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IMPROVING MECHANICAL PROPERTIES OF LIGHTWEIGHT FOAMED CONCRETE USING SILICA FUME AND FIBERS

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Abstract: Lightweight foamed concrete (LWFC) is characterized as a light in self-weight, self-compacting (no need vibration), self-leveling, and thermal and sound isolation. The application of (LWFC) in the building construction is limited because of its the low strength and the low ductility. In this study the workability of the fresh mix of (LWFC), the hardened properties include, compressive strength, tensile splitting strength, flexural strength, and modulus of elasticity were evaluated. This study focuses mainly on the effect of the adding of silica fume and fibers on the mechanical properties of (LWFC). Silica fume was added as 5% and 10% by the weight of cement. Steel fiber and polypropylene fiber volume fraction were of (0.2%, 0.4%), While the hybrid fibers (steel+ polypropylene) volume fraction was (0.2% steel+0.2%PP), and (0.4%steel+0.2%PP) of the total mix volume. The results of the program test show that the increase of silica fume improves the mechanical properties of (LWFC) significantly. The adding of fibers to the (LWFC) reduces the flowability and improves the mechanical properties. The hybrid fibers mix (0.4% steel+0.2% PP) presented the best test result of the mechanical properties as (10%,21%,53%, 24.4%) for the compressive strength, flexural strength, tensile splitting strength, and modulus of elasticity, respectively.

Keywords: *Lightweight, Foamed Concrete, Silica fume, Steel fiber, Polypropylene fiber, Mechanical properties.*

تحسين خواص الخرسانة الخلوية الخفيفة الوزن بأستعمال السيليكا فيوم والالياف

الخلاصة : تتميز الخرسانة الخلوية الخفيفة الوزن بالعديد من المميزات منها خفة الوزن، ذاتية الرص(لاتحتاج الى رص)، ذاتية الاستواء، وذات عزل حراري وصوتي جيد. يعد تطبيق الخرسانة الخلوية الخفيفة الوزن في البناء الانشائي محدود بسبب ضعف مقاومتها وقلة ليونتها. في هذه الدراسة تم فحص قابلية التشغيل، الخواص الميكانيكية للخرسانة الخلوية الخفيفة الوزن المتمثلة بمقاومة الانضغاط، مقاومة الشد، مقاومة الانثناء،و معامل المرونة. ركزت هذه الدراسة بصورة رئيسية على تأثير أضافة غبار السيليكا و الالياف على الخواص الميكانيكية للخرسانة الخلوية الخفيفة الوزن. كانت اضافة غبار السيليكا بنسة (5% و 10%) من وزن السمنت. تم استخدام الياف الحديد و الياف البوليبروبلين لغرض تحسين الخوص الميكانيكية للخرسانة الخلوية الخفيفة الوزن. وتم استخدام الياف الحديد مع الياف البوليبروبلين معا للحصول على الالياف الهجينة. وكانت نسبة اضافة كل من الياف الحديد والياف البوليبروبلين بنسبتين (0.2% و 0.4%) من حجم الخلطة الكلي، بينما في حالة الالياف الهجينة كانت نسبة الالياف (الياف الحديد+الياف البولبروبلين) هي (%0.2steel+%0.2PP) و (%0.4steel+%0.2 PP) من حجم الخلطة الكلي. وقد بينت نتائج الفحص ان زيادة نسبة دخان السيليكا يرافقها تحسن ملحوظ في الخواص الميكانيكية للخرسانة الخلوية الخفيفة الوزن. أضافة الالياف بأنواعها يقلل من قابلية التشغيل ويحسن من خواص الخرسانة الخلوية الخفيفة الوزن.حيث اظهرت الخلطات ذات الالياف الهجينة (0.4% steel+0.2% PP) افضل النتائج وبنسب (10%،21%،53%،24%) لمقاومة الانضغاط، مقاومة الانثناء، مقاومة الشد،ومعامل المرونة على التوالي.

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1. Introduction

Lightweight foamed concrete, is a type, of concrete has a lighter, weight compared with normal concrete. Using lightweight foamed concrete as a construction material lead to reduce the self-weight of a structure and offers better thermal and sound insulation and better fire protection than normal weight concrete.

According to the ACI 116R-00, silica fume is defined as " a very fine non-crystalline silica produce in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon" [1].

