Effect of glass fibers on mechanical properties of structural lightweight foamed concrete(SLFC)

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Abstract

Lightweight foamed concrete exhibits many advantages and excellent features comprising more efficient strength-to-weight ratio in structural elements, high strength, reduced dead load, decrease foundation loads, energy saving, waste consuming, temperature conservation, and noise insulation. This work was prepared to investigate the effect of glass fibers on mechanical properties of structural lightweight foamed concrete (SLFC), Foam agent (organic material) was used to produce SLFC using different mix proportions to obtain structural compressive strength and high workability with slightest fresh density. Five mixes of SLFC with Superplasticizer is experimentally studied, also five mixes without Superplasticizer were tested. The compressive strength, flexural strength, ultrasonic pulse velocity (UPV), workability (flowability) and density were measured. Superplasticizer used in some mixes was 1% by weight of cement. Glass fibers were added in different volume fraction for SLFC and SLFC with superplasticizer. The volume fractions of the glass fibers used are: 0.06, 0.2, 0.4, and 0.6 % total volume. The results of SLFC mixes showed that the increase of glass fibers content can produce foam concrete with enhanced mechanical properties. For all percentages of glass fibers in the mixes it increases in compressive strength and flexural strength. But the increase in compressive strength was 51% for 0.6% glass fibers. Also the flexural strength increased 19.2% for 0.6% glass fibers. The compressive and flexural strength increased with the increase of glass fibers with acceptable range of workability.

Keywords: Structural lightweight foamed concrete (SLFC); Lightweight concrete; foamed concrete; Glass fibers; Mechanical properties.

تأثير اضافة الالياف الزجاجية على الخصائص الميكانيكية للخرسانة الرغوية الخفيفة الوزن الانشائية

الخلاصة:

الخرسانة الرغوية الخفيفة الوزن لها العديد من الايجابيات والخصائص والتي تتضمن: مقاومة عالية مقارنة بوزن العنصر الانشائي و تقلل من الحمل الميت و تقليل الاحمال على الاسس و استخدام المخلفات و هي عازلة للحرارة

والصوت. ان هذا البحث يهدف الى دراسة تأثير الالياف الزجاجية على الخصائص الميكانيكية للخرسانة الرغوية الخفيفة الوزن الانشائية. استعمل العامل الرغوي للحصول على خرسانة رغوية الخفيفة الوزن الانشائية، حيث تم عمل عدة نسب خلط للوصول او الحصول على مقاومة انضغاط انشائية مع قابلية تشغيل عالية وبأقل كثافة. خمس نسب خلط للخرسانة الرغوية الخفيفة الوزن الانشائية مع الملدن المتفوق وخمس نسب خلط اخرى للخرسانة الرغوية الخفيفة الوزن الانشائية بدون الملدن المتفوق ، كل هذه الخلطات اجريت عليها فحص مقاومة الانضغاط وفحص مقاومة الانحناء و فحص سرعة الموجات فوق الصوتية وقياس قابلية التشغيل والكثافة. استخدم الملدن الفائق بنسبة ١% من وزن السمنت. كانت نسبة الالياف الزجاجية المضافة للخرسانة الرغوية الخفيفة الوزن الانشائية مع الملدن الفائق و الخرسانة الرغوية الخفيفة الوزن الانشائية بدون الملدن الفائق هي ٠,٠٦ و ٠,٢ و ٠,٤ و ٠,٦% من الحجم الكلي للخرسانة. النتائج اوضحت ان اضافة الالياف الزجاجية للخرسانة الرغوية الخفيفة الوزن الانشائية يحسن من مقاومة الانضغاط بنسبة ٥١% بنسبة الياف زجاجية ٠,٦% مقارنة مع الخلطة التي بدون الياف زجاجية. كذلك بالنسبة لمقاومة الانحناء تحسنت بنسبة ١٩,٢% عند اضافة ٠,٦% من الالياف الزجاجية. وكذلك بالنسبة لباقي نسب الخلط حيث ان مقاومة الانضغاط والانحناء لكل النسب ازدادت بزيادة نسبة الالياف الزجاجية اي ان اضافة الالياف الزجاجية الى الخرسانة الرغوية الخفيفة الوزن الانشائية سوف يحسن من مقاومة الانضغاط ومقاومة الانحناء مع الحفاظ على قابلية التشغيل.

الكلمات الدالة: الخرسانة الرغوية الخفيفة الوزن الانشائية ، الخرسانة الخفيفة الوزن ، الخرسانة الرغوية ، الالياف الزجاجية ، الخصائص الميكانيكية.

1. Introduction

Lightweight concrete is widely used for modern construction as it is mortar less and can be produced with different densities. Lightweight concrete also known as aerated, cellular lightweight concrete, or foam concrete (Kamarulzaman, 2010) [1]. Lightweight concretes have an oven-dry density varies from 300 kg/m^3 to 2000 kg/m^3, with compressive strength for cube may reach to more than 60 MPa (Owens et al., 2003)[2]. Recently, with the rapid development in the construction, the lightweight concrete has been used for structural purpose and many applications for modern construction. The advantages of lightweight concrete are high strength/weight ratio, good tensile strain capacity, low coefficient of thermal expansion due to the voids, thermal insulation, increased fire resistance over ordinary concrete, improved durability properties, smaller cross-sections in load-bearing elements and reduction in the size of foundations. The applications of lightweight concrete are tall buildings, long span structure, the requirements for high performance are higher strength and higher toughness (Libre et al., 2011)[3]. Structural lightweight concrete have bulk density lower than 1950 kg/m^3 with compressive strength more than 17 MPa, such concrete can be produced with 25% lighter than normal-weight concrete with a compressive strength up to 60 MPa (Li, Z., 2010)[4]. 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 varies from 300 to 1600 kg/m^3 (Fouad, 2006)[5]. Aerated concrete is known as foamed concrete. Foamed concrete is classified in two types according to the 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 produce voids inside the concrete (Ramamurthy et al., 2009)[6]. Density of foam concrete depend on proportion of foam agent and water (Ramamurthy et al., 2009)[6]. The compressive strength of foam concrete is just about 1 to 60 Mpa compare to normal concrete which achieved 100Mpa in compressive strength (Zahari, 2009)[7]. Foam concrete can be used for structural application, partition, insulation and filling grades (Ramamurthy et al., 2009)[6].

