 10 minutes. On the other hand, dry materials such as cement, sand, and fly ash were mixed thoroughly then added the water to dry materials. Next, the prepared foam added to the mortar and blended the mixing uniformly. The foamed concrete was ready for pouring once the foam had been thoroughly integrated. The foamed concrete was manually placed. After 24 hours, the foamed concrete has achieved green strength and must be left to air cure before water curing can begin. This approach was employed in Reddy et al. (2017).

The conducted experimental program was divided into two stages. The first stage was performed to study the effect of using foaming agent and fly ash on the fresh and hardened concrete properties. Based on the test results of the previous stage, the best-recorded values were used in the second stage. The second stage was conducted to study the effect of using polypropylene fiber with different volume fraction in foamed concrete on the fresh and hardened concrete properties.

a) Mix of the dry components　　b) Foam generated　　c) The mix after adding foaming agent

Fig. 2. Procedures of foamed concrete mixture.

Table 3. Constituents of concrete mixes (kg/m^3).

	Sample Type	Mix no	Cement	Sand	Water	Fly ash	Polypropylene (fiber)	Foaming agent (% of mixture volume)
	0% F	C1	746.27	1119.36	335.80	0.00		0.0
	10% F	C2	671.64	1007.46	201.49	0.00		100
	20% F	C3	597.01	895.58	179.10	0.00		200
	40% F	C4	447.76	671.64	134.33	0.00		400
	10% FA + 10% F	M1	604.476	1007.46	201.49	67.16		100
	10% FA + 20% F	M2	537.309	895.58	179.10	59.70		200
Stage 1	10% FA + 40% F	M3	402.984	671.64	134.33	44.78	0.00	400
	25% FA + 10% F	M4	503.73	1007.46	201.49	167.91		100
	25% FA + 20% F	M5	447.76	895.58	179.10	149.25		200
	25% FA + 40% F	M6	335.82	671.64	134.33	111.94		400
	50% FA + 10% F	M7	335.82	1007.46	201.49	335.82		100
	50% FA + 20% F	M8	298.505	895.58	179.10	298.50		200
	50% FA + 40% F	M9	223.88	671.64	134.33	223.88		400
	0.5% PP + 25% FA + 10% F	M10	504.73	1009.5	201.89	168.25	4.50	100
Stage 2	0.75% PP + 25% FA + 10% F	M11	503.29	1006.58	201.32	167.76	6.75	100
	1.0% PP + 25% FA + 10% F	M12	501.88	1003.75	200.75	167.29	9.00	100

PP: Polypropylene fiber　FA: Fly ash　F: Foaming agent

3.3. Testing method

3.3.1. Slump test

Inverted slump test was conducted to determine the consistency of foamed concrete. This test was conducted according to ASTM C143M-03.

3.3.2. Dry density

The dry density test was determined from the dried weight (105 °C for 24 hrs). Three 50mm cubes were measured in each sample tested. The density defined as the mass of the concrete divide in its volume. The dry density it tested at age (28) days. Also, after the specimens exposed to elevated temperatures densities were calculated.

3.3.3. Compressive strength

Cube specimens of dimensions 100x100x100 mm are prepared for evaluating the compressive strength. According to ASTM C109 the compressive strength test was carried out. A 2000 KN capacity compression testing machine is used. Average compressive strength was obtained based on three cubic specimens.

3.3.4. Splitting tensile strength

Cylindrical concrete specimens, 100 mm in diameter and 300 mm in high, are prepared to evaluate the splitting tensile strength. Indirect tension test (splitting method) is performed to determine the tensile strength of concrete mixes. ASTM C39 was used to conduct the splitting tensile strength. A 2000 KN capacity compression testing machine is used.

3.3.5. Flexural strength

This test method evaluates the flexural strength obtained by a testing simply supported beam (prism) under four - point loading at universal testing machine according to ASTM C78.

3.3.6. Elevated temperature and testing methodology

Throughout this investigation, three specimens representing the same ingredient are utilized for each test, and the average values are presented.