When two different fibers added to concrete to make the composite structure gives maximum strength to concrete that type of concrete is hybrid fiber reinforced concrete. Mydin and Sahiduna in (2015) studied the mechanical properties; compressive strength, flexural strength and tensile splitting strength, of lightweight foamed concrete contain steel fiber with volume fraction (0.2 % and 0.4%) and found that the addition of steel fibers improve the mechanical properties of LWFC [2].

Bing et al. (2012) studied the development of the structural foamed concrete application by using silica fume, fly ash, and polypropylene fiber. The results show the adding polypropylene fiber significantly improved the compressive strength, the splitting tensile strength, and drying shrinkage resistance [3]. Awang and Ahmad in (2012) studied the mechanical properties and durability of the lightweight foamed concrete use steel fibers as two percentages inclusion, 0.25% and 0.4% by total volume fraction, and 30% replacement of cement by fly ash, they showed that the addition of steel fibers is a very good contribution in the compressive strength, flexural strength and tensile split strength test results [4]. Mydin and Soleimanzadeh (2012) studied the effect of volume fraction (0.1, 0.2, 0.3, 0.4, 0.45 and 0.5%) of polypropylene fiber on the flexural behavior of lightweight foamed concrete before and during exposing it to high temperature. They found the adding more than 0.4% volume fraction of polypropylene fiber reduces the flexural strength considerably [5].

Fathilah et al. (2012) studied the flexural strength of lightweight foamed concrete using cement to sand ratio (3:1) with inclusion of polypropylene fiber, using the targeted density of 1500 kg/m^3 and polypropylene fiber with 0.25% and 0.40% volume fraction. They found the inclusion of polypropylene fiber into the lightweight foamed concrete samples has more contribution in flexural strength as compared to control sample without the fibers and 0.25% is an optimal volume of fibers that should be included to contribute the maximum flexural strength of the lightweight foamed concrete [6].

Asok and Dr. George (2016) investigated the hybrid normal concrete using steel and polypropylene fibers and they found that the addition of fibers is helpful to improve the fracture properties of concrete [7].

This study aims to investigate the mechanical properties of lightweight foamed concrete with the inclusion of steel fiber and polypropylene fiber in terms of compressive, flexural, tensile splitting strengths, and modulus of elasticity.

2. Experimental work

2.1 Material

2.1.1 Cement

Ordinary Portland cement used in this study to produce lightweight foamed concrete. It conform to the Iraqi Standard Specification (I.Q.S. No.5, 1984) [8]. Table 1 and Table 2 show the chemical and physical properties of cement used in this study, respectively.

Table 1. Chemical properties of cement.

Oxide composition	Results % by weight	Limit of Iraqi specification No.5/1984
SiO_2	20.4	—
CaO	61.7	—
$Al_2 O_3$	5.45	—
Fe_2O_3	4.79	—
MgO	1.5	5.0 (max)
SO_3	1.9	2.8 (max)
C_3A	6.35	—
C_3S	47.23	—
C_2S	23.06	—
C_4AF	14.6	—
Insoluble Residual (I.R)	0.42	1.5 (max)
Loss of Ignition (L.O.I)	2.08	4.0 (max)

Table 2. Physical properties of cement

Physical properties test	Results	Limit of Iraqi specification No. 5/1984
Fineness using Blaine air permeability apparatus (m^2/kg)	405	230 (min)
Soundness using autoclave method	—	0.8% (max)
Setting time using Vicat's instruments		
Initial(min.)	137	00:45 (min)
Final(hr.)	3:25	10:00 (max)
3-day compressive strength for cement Paste	24.2 MPa	15 (min)
7-day compressive strength for cement Paste	32.5 MPa	23 (min)

2.1.2. Sand

Fine aggregate used was imported fine standard sand with a specific gravity of 2.60 and percentage from size 600 micro no 3. This type of sand is supplied by (Al-Umaraa) company as shown in Fig.1. Table 3 shows the sieve analysis of sand used in this study according to ASTM C778 (ASTM Designation: C778, 2013) [9].

Table 3. The sieve analysis of sand

Sieve size	Passing%
600 μm	93
300 μm	23
150 μm	4.5
pan	0.0

2.1.3 Silica fume

Silica fume is an additive for concrete and mortars. It meets the requirements of (ASTM C-1240) [10]. Table 4 shows the properties of silica fume.

Table 4. Silica fume properties.