Concrete is considerable as brittle material, which results in poor fracture toughness, poor resistance to crack propagation, and low impact strength. This inherent brittleness has limited their application in fields requiring high impact, vibration and fracture strengths Therefore, to improve the mechanical properties of concrete, fibers can be used. Fibers are used to modify the tensile and flexural strengths, toughness, impact resistance, fracture energy, arrest crack formation and propagation, and thus improve strength and ductility (Dawood and Ramli, 2011)[8].

Glass Fibers is one type of fiber reinforced concrete, the main applications used in exterior building facade panels and as architectural precast concrete. The fibers glass is less dense than steel thus is very good in making fair face in front of any building (Abdullah and Jallo, 2012)[9]. Glass fibers improve the strength of the material by increasing the force required for deformation and enhance the toughness by increasing the energy required for crack propagation (Chandramouli et al., 2010)[10]. The glass fibers when added to the mix would enhance the mechanical properties, flexural strength, compressive strength, tensile strength and young modulus of the materials (Abdullah and Jallo, 2012)[9]. However, the use of glass fibers decreases the workability of fresh concrete and this effect is more prominent for fibers with higher aspect ratios (Chandramouli et al., 2010)[10].

Therefore, this paper was conducted to produce structural lightweight foam concrete with structural compressive strength, high workability (flowability), and acceptable range of density. Adding glass fibers to structural lightweight foam concrete with different ratio to study the effect of glass fibers on compressive strength, flexural strength, ultrasonic pulse velocity, workability and density.

2. Materials and mix proportions

2.1. Materials

2.1.1. Cement: ordinary Portland cement type I from Badoosh manufacture in Nineveh Governorate of Iraq was used in this study, the physical characteristics according to IQS : 5/1984[11] are shown in Table 1, the chemical compositions of cement according to IQS : 5/1984[11] are shown in Table 2.

2.1.2. Fine aggregates (Sand): sand used in this study was natural sand supplied from Kanhash region (Mosul). The specific gravity of sand 2.63 and fineness modulus is 2.69. The grading limits according to ASTM C33[12] are given in Table 3.

2.1.3. Water: Potable water was used in this study.

2.1.4. Foam agent: was used to obtain structural lightweight foam 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 manufacturer.

2.1.5. Glass fibers: were used in the lightweight foam concrete, the properties of the glass fibers are listed in Table 4 and Figure 1. Different volume fractions of glass fibers are used as given in Table 5.

2.1.6. Superplasticizer: a high Range Water Reducing based on naphthalene sulphonate (RHEOBUILD® 181 K) (BASF the chemical company) was used in this study. The technical data of High Range Water Reducing based on naphthalene sulphonate shown in Table 6.

Table 1.
Physical characteristics of ordinary Portland cement.

Test	result	IQS : 5/1984
Initial setting time (minute)	210	Min. 45 minute
Final setting time (minute)	330	Max. 600 minute
Fineness (Blain m^2/kg)	263	Min. 230 (m^2/kg)

Table 2.

Chemical properties of ordinary Portland cement.

Constituent	Component of OPC (%)	Limits of IQS : 5/1984
SiO_2	21.31	…
Al_2O_3	5.89	…
Fe_2O_3	2.67	…
CaO	62.2	…
MgO	3.62	$\leq$ 5%
SO_3	2.6	$\leq$ 2.8%
Loss of ignition	1.59	$\leq$ 4%
Insoluble residue	0.24	$\leq$ 0.75%
Free CaO	1.74	…
L.S.F.	0.8818	…
C_3S	33.37	…
C_2S	35.92	…
C_3A	11.09	…
C_4AF	8.12	…

Table 3.

Grading of fine aggregates.

Sieve No. (mm)	Passing (%)	Limits of ASTM C 33
No.4 (4.75)	100	95-100
No.8 (2.36)	80.96	80-100
No.16 (1.18)	66.33	50-85
No.30 (0.6)	51.5	25-60
No.60 (0.3)	24.65	5-30
No.100 (0.15)	7.26	0-10

Table 4.

Properties of glass fibers.

Fiber properties	Quantity
Fiber length	1.2 cm.
Aspect ratio	24
Specific gravity	2.68 g/cm^3
Modulus of elasticity	72 GPa
Tensile Strength	1,700 MPa
Chemical Resistance	Very high
Electrical Conductivity	Very low
Softening point	860 °C
Material	Alkali Resistant Glass

Table 5.

The volume fraction of glass fibers and Superplasticizer in lightweight concrete mixes.

Mix no.	N0	N1	N2	N3	N4	N5	N6	N7	N8	N9
Glass fiber ratio* (%)	0.0	0.06	0.2	0.4	0.6	0.0	0.06	0.2	0.4	0.6
Superplasticizer# (%)	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1

* Percentages of glass fibers taken by total volume of concrete.
# Percentages of Superplasticizer taken by weight of cement.