The compressive strength of an unheated control specimen is measured after 28 days; the other specimens are heated to target temperature in an electric furnace with a capacity of 1200 °C, as shown in Fig. 3, at a heating rate of 10 °C/min. There are two target temperatures: 200 °C and 400 °C. For 1.5 hours, the specimens are held at each temperature. The specimens are allowed to cool for 24 hours at laboratory room temperature after being subjected to the required temperature before being evaluated to assess residual strength after 1 day. On a dry surface, the specimens are assessed. For each test data point, three data points were gathered.

Fig. 3. Electric furnace used in this research.

4. Results and Discussions

The characteristics of Foamed Concrete were studied using various parameters. The outcomes of the experimental program are described in detail in the following sections.

4.1. Consistency of the foamed concrete

Fig. 4 shows the results of slump tests performed using foaming agents. The figure also demonstrates the relation between the slump and the amount of foaming agent used (as a ratio of volume concrete mixture). The results demonstrated that as the foamy agent dose increased, the slump values increased when compared to the control mix with 0.0% foaming agent. The workability of foaming agent and fly ash mixtures increased as the foaming agent increased. For example, for 10%, 20%, and 40% foaming agent, the slump results were 100, 140, and 200 mm, respectively.

Furthermore, it demonstrates that when the fly ash concentration increases, the workability of concrete decreases, which may be ascribed to the higher particle surface of fine fly ash compared to cement as described by Othman et al. (2021).

Fig. 5 shows the results of slump tests conducted using polypropylene fibers. The figure also illustrates the relationship between slump and fiber percentage (volume fraction). When compared to a control mix of 25% fly ash and 10% foaming agent, the slump values reduced as fiber increased. Slump findings demonstrate that fibers with 0.5, 0.75, and 1.0% V_f have 115, 80, and 30 mm, respectively. The decrease in slump because of polypropylene fiber tend to absorb water which lead to, the weakening of resistance between the structures of the mix and contraction of the free water amount, that explains the decrease of slump diameter consistently to the presence of polypropylene fiber Mydin et al. (2023).

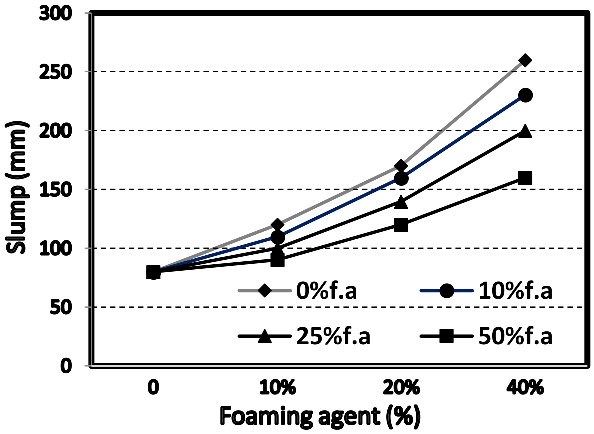

Fig. 4. Slump values of foamed concrete due to foaming agent.

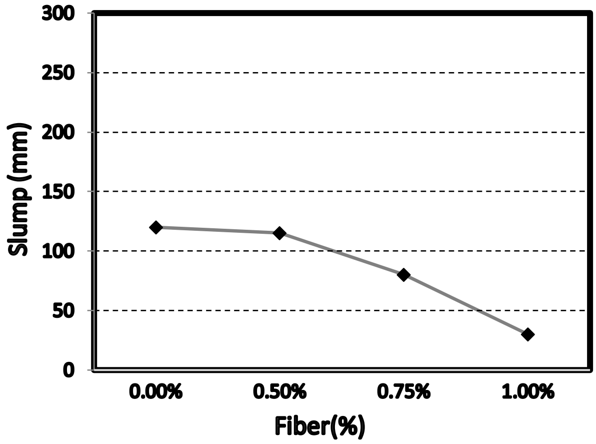

Fig. 5. Slump values of foamed concrete due to polypropylene fibers.

4.2. Dry density of the foamed concrete

The dry density has been investigated, as seen in Fig. 6. The density of the mixes with foaming agent was somewhat greater than the density of the fly ash mixtures. The result indicated that for mixes with foaming agent only, the densities declined when compared to the control mix with 100% cement. The lowest dry density was 1600 kg/m^3 for the mix with 40% foaming agent.