Technical Properties	
Form/Color:	Grey Powder
Surface area	27.3246 cm^2/g
Bulk density	660kg/m3
Moisture content	0.6%
Loss on ignition	3.4%
Sulfuric anhydride	0.3%
Total silica content SiO2	94.7%
Available alkali	0.1%
Chloride ion	0.055%
Relative strength	116%

2.1.4 Superplasticizers

Is an additive based on modified polystearic-esters free of chlorides, whose action is improves concrete flow without segregation. The superplasticizer “Sika Viscocrete 5930” was used which complies with (ASTM C494/C494M, 2015) types G and F [11]. Table 5 shows the properties of superplasticizers.

Table 5. Properties of Superplasticizers

Technical Properties	
Form / Color	Liquid, amber
Density (at 25°C)	Approximately 1.11 kg/lt
Specific Gravity	1,07 ± 0,01 kg/L
ph	Approximately 5.5
Chloride Content	Nil (EN 934-2)

2.1.5 Water

Top water will be used, and which shall be clean and free organic materials.

2.1.6 Foaming Agent

Foam is a form of stable bubbles, produced by mixing foaming agent and water in foam generator. The purpose of the foam is to control the density of lightweight foamed concrete by incorporating dry preformed stable foam into fresh lightweight foamed concrete. For this study, the ratio of foaming agent to water was (1:30) by volume.

Table 6 shows the properties of foaming agent. It is produce lightweight foamed concrete according to (ASTM C796/C796M, 2012) [12].

Table 6. Properties of foam agent

Appearance / Colors	Yellow transparent liquid
Chemical Base	Air entraining synthetic liquid
Density	1.0075 – 1.0175 kg/L, at 20°C
pH Value	9-11
Total Chloride Ion Content	Max. 0.1%, Chloride-free

2.1.7 Steel Fiber

The steel fibers used in this study are hooked-end low carbon produces by Sika. According to (ASTM A820) [13]. Table 7 and Fig. 1 show the properties and geometry of steel fiber used respectively.

Table 7. Steel Fibers Properties

Technical Properties	
Type of steel fiber	hooked-end
Fiber Length (mm)	60mm
Fiber width, (mm)	0.75 mm
Aspect Ratio (L/d)	80
Shape	hook
Tensile strength (MPa)	>1100
Ultimate elongation (%)	<2
Specific Gravity	7.8

Fig.1The geometry of steel fibers.

2.1.8 Polypropylene Fiber

Synthetic fibers that are resulted from the petrochemical and textile industries. The existing of polypropylene fibers in concrete is reduced plastic shrinkage cracking and subsidence cracking over steel reinforcement. Table 8 shows the properties of polypropylene fibers and Fig. 2 shows the geometry of polypropylene fibers.

Fig. 2 Polypropylene fibers geometry.

Table 8. Polypropylene fibers properties.

Technical Properties	
Form	100% virgin polypropylene fibers
Length	12mm
Specific gravity	0.91
Alkane content	No
Sulphat content	No
Chloride content	No
Modulus of elasticity	3500-4800 MPa
Tensile strength	350 MPa
Melting point	160-170°C
Ignition point	590°C
Cement compatibility	Excellent

2.2 Preparing Foaming Agent

To prepare foaming agent that use in the mix is added the liquid of foam and water in the foam pump device by 1:30, and with pressure to get the foaming agent as shown in Fig. 3.

Fig. 3 Foam output.

2.3 Producing of Lightweight Foamed Concrete and Specimen Preparation

The foam is prepared first by adding foaming agent with water to the foam generator, the foam is produced with presence of air. The objective of this research is improving the properties of control mix lightweight foamed concrete by using the addition of two types of fibers which are steel fiber and polypropylene fiber. Portland cement and silica fume of (10%) by the weight of cement were used as the cementitious materials. the water/cementitious materials ratio was 0.28, and superplasticizers of (0.8%) by the weight of cementitious materials. The base mix is prepared by mix the dry material; cement, sand, and silica fume in the mixer with the cement-sand ratio of (1:1). After the dry materials are mixed well, water premixed with superplasticizers is added to the base mix as seen in Fig. 4 (a). Table 9 shows the material and mix design. When the mortar become ready, the steel fiber and polypropylene fibers are added as shown in Fig.4 (b). After that foam agent is added to the mix and the mortar density was measured as seen in Fig. 4 (c) and (d) below.

Promptly after mixing, the concrete was placed in molds in order to prevent breaking down of the air bubbles before it was set as shown in Fig. 5 below. At about 24 hours after that, concrete molds were removed and warped with nylon to prevent moisture evaporation.

Table 9. Mix proportion.