Table 6.

Technical date of High Range Water Reducing based on naphthalene sulphonate.

Technical data	
Structure of the materials	Napthalene Sulphonate Based
Color	Brown
Density	1.153-1.213 kg/liter
Chloride content %(EN 480-10)	< 0.1
Alkaline content %(EN 480-12)	< 10

Figure 1: Micro glass fiber.

2.2 Mix proportions

The mix proportion used in this study was 1:2.25 cement and sand respectively with water cement ratio w/c=0.4 for mixes with superplasticizer and w/c =0.49 for mixes without superplasticizer. The foam agent used was 1 kg/m^3 see Table 7. The procedure of mixing is achieved by blending the cement with sand according to the mix proportion and then the water was added to prepare the mortar. After that, the foam was added to the mortar to obtain lightweight foamed concrete. It should be mentioned that the preparation of the foam is done using the foam agent which is diluted in 40 parts of water according to manufacturer. This is calculated as a part of the total water of the mix shown in Table 7. When the foam added to the mortar, the foam should be blended to make homogeneous mixture. Glass fibers are incorporated in different proportions of volume fraction as shown in Table 5. Finely, Gradually added the glass fibers to the mix (foamed concrete). 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)[13]. Superplasticizer used in the mix as 1% from weight of cement as shown in Table 5. Each mix proportion was measured in term of flow according to ASTM C 1437[14] and ASTM C 230[15].

Table 7.

Mix proportions.

Series	Mix No.	Mix proportion	Glass fibers (kg/m³)	w/c	Cement (kg/m³)	Sand (kg/m³)	Water (kg/m³)	Foam agent (kg/m³)	Theoretical density (kg/m³)	Flow (%)
Series I	N0	(1 : 2.25) (cement : sand)	0.0	0.49	481.2	1082.7	235.8	1	1799.6	130
	N1		1.6	0.49	484.8	1090.8	237.5	1	1813.1	125
	N2		5.4	0.49	488.4	1098.9	239.3	1	1826.6	120
	N3		11	0.49	490.2	1103.0	240.2	1	1833.4	113
	N4		16	0.49	493.2	1109.7	241.6	1	1844.5	95
Series II	N5		0.0	0.4	510.6	1148.9	204.2	1	1863.7	118
	N6		1.6	0.4	517.6	1164.7	207.0	1	1889.3	114
	N7		5.4	0.4	521.4	1173.2	208.5	1	1903.1	107
	N8		11	0.4	522.7	1176.1	209.0	1	1907.8	92
	N9		16	0.4	523.3	1177.5	209.3	1	1910.1	84

3. Experimental work

Test specimens of 50×50×50 mm^3 cubes were used for testing the compressive strength of lightweight concrete according to ASTM C 109[16] as shown in Figure 2. The average of three cubes was used to determine the compressive strength for each age (7 and 28 days) of test. The prisms of 40×40×160 mm^3 were used to determine the flexural strength according to ASTM C 348[17] as shown in Figure 3. The average of three prisms was used to determine the flexural strength. In the laboratory the foam produced by using a mixer, which forming the foam according to the pre-foaming method, adding the preformed foam to a base mix (cement, sand, and water). The structural lightweight foamed concrete mixture was divided into two series: series I, used fibers glass only, and series II, used fibers glass and superplasticizer as shown in Table 8. The fresh density was measured by using container of known weight and volume. The specimens were stripped approximately 24 h after casting and placed in water using a water tank as a normal water curing method with a controlled temperature of 23 ºC ± 2 ºC according to ASTM C 192[18]. Each mix was tested in the compressive strength and flexural strength at ages (7 and 28 days) according to ASTM C109[16] and ASTM 348[17] respectively. The ultrasonic pulse velocity (UPV) test was performed on cube of structural lightweight foamed concrete for all mixes, the ultrasonic tester PUNDIT (Portable Ultrasonic Non-destructive Digital Indicating Tester) used to measure the ultrasonic pulse velocity Figure 4 (a), direct transmission manner was used in this test as shown in Figure 4 (b), The oven dry density and voids were determined using 100 mm cubes according to ASTM C 642[18] for each mix.

Figure 2: **a)** Compressive strength test machine. **b)** Test specimens 50×50×50 mm^3. cubes. **c)** Specimen inside the testing machine.

Figure 3: Flexural strength test machine and specimen inside the testing machin

Figure 4: a) Ultrasonic tester (PUNDIT). **b)** Direct transmission manner of ultrasonic pulse velocity test.

4. Results and discussion

4.1. Workability

The workability (flow) was measured according to ASTM C 1437[14], the flow for foamed concrete reinforced with glass fibers varied among mixes depending on volume fraction of glass fiber, the flow of mixes given in Table 7. The flow varied between (130-84%), the flow was about 130% for mix N0 (series I), and flow reduced with the increase of glass fibers. Thus, the use of 0.6% of glass fibers reduced the flow to 95%. Regression analysis was used in all figures to obtain the equation. Regression analysis was used to show the relationship between glass fibers and workability of foamed concrete as shown in Figure 5. This relationship illustrates that the workability (flow) reduces with the increase of fibers (Neville and Brooks, 2010)[20].

The flow for mixes containing superplasticizer decreases due to the reduction in water-cement ratio (w/c=0.4) and also the use of glass fibers as shown in Table 7. The flow was 118% for mix N5, and also with the fiber increase the workability (flow) would decrease. For mix N9, with glass fibers 0.6%, the flow is 84% and thus the percentage of reduction in the flow is about 28.81% compared with reference mix (N5). Figure 5 shows the effect of glass fibers on the flow of mixes containing superplasticizer (series II).