The similar pattern was seen in mixes with fly ash replacement with cement. The lowest dry density was 1565 kg/m^3 for mix-9, followed by 1570 kg/m^3 for mix-6, and 1585 kg/m^3 for mix-3. Because cement has a higher specific gravity than fly ash, the density of mixtures including fly ash is lower. The density of foamed concrete, according to Nambiar and Ramamurthy (2006), is dependent on the filler type, such as fly ash, which has a low specific gravity compared to fine sand. Similarly it was reported by Gencel et al. (2022) and Krishna et al. (2021) the dry density decreased as the volume of foam and the weight of fly ash increased.

The effect of fiber on dry density has been explored in Fig. 7. The density of the mix with 0.50% V_f of fiber was rather greater than the density of the control mixes without fiber (25% fly ash + 10% foam). Moreover, when the fiber content increased, the dry density reduced. The lowest dry density for 1.0% V_f fiber was 1748 kg/m^3, followed by 1750 kg/m^3 for 0.75% V_f, and 1760 kg/m^3 for 0.5% V_f.

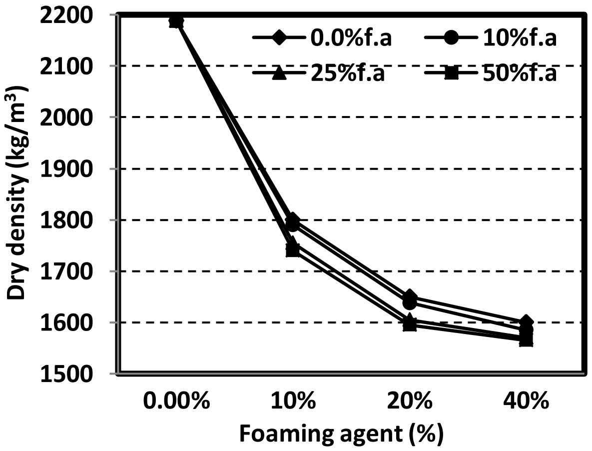

Fig. 6. Relation between foaming agent and dry density.

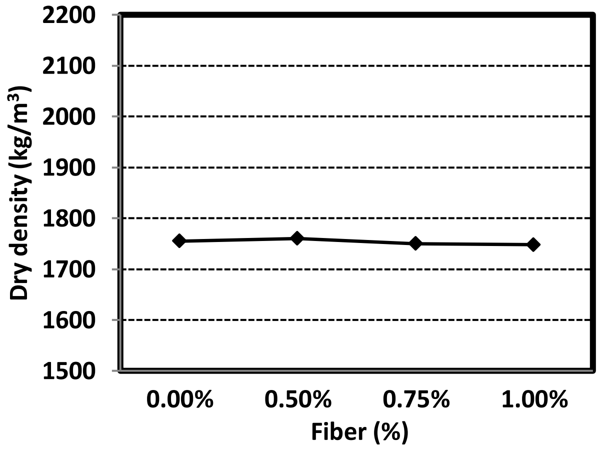

Fig. 7. Relation between fiber and dry density.

4.3. Compressive strength of the foamed concrete

Figs. 8-11 show the findings of the mechanical properties evaluated. Figs. 8 and 9 illustrate the relationship between foaming agent dose and compressive strength values for mortars with 0.0, 10, 25, and 50% fly ash replacement with cement after 7 and 28 days. The figures revealed that when the foaming agent was increased, the compressive strength decreased compared to the control mix for the mix without fly ash. However, when comparing the fly ash-containing mixtures, at all the foaming agent doses were more than the control mixture. Gopalakrishnan et al. (2020) achieved comparable findings. At test ages of 7 and 28 days, the optimum compressive strength for mix with a foaming agent only achieved at 10% foaming agent which was less than the control mix by 36%. Consequently, when the fly ash content increased, the compressive strength increased. The compressive strength, increased up to 25 % fly ash then decreased compared to control mix. At 7 and 28 days, the ultimate compressive strength of mixes containing 25, 10, and 50% fly ash was 45, 34.5, and 29% greater than the control mix. The increase in compressive strength owing to CSH production is connected to the constant reduction of pore size and the reduction of calcium hydroxide (CH) crystals, both of which have a damaging effect on the binding between the cement paste and aggregates.