Mix code	Cement kg/m^3	Sand kg/m^3	Water Lt./ m^3	Sp* %	Silica fume %	ST %	PP%
FB	747.5	747.5	230.23	0.8	10	0	0
FST1	741	741	228.23	0.8	10	0.2	0
FST2	734.5	734.5	226.24	0.8	10	0.4	0
FPP1	746.76	746.76	229.98	0.8	10	0	0.2
FPP2	746.0	746.0	229.7	0.8	10	0	0.4
FSTP1	740.3	740.3	228	0.8	10	0.2	0.2
FSTP2	733.8	733.8	226	0.8	10	0.4	0.2

*Sp: superplasticizer add as a ratio of cementitious material, ST: Steel Fiber, PP: Polypropylene fiber.

(a) Material mixing

(b) Fiber adding.

(c) Foam agent adding.

(d) The measured of mix density.

Fig. 4 Producing of Lightweight Foamed Concrete

Fig. 5 Concrete mix in molds.

3. Experimental tests

3.1 Fresh Properties Test (Flow Test)

This test of concrete mix is done to give us some notion on the workability of concrete mix as shown in Fig.6 according to the standard specification ASTM C1437 [14]. The flow result can be calculated as the formula in (1):

$$\text{Flow} = \frac{d_1 - d_2}{d_2} \text{ x } 100 \qquad (1)$$

Where d_1 is the average of four readings in mm , and d_2 is the original inside base diameter in mm.

Fig.6 Flow table test.

3.2 Compression Test

Compressive strength of (LWFC) is an important parameter because it indirectly gives other mechanical properties such as flexural strength, splitting tensile strength and modulus of elasticity. Compression test is required to determine the strength of concrete as in the Fig.7 according to (ASTM C39/C39M, 2015) [15]. In this test used cubes moulds with diminution (100 x 100 x 100 mm).

Fig.7 Compressive strength test.

3.2 Flexural Test

The objective of this testing is to determine the modulus of rupture of lightweight foamed concrete using prism dimension (100 x 100 x 500 mm) according to (ASTM C78/C78M, 2015) [16] as seen in Fig.8.

Fig.8 Flexural strength test.

3.4 Splitting Tensile Test

The lightweight foamed concrete were tested for tensile splitting strength at 7 and 28 days by the application of a diametric compressive load on a cylindrical concrete specimen with a diameter (150 mm) and a height (300 mm) placed with its axis horizontal between the plates of a testing machine according to (ASTM C496, 2011), as seen in Fig.9 [17]. The Tensile strength of the specimen was calculated by using the formula in (2):

$$\text{Tensile strength} = \frac{2P}{\pi\, LD} \qquad (2)$$

where P is the applied load kN, L is the length of cylinder in (mm), and D is the diameter of cylinder in (mm).

Fig.9 Tensile splitting strength test.

3.5 Modules of Elasticity

The modulus of elasticity of an object is defined as the slope of its stress–strain curve obtain from the test as shown in Fig.10. This test is produced according to (ASTM C469/C469M, 2014) [18]. The modulus of elasticity can be calculated by the formula in (3):

$$E_c = \frac{S_2 - S_1}{\varepsilon_2 - 0.000050} \qquad (3)$$

Where E_c is chord modulus of elasticity in MPa, S_2 is stress corresponding to 40% of ultimate load, S_1 is stress corresponding to a longitudinal strain (ε_1) of (0.000050), and ε_2 is longitudinal strain produced by stress S_2 .

Fig.10 Modulus of elasticity test.

4. Results and Discussions

4.1 Properties of Fresh Concrete (Flowability)

Lightweight foamed concrete is characterized by having a high workability because it is consist of fine particles in addition to high w/c ratio or superplasticizer. The adding of silica fume reduces the water/cementitious materials so leads to decreases the flowability of the mix. The adding of steel fibers and polypropylene fibers decrease the workability of the mix as shown in Fig. 11, which shows the results of the flow test. The improved uniformity is due to the fact that polypropylene fiber can form a network structure in lightweight foamed concrete which can effectively restrain the segregation of steel fiber.

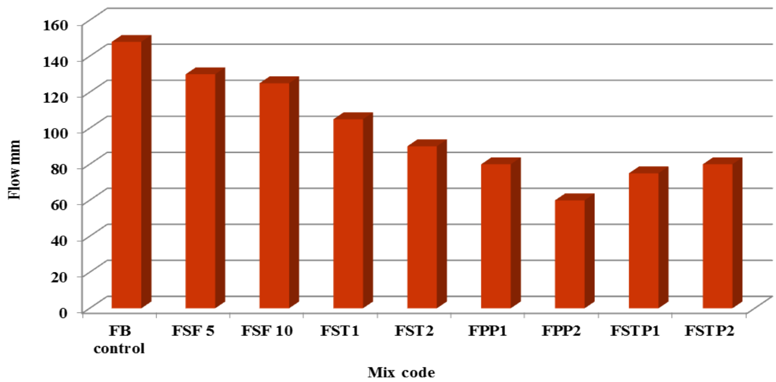

Fig. 11 Flow test results.