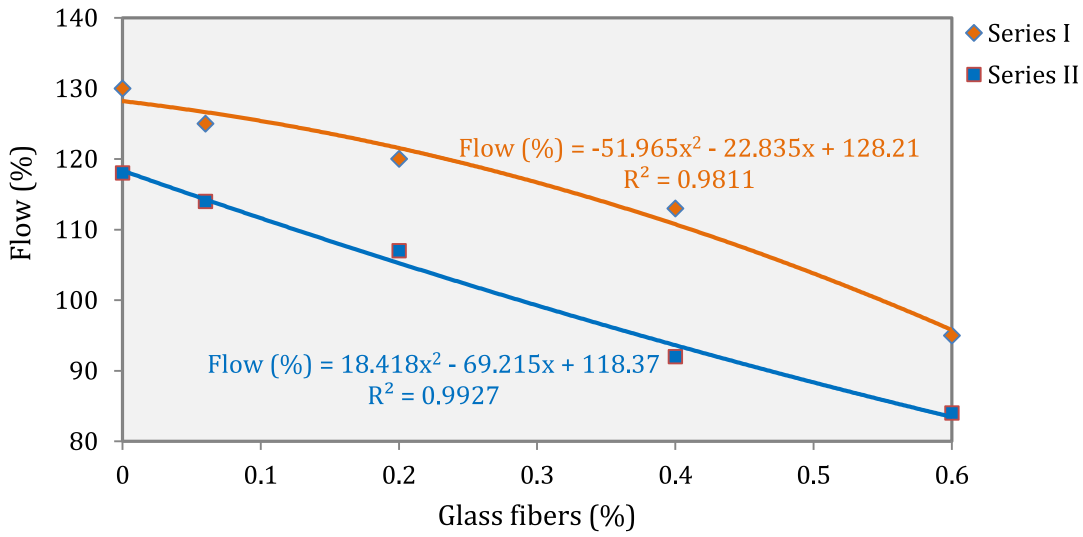
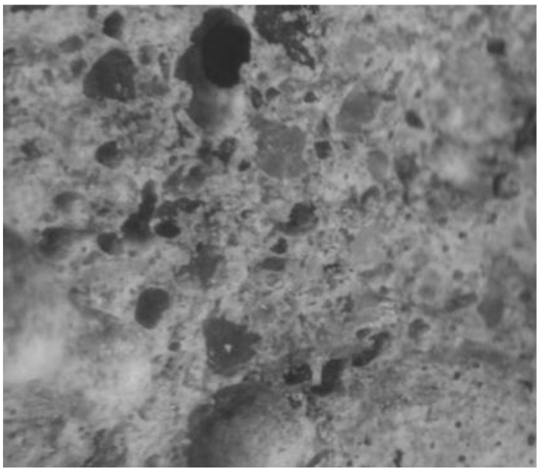


Figure 5: Effect of glass fiber (%) on the flow of the mixes.

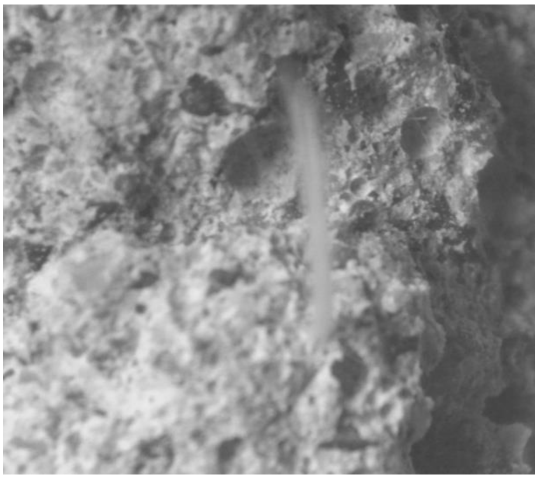
4.2. Microstructure

Microstructure of structural lightweight foamed concrete reveal the effect of foam and fibers on the mechanical properties. The microstructure of the mixes is shown in Figure 6, this images taken by stereo microscope. It seems that increase internal voids (pore) microstructure of the structural lightweight foamed concrete would decrease the density. The increase in the number of the larger voids tends to lower the density of such concrete but the density increased when the voids be smaller and more unbroken in size (Mydin and Soleimanzadeh, 2012)[21]. The microstructure for each mixes is varied widely depending on the density, addition of glass fibers, and volume fraction of glass fibers for mixes. Figure 6 (a and b) shows the image for structural foamed concrete without glass fibers , and also exhibit the shape of voids inside of concrete. The amount of foam influences the production of bubbles inside the concrete and creating the voids (Awang et al., 2012)[22]. The addition of glass fibers would increase the density, resulting from the reduction of the pores and voids within the foam concrete as seen in Table 8. Figure 6 (c and d) shows the microstructure of structural lightweight foamed concrete with 0.2% volume fraction of glass fibers. In these images it can be observed that a reduction of the voids within concrete due to the glass fibers affects the voids and weight of foam concrete. The density of structural lightweight foam concrete increased with the addition of glass fibers as seen in Table 8. Figure 6 (e and f) images for structural lightweight foamed concrete with 0.6% glass fibers. In this percentage of glass fibers the density of structural lightweight foamed concrete will increased and the voids decrease resulting enhance in performance of mechanical properties such as compressive and flexural strength as shown in Table 8.