Figs. 10 and 11 indicate the relationship between fiber % and compressive strength after 7 and 28 days, respectively. The analysis indicated that as the fiber density increased, the compressive strength reduced in comparison to the control mix. For 0.5, 0.75, and 1.0% V_f, the reduction was 20.67, 32.5, and 42.17%, respectively. The decrease in compressive strength was due to the addition of polypropylene fiber, especially at 0.75 and 1.00% V_f. The addition of fiber produces additional pores and voids, resulting in a weak connection between pore, void, and matrix as mentioned by Roslan et al. (2013). This is agreed with Falliano et al. (2019) that concluded the effect of fiber on compressive strength can be neglected specifically on dry density lower than 400 kg/m^3. This is because the compressive strength is influenced by the volume of produced air provided by the foam (air/cement ratio), which is not affected to normal-weight concrete but of interest in light weight concrete. Modes of failure under compression loads are presented in Fig. 12.

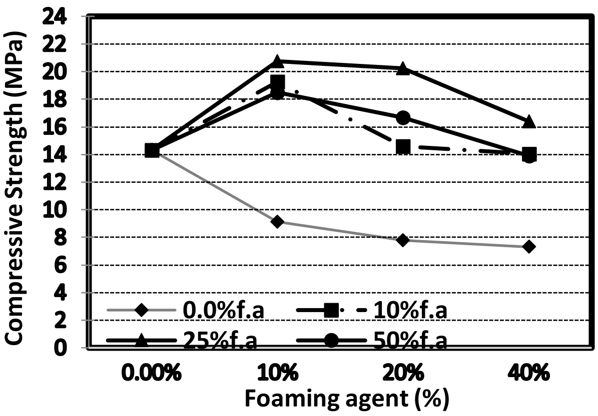

Fig. 8. Compressive strength values at 7 days of foaming concrete due to foaming agent and fly ash.

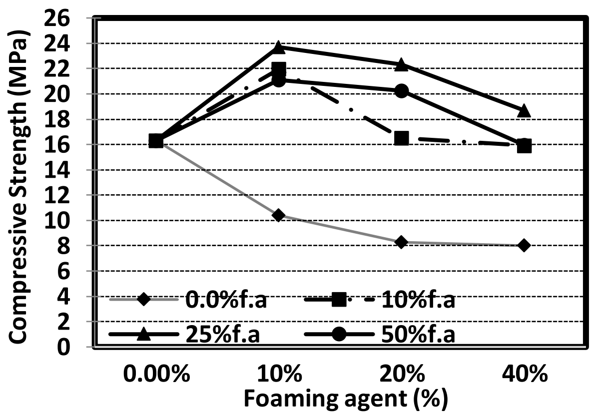

Fig. 9. Compressive strength values at 28 days of foaming concrete due to foaming agent and fly ash.

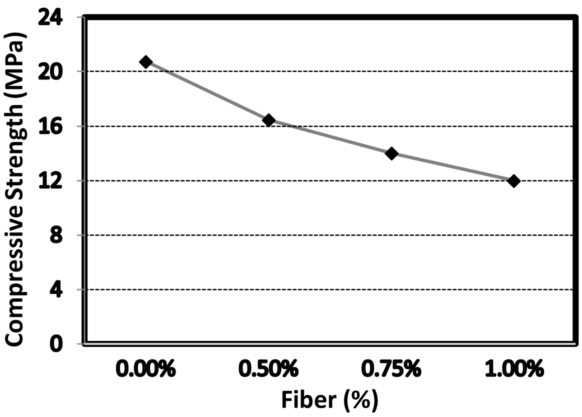

Fig. 10. Compressive strength values at 7 days of foaming concrete due to PP fiber.

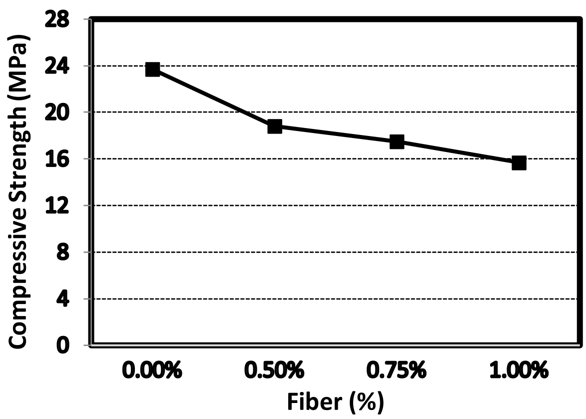

Fig. 11. Compressive strength values at 28 days of foaming concrete due to PP fiber.