4.2 Compressive Strength

Lightweight foamed concrete has a low compressive strength comparing with normal concrete. The addition of silica fume improves the compressive strength of lightweight foamed concrete significantly due to the pozzolanic characteristics of silica fume leading to an improved the matrix bond of concrete [19]. Silica fume increases the compressive strength about 22% for mix with silica fume (5%), and 59% for mix with silica fume (10%). The addition of steel fiber improve the compressive strength of lightweight foamed concrete due the steel fiber matrix bond mechanism and amount percentage of steel fiber introduce into the lightweight foamed concrete [2]. Comparing with the mix without steel fiber (FSF10), the addition of steel fiber increases the compressive strength about 9% for mix with steel fiber (0.2%) and 11.6% for the mix with steel fiber (0.4%).

But the addition of polypropylene decreases the compressive strength about 9.7% for mix with 0.2% polypropylene fiber, and 11.25% for mix with 0.4% polypropylene compared with the mix without fibers (FSF10). This reduction may be attributed to the low stiffness of polypropylene fibers and also the ductility of the polypropylene fibers that may affect the compressive strength of such concrete [20]. The addition of hybrid fibers (0.2% steel + 0.2% PP), (0.4% steel+0.2% PP) fibers increased the compressive strength as (4.8%,10%) for mix with fibers and this increase depends on the volume fraction of steel fiber as shown in Fig. 12.

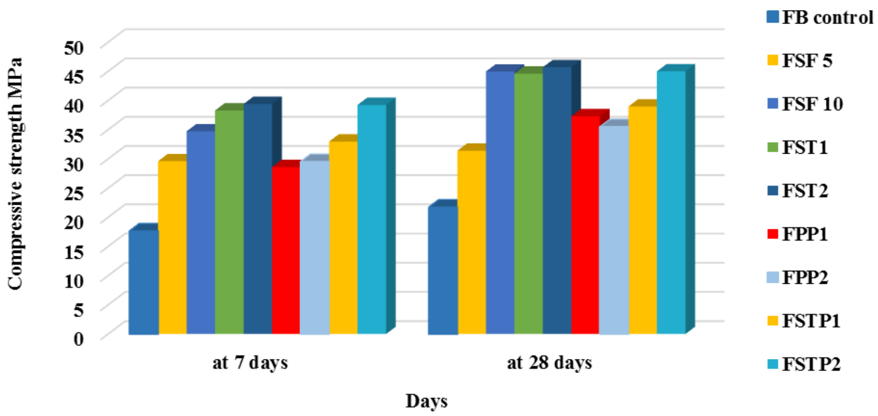

Fig.12 Compressive strength test results.

4.3 Flexural Strength

The flexural strength of lightweight foamed concrete is proportional to the compressive strength. Fig.14 shows the flexural strength test results of lightweight foamed concrete at 7 and 28 days. The addition of silica fume increases the flexural strength as 32% for mix with (5%) silica fume, and as 80% for mix with silica fume (10%) is compared with control mix without silica fume (FB control).

The addition of steel and polypropylene fibers increase the flexural strength because of its role in reducing the cracks. The beginning cracks on the flexural specimen were not visible until the maximum load was reached due to continuous and bonding of steel and polypropylene fibers [5]. The steel fiber holds the critical part together giving the alert timing before it cracks. This is because of the hooked-end shape of steel fiber that holds the cracked parts together and preventing the structure from cracking into two parts as shown in Fig. 13.

Fig. 13 Cross section of the prism contain fibers.

In compared with mix without fibers (FSF10), the flexural strength increased as 32% and 41.6% for mixes with (0.2%) and (0.4%) steel fiber, respectively. Also for the mixes with (0.2%) and (0.4%) polypropylene fiber, the flexural strength increased by 5.5% and 9%, respectively. The addition of hybrid fibers (0.2% steel +0.2% PP) and (0.4% steel+0.2% PP) fibers exhibited significant increasing in the flexural strength as (9%, 21%) in compared with mix without fibers, respectively.