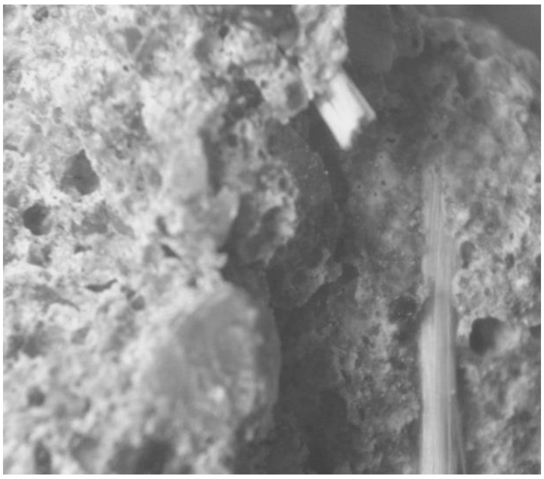


(a) Mix no. N0 24X

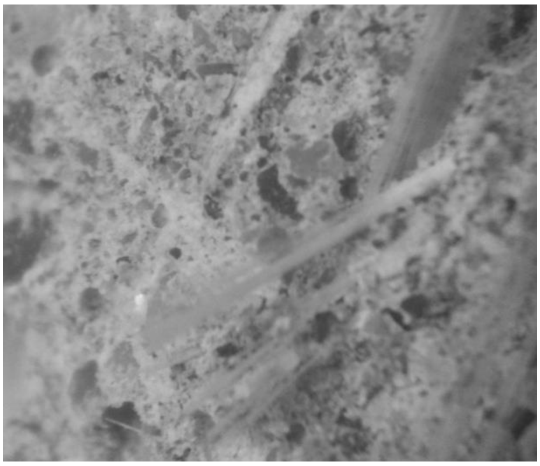
(b) Mix no. N5 24X



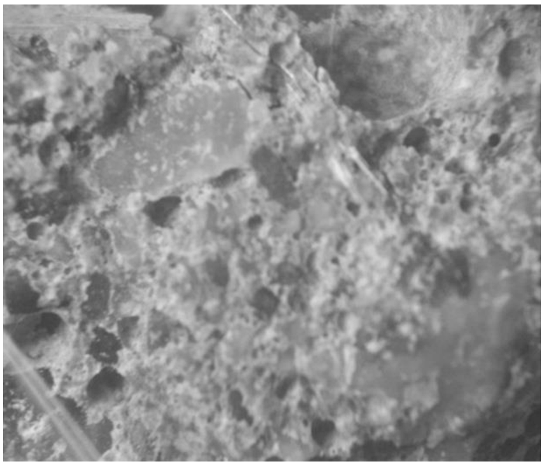
(c) Mix no. N2 24X



(d) Mix no. N7 24X



(e) Mix no. N4 24X



(f) Mix no. N9 24X

Note. (24X: mean the image zoom in 24 times)

Figure 6: Microstructure for structural lightweight foamed concrete for different mixes and density.

4.3. Compressive strength

The results of compressive strength at the age of 7 and 28 days are shown in Table 8. The compressive strength of structural lightweight foamed concrete incorporated with different percentage of glass fibers as 0.06, 0.2, 0.4, 0.6 % volume fraction. Compressive strength increases with the percentage increase of glass fibers as seen in Table 8 agree with (Deshmukh et al., 2012)[23]. Figure 7 shows the relationship between the compressive strength and percentage of glass fibers for two group mixes: series I and series II (without and with superplasticizer), respectively.

For series I mixes, it can be seen that the compressive strength increased by 14.28% with the addition of 0.06% of glass fibers compared with reference mix N0. Also, it can be noticed that the compressive strength is increased by 35.2% with the addition of 0.2% of glass fibers. Whereas, the incorporation of 0.4% glass fibers the compressive strength increased by about 45.2% compared with mix N0, and the compressive strength increased by about 51% with the addition of 0.6% of glass fibers as shown in Figure 7.

For series II mixes, also the compressive strength increased with the glass fibers increase, the compressive strength increased by about 26.2% with the addition of 0.06% of glass fibers compared with reference mix N5. The addition of 0.2% of glass fibers would increase the compressive strength by about 48.1%. However, the incorporation of 0.4% of glass fibers increases the compressive strength by about 45.3%. Furthermore, the compressive strength increases by about 60.6% with the addition of 0.6% glass fibers as can be noticed in Figure 7.

The results of compressive strength of series II mixes containing superplasticizer show the compressive strength at early age (7 days) exhibits better performance compared with mixes without superplasticizer (series I). Figure 8 shows the gain in compressive strength of foam concrete for mixes with and without superplasticizer (series II and series I).