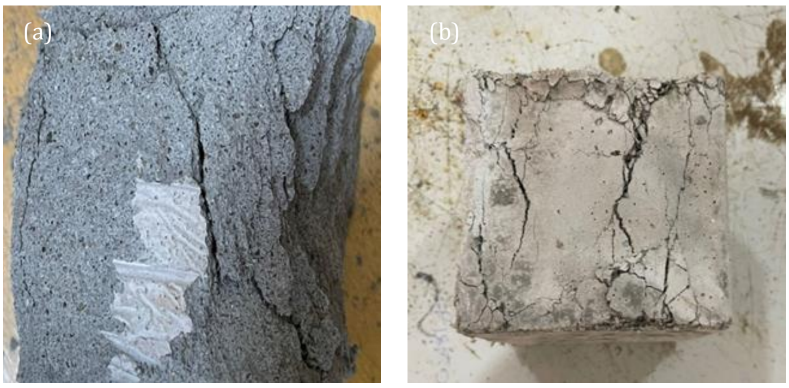

Fig. 12. Modes of failure under compression loads: (a) Normal LFC; (b) LFC with PP fiber.

4.4. Split tensile strength of the foamed concrete

Fig. 13 shows the relationship between the foaming agent dosage and the tensile splitting strength for mortars at 0.0, 10, 25, and 50% fly ash replacement with cement at 28 days. The splitting tensile strength gives the same trend as compressive strength. From Fig. 13, for mix without fly ash as the foaming agent increased the splitting tensile strength decreased compared to control mix. The maximum tensile splitting strength at 28 days obtained at foaming agent dosage equal to 10% of volume mixture.

For the mixes with fly ash the tensile strength increased as the fly increased up to 25 % fly ash then decreased compared to control mix. The maximum tensile strength recorded at 10% foaming agent. For mixes with 10, 25, 50 % fly ash replacement with cement, which, increment by 12.5, 14.4, and 10% respectively compared with control mix. On the other hand, mixes with 25, and 50% fly ash recorded increment by 12.5, and 8.75 % at 20% foaming agent, and increment by 6.25% at 40 % foaming agent compared to control mix. While mixes with 10% fly ash show decrement in strength by 0.0, and 6.25% at 20, and 40 % foaming agent compared to control mix.

The spitting tensile strength of foamed concrete due to fiber is presented in Fig. 14. It can be seen the mixes with fibers improved the tensile strength compared to control mix. The maximum tensile strength recorded is at 0.50% V_f of fiber. The increment by 57, 20, 9% at 0.50, 0.75, and 1.00% V_f of fiber respectively compared to control mix. The increase occurs due to the increasing density and decreasing foam volume Hazlin et al. (2017).

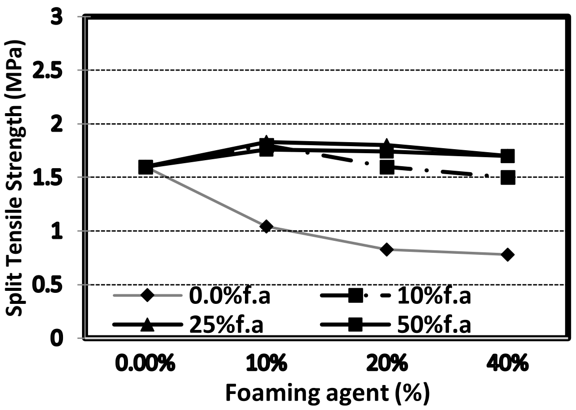

Fig. 13. Splitting tensile strength values at 28 days for foamed concrete due to foaming agent and fly ash.