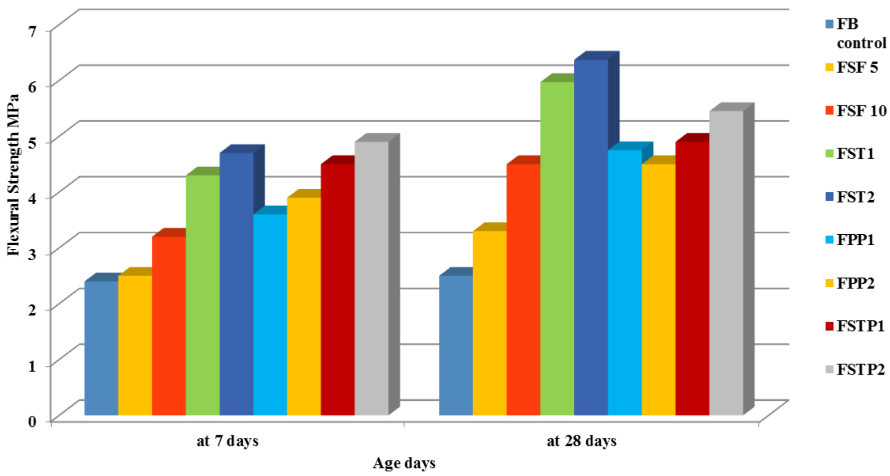

Fig.14 Flexural strength test results.

4.4 Tensile Splitting Strength

Generally, lightweight foamed concrete has a low tensile strength and brittle nature. From the results drawn in Fig. 15,the adding of 5% and 10% silica fume increase the tensile splitting strength as 30.6% and 55% in compared with control mix (FB control). the addition of (0.2%) and (0.4%) steel fiber increases the splitting tensile strength of lightweight foamed concrete as 34.4% and 26.4% respectively. This is because the hook-end shape of the steel fiber are sufficiently strong and bonded to lightweight foamed concrete mix [1]. On the other hand, the addition of (0.2%) and (0.4%) polypropylene fiber caused an increase as 3% and 8% in tensile splitting strength. This is due to the polypropylene fibers reduces the fine cracks in the LWFC matrix. The addition of hybrid fibers (0.2% steel +0.2% PP) and (0.4% steel+0.2% PP) fibers exhibited significant improvements in tensile splitting strength as 26% and 53% compared with mixes without fiber addition (FSF10), respectively. The steel fiber have more effect on tensile splitting strength of LWFC than that of polypropylene fibers. This can be attributed to the ability of lightweight foamed concrete with steel and polypropylene fibers to reduce and restrain the cracks effectively.

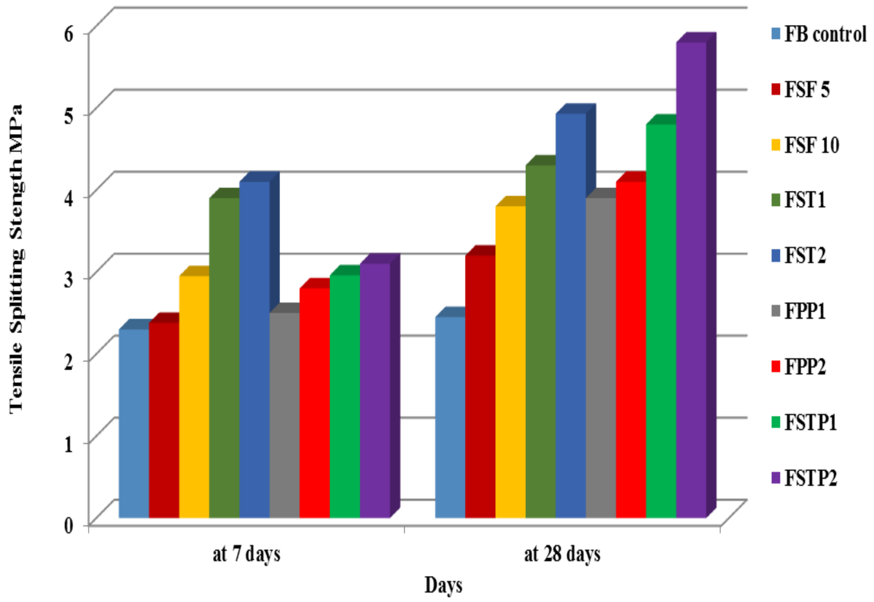

Fig.15 Tensile splitting strength test results.