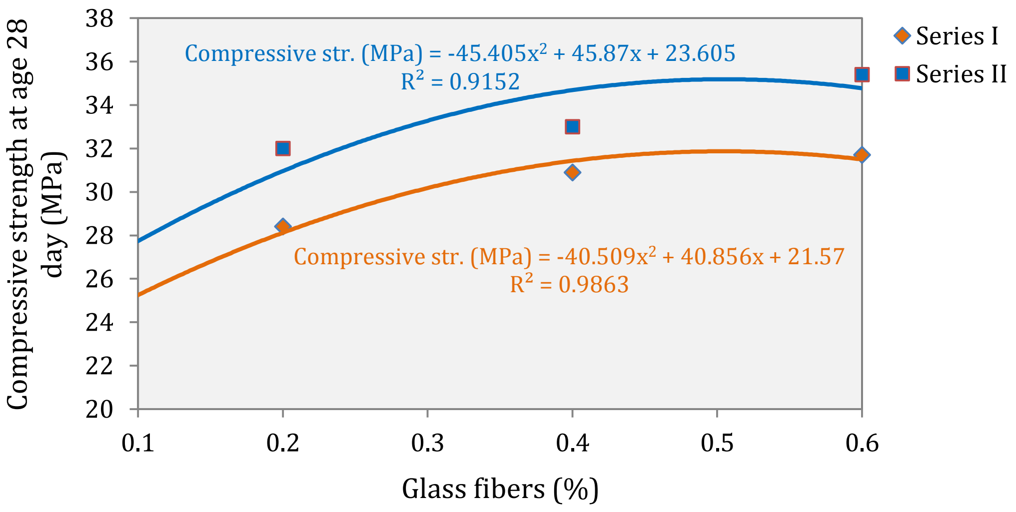


Figure 7: Relationship between the compressive strength at 28 day and percentage of glass fibers.

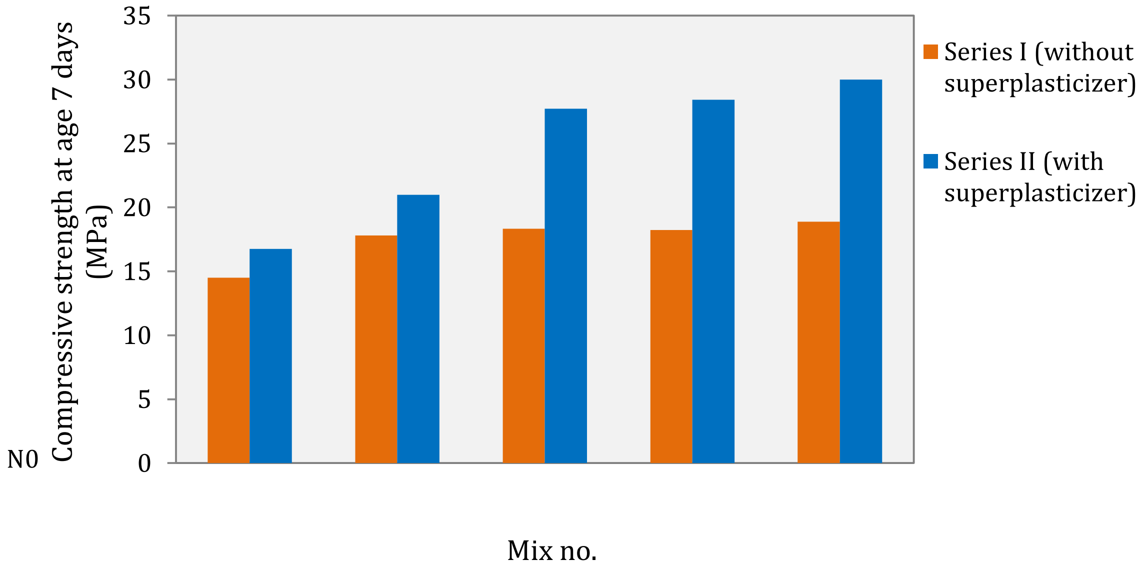


Figure 8: The influence of the addition of superplasticizer on the early strength at age 7 days of foam concrete

Table 8.

Hardened structural lightweight foamed concrete properties.

Series	Mix No.	Fresh density (kg/m³)	Dry density (kg/m³)	Compressive strength (MPa)		Increase (%)	Flexural strength (MPa)	Increase (%)	Voids (%)
				7 days	28 day		28 day		
Series I	N0	1760	1718	14.50	21.00	------	7.48	------	20.0
	N1	1784	1759	17.8	24.50	14.2	7.87	5.2	19.4
	N2	1810	1787	18.34	28.40	35.2	8.06	7.7	18.8
	N3	1850	1824	18.23	30.50	45.2	8.44	12.8	18.5
	N4	1881	1868	18.88	31.70	51.0	8.92	19.2	18.0
Series II	N5	1775	1731	16.75	22.03	------	6.90	------	19.7
	N6	1819	1795	21.00	27.80	26.2	7.48	8.4	18.6
	N7	1845	1822	27.73	32.64	48.1	7.68	11.3	18.0
	N8	1870	1849	28.42	32.00	45.3	7.86	14.0	17.8
	N9	1886	1861	30.00	35.40	60.6	8.16	18.2	17.7

4.4. Flexural strength

Table 8 gives the test results of flexural strength at 28 days. For series I mixes, the average flexural strength without glass fibers mix N0 is 7.48 MPa. However, the addition of glass fibers will enhance the flexural strength of structural lightweight foamed concrete with glass fibers percentage increase. It can be observed that the flexural strength increased by about 5% with the addition of 0.06% glass fibers compared with mix N0. The use of 0.2% of glass fibers would increase the flexural strength by about 7.7%. Besides, the flexural strength increased by about 12.8% with the addition of 0.4% glass fibers. Whereas, the use of 0.6% glass fibers increases the flexural strength of foamed concrete by about 19.2%. Figure 9 shows the relationship between flexural strength and glass fibers percentage. It can be noticed that flexural strength of foamed concrete increases with the glass fibers increase, agree with (Chandramouli et al., 2010 ; Deshmukh et al., 2012).

For series II mixes the average flexural strength without glass fibers mix N5 is 6.9 MPa. It can be observed that the flexural strength increased by about 8.4% with the addition of 0.06% glass fibers compared with reference mix N5 as can be noticed in Table 8. The flexural strength increases with the addition of 0.2% of glass fibers and the percentage of increase is 11.3%. The flexural strength increases by about 14% with the addition of 0.4% of glass fibers, and the incorporation of 0.6% glass fibers increases the flexural strength by about 18.2% as shown in Figure 9. Figure 10 (a & b) seen the structural lightweight foamed concrete and structural lightweight foamed concrete with glass fibers for prism specimen after flexural test.