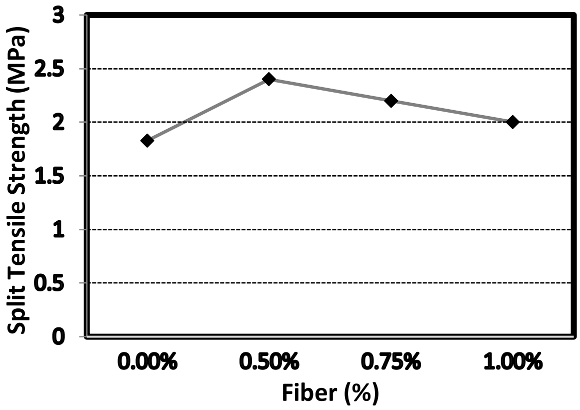

Fig. 14. Splitting tensile strength values at 28 days for foamed concrete due fiber.

4.5. Flexural strength of the foamed concrete

The relationship between the foaming agent dose and the flexural strength for mortars at 0.0, 10, 25, and 50% fly ash replacement with cement at 28 days is shown in Fig. 15. The figure shows that the flexural strength of the mix without fly ash decreased as the foaming agent increased when compared to the control mix. Flexural strength decreased by 37, 49.6, and 49.75% for mixes containing 10, 20, and 40% foaming agent, respectively, as compared to the control mix. Furthermore, for mixes including fly ash, the flexural strength dropped as the foaming agent increased. The greatest flexural strength was observed at 10% foaming agent in mixes with 10, 25, and 50% fly ash substitution with cement.

Fig. 16 displays the flexural strength of foamed concrete owing to fiber. The mixtures with 0.75% and 0.50% V_f of fibers had slightly higher flexural strength than the control mix without fiber. Then it fell to 1.00% V_f of fiber. The increase was 2.1, 3.25, and -3.56% for 0.50, 0.75, and 1.00% V_f of fiber, respectively, as compared to the control mix.

The increasing of fiber increased flexural strength this corresponds to the increasing in density. This is because the solid phase is higher (the porosity is lower) for that higher density for volume size of specimens. So that, the fibers collaborate with cementitious matrix in a more effective manner and contribute to the overall strength more significantly Falliano et al. (2019). It can be drawn that the presence of fiber acts as a reinforcing tissue to bind the matrix of composite material firmly compared to the specimen without any fiber applied in the tensile zone as reported by Roslan et al. (2013) and Serudin et al. (2019). The use of fiber not only reduced the strength of the foamed concrete, but also demonstrated ductile behavior and prevented the specimen from being split into two sections. Fig. 17 represents the mode of failure due to fiber in foamed concrete.

4.6. Effect of elevated temperature on the foamed concrete

Fig. 18 displayed the calculated compressive strength of foamed concrete after 1.5 hours of exposure to 200 and 400 °C due to foaming agent and fly ash. As the exposure temperature increased, the compressive strength of foamed concrete deteriorated. According to Fig. 18 the compressive strength after exposure to 200 and 400°C for the mixes contain (10-40%) foaming agent are lower than that of control mix at the same temperature. From results, the reduction in compressive strength of its original at 200 °C by 27.9, 18.1, 10% and at 400°C by 32.7, 39.8, and 15 % for 10, 20, and 40% foaming agent respectively. This is due to the dehydration of CH into calcium oxide causes the paste to shrink and fracture after being exposed to increased temperatures of 200 °C and higher. As calcium oxide rehydrates, it expands and cracks, causing more disintegration.

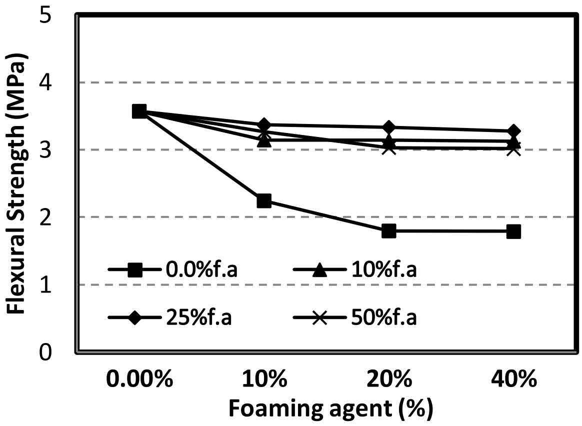

Fig. 15. Flexural strength values at 28 days for foamed concrete due to foaming agent and fly ash.