4.5 Modulus of Elasticity

The modulus of elasticity is calculated as the secant modulus from the slope of the experimental stress-strain curve for cylinder compressive test at the point where the material changed from elastic behavior to plastic behavior as the slope of the line drawn from zero stress to a compressive stress of (0.45 $f_c{}'$). The modulus of elasticity of lightweight foamed concrete depends on the, compressive, strength of concrete. as shown in Fig. 16. The adding of silica fume to the LWFC increases the modulus of elasticity 21.5% and 29% for mixes with 5% and 10% silica fume, respectively. This because the adding of silica fume increases the stress capacity of the mix.

Also, the modulus of elasticity increases as increasing of the adding of steel fibers into the lightweight foamed concrete, where the adding (0.2%) and (0.4%) steel fiber increase the modulus of elasticity in compared with mix without fibers (FSF10) as 8.5% and 11.45%, respectively.

This is an indication of the strong bonding between the fibers and the matrix where the steel fiber play a significant role in the stress transfer where that decreases the strain and therefore improving the stiffness of mix. The adding of polypropylene fiber into the lightweight foamed concrete reduces the compressive strength that leads to the decrease in the modulus of elasticity. where the adding (0.2%) and (0.4%) polypropylene fiber reduce the modulus of elasticity as 6.25% and 19.3% in compared with mix without fibers (FSF10).

In compared with LWFC mix without fibers (FSF10), the modulus of elasticity of LWFC increases as 13% and 24.4% for hybrid mixes (0.2% steel + 0.2% PP) and (0.4% steel + 0.2% PP) fibers, respectively.

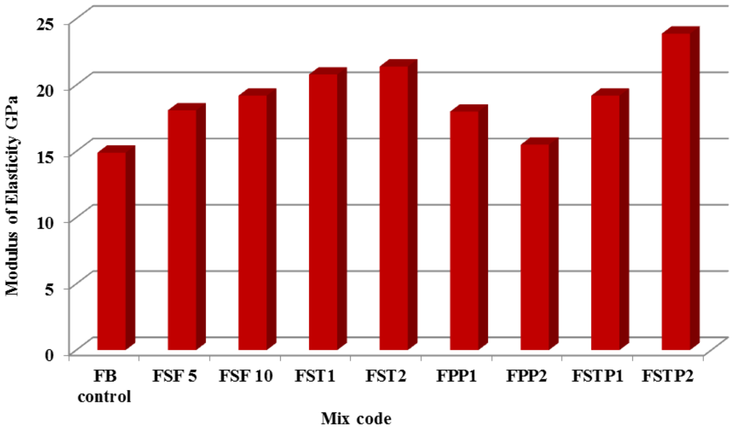

Fig.16 Modulus of elasticity test results.

5. Conclusions

The behavior of steel fiber at volume fraction (0.2% and 0.4%), polypropylene fiber at volume fraction (0.2% and 0.4%), and hybrid fibers on the mechanical properties of lightweight foamed concrete were investigated. The following conclusions are drawn from this study:

- The adding of silica fume to the LWFC mix improve the compressive strength due to the pozzolanic action of silica fume leading to an improved the matrix bond of concrete that leads to improve the flexural strength, tensile splitting strength and modulus of elasticity.
- The adding of silica fume increase the compressive strength, flexural strength, the tensile splitting strength, and modulus of elasticity as (22%,32%,30.6%,21.5%) for the mix of (5%) silica fume, and as (59%, 80%, 55%, 29%) for the mix with (10%) silica fume in compared with control mix (FB).
- The addition of steel fiber improve the mechanical properties of LWFC due the steel fiber matrix bond mechanism and the hooked-end shape of steel fiber that holds the cracked parts together and preventing the structure from cracking into two parts.
- The adding of steel fiber into the LWFC mix increase the compressive strength, flexural strength, tensile splitting strength, and modulus of elasticity as (9%, 32%, 34.4%, 8.5%) for the mixes with (0.2%) steel fiber, and as (11.6%, 41.6%, 26.4%, 11.45%) for the mixes with (0.4%) steel fiber in compared with mix without fibers (FSF10).
- Due to the low stiffness and the ductility of polypropylene fibers that decrease the compressive strength as (9.7%,11.25%) and reduce the modulus of elasticity lightweight foamed concrete as (6.25%,19.3%) for mix with (0.2%,0.4%) polypropylene fiber in compared with the mix without fibers (FSF10), respectively.
- The addition of polypropylene fiber increases the flexural strength as (5.5%,9%) and tensile splitting strength as (3%,8%) for the mixes with (0.2%,0.4%) polypropylene fiber in compared with the mix without fibers (FSF10), respectively. This is because of polypropylene fibers play a significant role in reducing the cracks.