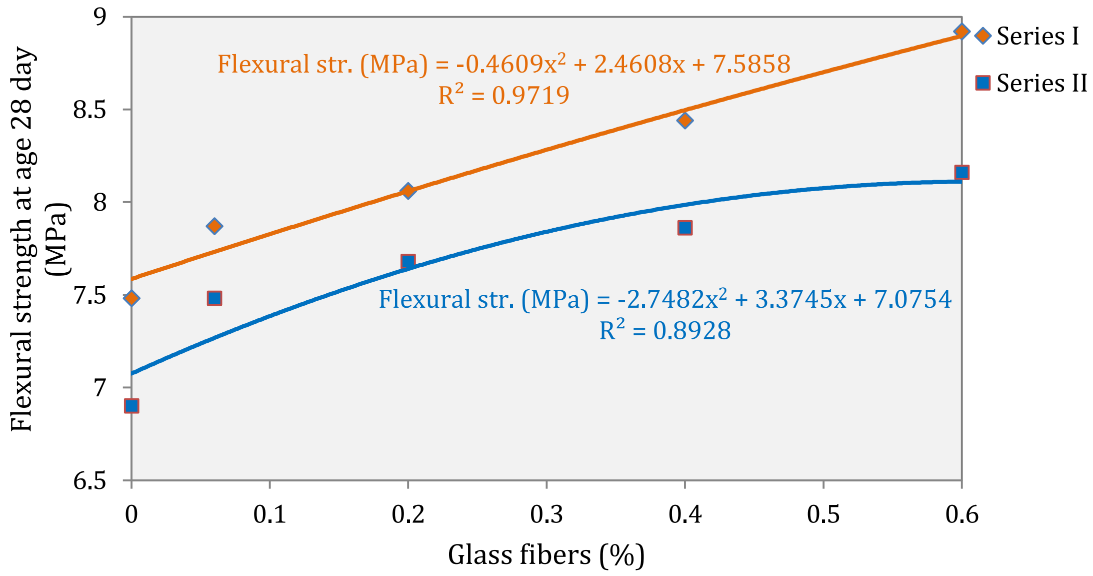


Figure 9: Relationship between flexural strength and glass fiber percentage.

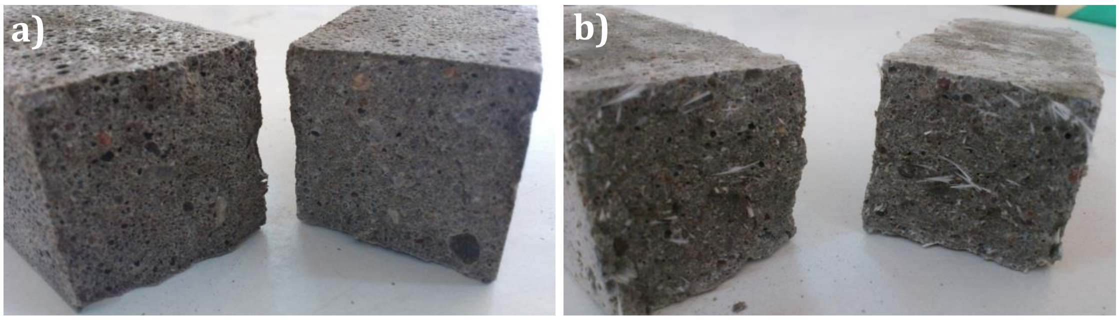


Figure 10: a) The structural lightweight foamed concrete for prism specimen after flexural strength testing (mix N0). **b)** The structural lightweight foamed concrete addtion glass fibers for prism specimen after flexural strength testing (mix N3).

4.5. Ultrasonic Pulse Velocity Measurements

Figure 11 shows the relationships between UPV and compressive strength at the age of 28 days of structural lightweight foamed concrete and structural lightweight foamed concrete with superplasticizer. It can be observed that the pulse velocity of structural lightweight foamed concrete without superplasticizer ranges from 3.37 to 3.7 km/sec at age 28 day, and the pulse velocity of structural lightweight foamed concrete with superplasticizer ranges from 3.49 to 3.84 km/sec at age 28 day, the observation of figure

11, it is show that UPV increase with increase compressive strength of strucutral lightweight foamed concrete (Bungey et al., 2006)[24]. the data in Figure 11 illustrates the mathematical correlations for direct manner ultrasonic pulse test methods.

The relationship between UPV and dry density can be obsorved in Figure 12. The voids and pores were found to be effective on the reading of UPV. The density of structural lightweight foamed concrete increases with the UPV reading increase.