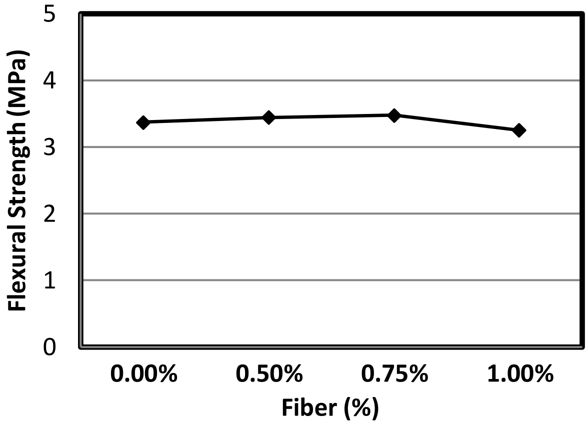

Fig. 16. Flexural strength values at 28 days for foamed concrete due to fibers.

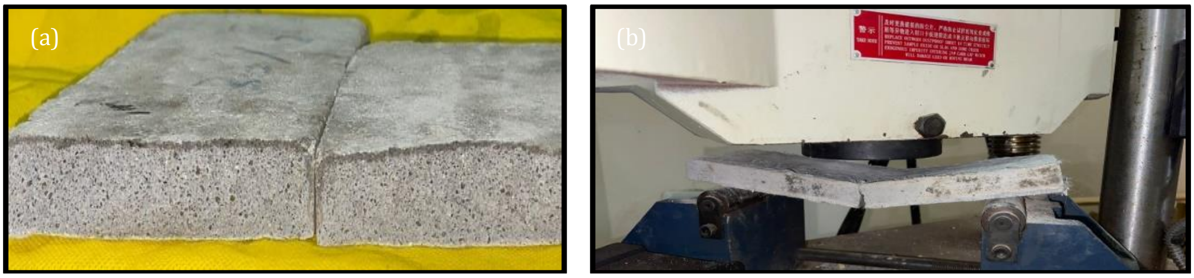

Fig. 17. Modes of failure under flexural load: (a) Normal LFC; (b) LFC with PP fiber.

The compressive strength after exposure to 200 and 400 °C for the mixes contain fly ash replacement with cement by (10, 25, and 50%) are higher than that of control mix at the same temperature. The minimum reduction in compressive strength of its value at 10 % fly ash, while the maximum reduction in compressive strength of its value recorded for mixes with 50% fly ash. The reduction by 20.4, 27.7, and 13.5% for 10, 20, and 40% foaming agent respectively.

Fly ash increases the strengths of concrete against high temperature due to the formation of tobermorite that is a product of lime and FA at high pressure and temperature which is about two to three times stronger than the CSH gel Soleimanzadeh et al. (2013)

Fig. 19 illustrates the compressive strength after exposure to 200 and 400 °C due to fibers. It can be concluded as temperature increased the compressive strength decreased for mixes with fiber compared with control mix with no fiber. The lowest residual compressive strength recorded for mix with 0.75 % V_f fiber followed by 0.5% V_f then 1.0% V_f, when the temperature reached 200 °C and 400 °C. The increase of fiber ratio caused a decrease in the strength after high temperature. This is due to after temperature increased melting of Polypropylene fiber at (160 °C) increases since, the void structure and deterioration of the internal structure causes the strength decreased Kaya and Köksal (2021), and Dawood et al. (2019). While Karahan et al. (2019) reported that the influence of Polypropylene fiber addition in mortar after elevated temperature showed that better behavior at 200 °C and 400 °C for any cooling method. Furthermore, at 600 °C and 800 °C, mortar with polypropylene fiber had behavior like to control mortar.

5. Conclusions

Based on the results and discussion presented in this paper, the following conclusions could be drawn as follow:

- Increasing the foaming agent dosage improved foam concrete workability while increasing the fly ash and fiber dosages decreased workability.
- The use of a foaming agent, fly ash, and fiber reduced the density of the mixes. This would stimulate the use of foamed concrete in projects with low density characteristics.
- It is possible to produce lightweight foamed concrete with densities ranging from 1550 to 1800 kg/m^3.
- Using foaming agent decreased the compressive strength. The optimum value for foaming agent is 10%, where the compressive strength at 28 days and dry density were 10.4 MPa and 1800 kg/m3, respectively.
- Using fly ash for the foamed concrete with 10% foaming agent improved the strength of the mix. The highest compressive strength and dry density were 23.7 MPa and 1755 kg/m^3, respectively at 25% of fly ash as a replacement of cement content as an optimum value.
- Using polypropylene fiber for the foamed concrete with 10% foaming agent and 25% fly ash as a replacement of cement content reduced the compressive strength. The maximum compressive strength and dry density were 18.8 MPa and 1760 kg/m^3 at 0.50% V_f of fiber as an optimum value.
- Using foaming agent dosage decreased the split tensile strength, the optimum tensile strength for foamed concrete was 1.04 MPa at 10% foaming agent as an optimum value. On the other hand, using of the fly ash

and fiber in foamed concrete developed the tensile strength. The optimum tensile strength was 1.83 and 2.4 MPa at 25% fly ash and 0.5% V_f respectively as an optimum value.

- Using foaming agent and fly ash in foamed concrete reduced the flexural strength. While, using fiber developed the flexural strength and mode of failure. The maximum flexural strength was 3.48 MPa at 0.75% V_f as an optimum value.
- In terms of residual strength, the performance of foamed concrete at increased temperatures up to 400 °C was quite efficient. The minimal drop in compressive strength of its original is 40% for mixes including 10% foaming agent, 25% of fly ash as a replacement of cement, and 0.75% volume fraction of polypropylene fiber. This would promote the usage of foamed concrete as an insulating material.
- Foamed concrete is being used for structural applications because of this study. Such as those utilized for thermal insulation, acoustic impedance, and fire breaks. Also used to create road foundations for roads built on soft soil.

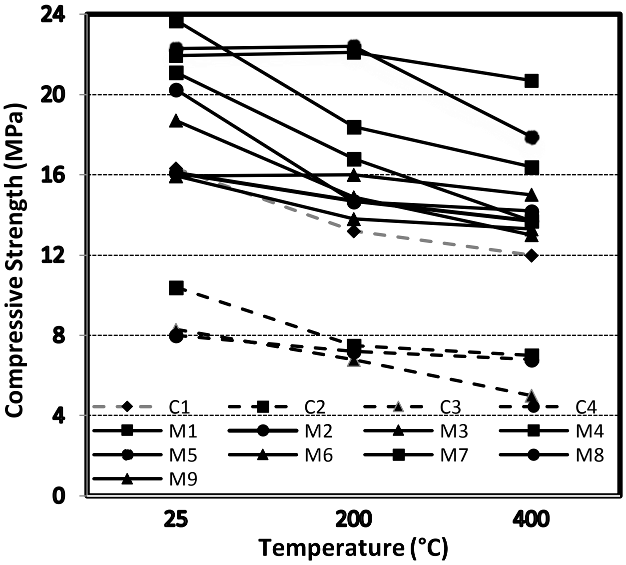

Fig. 18. Compressive strength at elevated temperature due to foaming agent and fly ash.

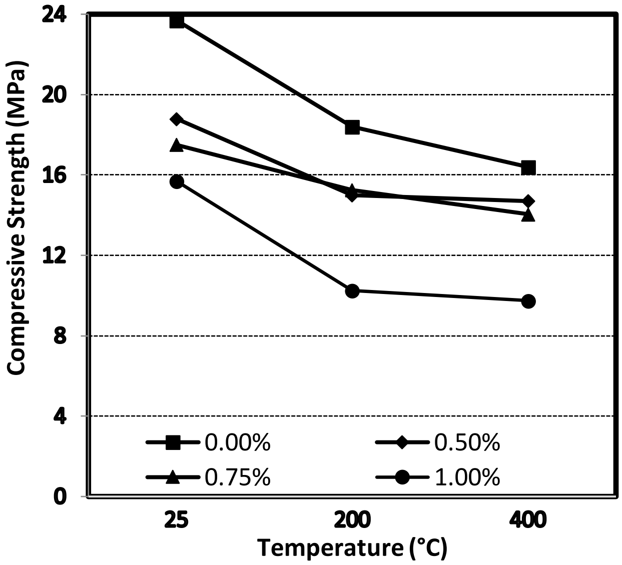

Fig. 19. Compressive strength at elevated temperature due to fibers.

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