- In hybrid fibers foamed concrete, polypropylene control the cracks at the microstructure size, and steel fiber control the post-cracks and holds the cracks parts to prevent structure from cracking into two parts.
- The addition of hybrid fibers increase the compressive strength, flexural strength, tensile splitting strength, and modulus of elasticity as (4.8%, 9%, 26%, 13%) for the hybrid fibers mix with (0.2% steel +0.2% PP) fibers, and as (10%,21%,53%, 24.4%) for the hybrid fibers mix with (0.4% steel +0.2% PP) fibers in compared with mix without fibers (FSF10), respectively.
- The best result of the mechanical properties was the hybrid fibers mix (0.4% steel+0.2% PP) which is suitable for use as a structural material in the construction.

6. References

1. ACI Committee 116R, (2000). Cement and Concrete Terminology. American Concrete Institute.
2. Mydin, M. A., Sahiduna, N. S., Yusof, M. Y., Noordina, N. M. (2015). "*Compressive, Flexural and Splitting Tensile Strength of Lightweight Foamed Concrete with Inclusion of Steel Fibers*", Journal Technology, vol.75:5, pp.45–50.
3. Bing, C., Zhen, W., and Ning, L. (2012). "*Experimental Research on Properties of High-Strength Foamed Concrete*", Journal of Materials in Civil Engineering, Vol. 24, No. 1.
4. Awang, H. and Ahmad, M. H. (2012). "*The effect of steel fiber inclusion on the mechanical properties and durability of lightweight foam concrete*", Elixir Adv. Egg. Info. Vol.48 , pp. 9348-9351.
5. Mydin, M. A. and Soleimanzadeh, S. (2012). "*Effect of polypropylene fiber content on flexural strength of lightweight foamed concrete at ambient and elevated temperatures*", Advances in Applied Science Research, vol.3 (5), pp. 2837-2846.
6. Fathilah, N. F., Tan, C. S. (2012). "*Flexural Strength of Lightweight Foamed Concrete using cement to sand ratio 3:1 with Inclusion of Polypropylene Fiber*", Faculty of Civil Engineering, University Technology Malaysia, Malaysia.
7. Asok, G., Dr. George, S. (2016). "*Investigation on Hybrid Concrete Using Steel and Polypropylene Fiber*" International Journal of New Technology and Research (IJNTR), Vol.2, Issue-5, pp. 61-64.
8. Iraqi Specifications No. (5). (1984). Portland cement. Baghdad-Iraq. Iraqi Central Organization for Standardization and Quality Control.
9. ASTM C778. (2013).Standard Specification for Standard Sand. Philadelphia, PA: American Society for Testing and Material.
10. ASTM C1240. (2015). "*Standard Specification for Silica Fume Used in Cementitious Mixtures*". American Society for Testing and Material International, Philadelphia, PA, USA.
11. ASTM C494/C494M. (2015). "*Standard Specification for Chemical Admixtures for Concrete*". American Society for Testing and Material International, Philadelphia, PA, USA.
12. ASTM C796/C796M. (2012). "*Standard Test Method for Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam*". American Society for Testing and Material International, Philadelphia, PA, USA.
13. ASTM A820. (2011). "*Standard Specification for Steel Fibers for Fiber-Reinforced Concrete*" American Society for Testing and Material International, Philadelphia, PA, USA.

14. ASTM C1437. (2013). "*Standard Test Method for Flow of Hydraulic Cement Mortar*" American Society for Testing and Material International, Philadelphia, PA, USA.
15. ASTM C39. (2015). "*Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*" American Society for Testing and Material International, Philadelphia, PA, USA.
16. ASTM C78. (2015). "*Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)".* American Society for Testing and Material International, Philadelphia, PA, USA.
17. ASTM C496. (2011). "*Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens*". American Society for Testing and Material International, Philadelphia, PA, USA.
18. ASTM C469/C469M. (2014). "*Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in compression*" American Society for Testing and Material International, Philadelphia, PA, USA.
19. Hilal, A. A., Thom, N. H., & Dawson, A. R. (2015). The use of additives to enhance properties of pre-formed foamed concrete. International Journal of Engineering and Technology, 7(4), 286.
20. Banthia, N., & Sappakittipakorn, M. (2007). Toughness enhancement in steel fiber reinforced concrete through fiber hybridization. Cement and Concrete Research, vol. 37, Issue 9, pp. 1366-1372, 2007.