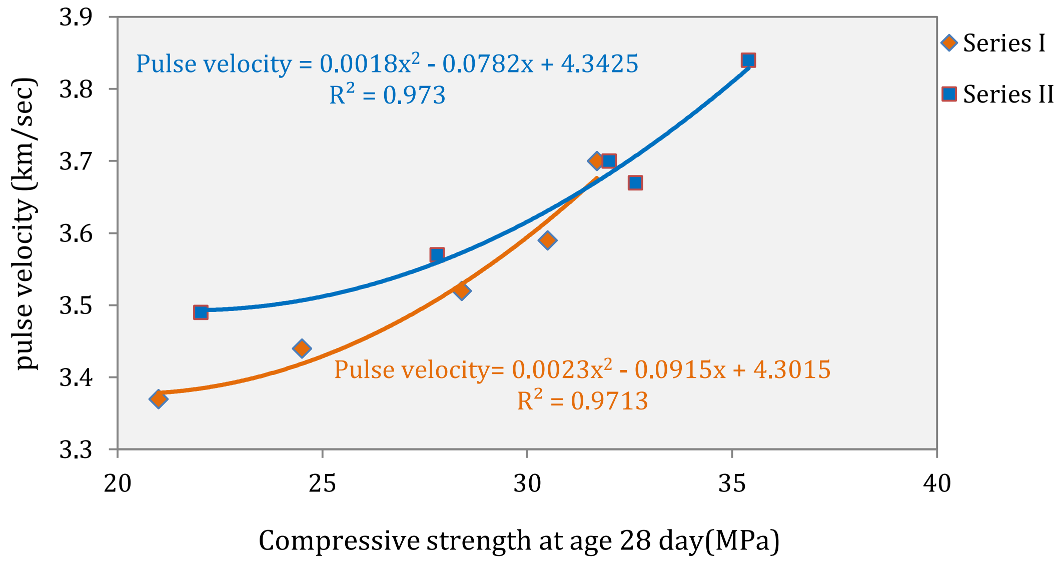


Figure 11: The relationship between compressive strength and pulse velocity.

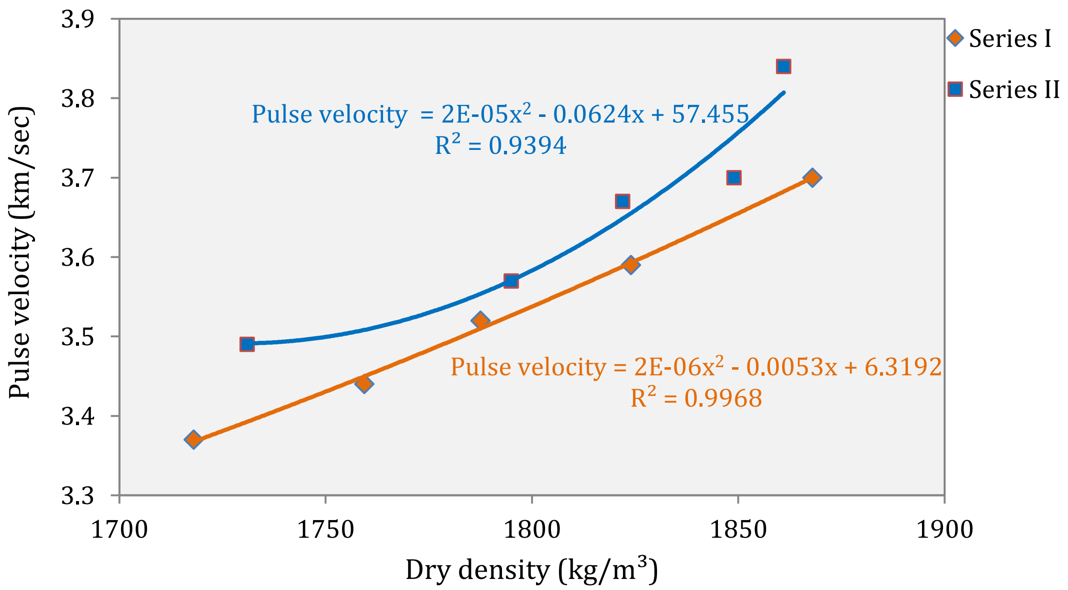


Figure 12: The relationship between dry density and pulse velocity.

5. Conclusion

In this paper Structural lightweight foamed concrete produced by using foam agent, with average density of 1750-1850 kg/m^3. Glass fibers and superplasticizer used in mixes. The glass fibers are used as reinforcement for foamed concrete to enhance the mechanical properties of such concrete. From the results we draw the following conclusions.

1. The workability of structural lightweight foamed concrete decrease with the increase of glass fibers percentages. The least value of flow is 84% with the use of 0.6% of glass fibers. This reduction in workability may be influenced by the high percentage of glass fibers. The increase of percentage of glass fiber more than 0.6% will significantly reduce the workability.
2. The microstructure of structural lightweight foamed concrete show that the percentages of glass fibers is more effective on internal voids of structural lightweight foamed concrete. The density increases with glass fibers percentage increase leading to a reduction in internal voids within structural lightweight foamed concrete.
3. The UPV reading was 3.37 to 3.7 km/sec for mixes without superplasticizer and 3.49 to 3.84 km/sec with superplasticizer, that's mean UPV reading will increase with the increase of density. Besides UPV reading would increase with compressive strength of strucutral lightweight foamed concrete increase.
4. The compressive strength of structural lightweight foamed concrete increases with the increase of glass fibers percentages in the mixes. For mixes without superplasticizer the best glass fibers percentages used are 0.2 and 0.4% , and for mixes with superplasticizer the best percentage is 0.6%. For all percentages of glass fibers in the mixes it can be observed increase in compressive strength would obtain with the volume fraction of glass fibers. For mixes without superplasticizer the compressive strength increases up to 51% with the addition of 0.6% glass fibers, and for mixes with superplasticizer the flexural strength increases by 60.6% with the addition of 0.6% of glass fibers.
5. The flexural strength increases with the increase of glass fibers percentages in the mixes. For mixes without superplasticizer the flexural strength increases up to 19.2% with the addition of 0.6% glass fibers, and for mixes with superplasticizer the flexural strength increases by 18.2% with the addition of 0.6% of glass fibers.

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