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Behavioral compression of polyolfin-aramid fiber and glass fiber on flexural strength of LECA concrete

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Abstract

Generally, normal concrete has some defects like high cement consumption and heavy ingredients which cause to arise the concrete price. The aim of light weight concrete (LWC) is removing the common defects of normal concrete and remaining its advantages. The fiber concrete is one of the materials to increase the strength and quality of LWC. It can use to strengthen the brittle concrete. In this research, the effect of Polyolefin-Aramid and glass fiber has been considered on flexural strength of LECA concrete. In this manner, the specimens were used with (15*15*15) cm for compressive strength and prismatic strength with (50*10*10) cm for flexural strength. In this test, the percent changes of Polyolefin-Aramid and glass fiber have been considered. The amount of Polyolefin-Aramid is 5, 5.2 and 5.7 in each cubic meter and 3, 5.4 and 6 for glass have been assigned.

Keywords: LECA concrete, Light Weight Concrete (LWC), polyolefin-aramid, behavioral compression, glass fiber, flexural strength.

1. Introduction

In recent years, using light weight concrete are very common in different shapes such as light weight aggregate concrete (ACI 213R-87, 1999), concrete without fine (Tittarelli et al. 2014) or concrete with bubble (Song et al. 2015). It is replaced by normal concrete in several applications because of its advantages like low specific weight and heat insulation (ASTM–C330, 2004; Mehta and Paulo 2014)

Adding fiber in concrete cause to inmprove its properties. Fiber have bonding in multi directions which avoid propagating a crack and increats the efficiency of concrete. (Alberti et al. 2014; ACI 544.3 1984; Shah 1984).

2. Purpose of the study

The main objective of this research is the effect of polyolefin aramid fiber and glass fiber in LECA (Light Expanded Clay Aggregate) concrete flexural strength.

3. Materials and methods

3.1 Definition

In this research, the effect of various percentage weights (in cubic meter) of polyolefin aramid fiber and glass fiber have been investigated in LECA concrete. (Lipatov et al. 2015). So, there are three different percentages which have been used with same concrete mix design. The tests have done in 7-days and 28-days. The cubic and prismatic samples used for compressive and flexural strength respectively (Figure 1) (BS-1881 1983; ASTM C293 2010).

3.2 Ingredient

3.2.1 Water

According to the Iranian Standard Concrete Code (ABA), water should be clean in the concrete. Generally drinking water is suitable in concrete (kumar and Paulo 2014 b). In this test, the Sari city drinking water is used in concrete.

3.2.2 Cement

In this research , Portland cement type II with 315 Kg/m^3 specific weight has been chosen. The modified Portland cement has an application in concrete which requires the hydration heating and mild sulfate attack (ASTM C150 2015; kumar and Paulo 2014 b).

3.2.3 Micro silica

The multipurpose gel is advanced and multipurpose material to have a strong, sealed, impermeable, durable concrete with high flexural and tensile strength. The properties of this material is its high efficiency supplementary reaction in sake of absorbing the free lime and change water to Calcium Silicate which casue to reduce the Alkaline properties of concrete and avoid reacting silica-alkaline between aggregates (Sanjuán et al. 2015). The additive gel effect will be analyzed after using concrete based on ASTMC 1202-05 standard. The amount of Micro Silica gel is 5% of cement (ASTM C 1202 2012).

3.2.4 Stone powder

Table 1
Chemical properties of stone powder

Chemical Compounds	Chlorine	Sylsyvm Oxide	Iron Oxide	Aluminum Oxide	Calcium Oxide	Magnesium Oxide	Sodium Oxide	Potassium Oxide	Phosphorus Oxide	Sulfur Oxide	Other	Drop Blush
Constitutive %	0.02	0.5	-	0.5	55.4	-	-	-	-	-	-	43.13

3.2.5 Natural aggregate

The sand has passed through a sieve no. 4. So, the size of sand is 0.5 mm in concrete with softness modulus of 3.04. The softness modulus evaluate the softness and coarseness of natural fine aggregate which should not be lower than 2.3 and greater than 3.1 [ASTM-C33m 2013; Alberti et al. 2015).

3.2.6 LECA

The LECA has been used with 4-10 mm from Save LECA factory.

3.2.7 Polyolefin aramid fiber

The Polyolefin aramid fiber is used as a reinforced material for concrete or mortar or asphalt in order to reduce the condensation and control the fraction and increase the long term durability. This kind of fiber has ineffective chemical material and it remains in alkaline environment without any problem (Alberti et al. 2014; Alberti et al. 2015).

The physical properties of Polyolefin-aramid fiber include:
Preliminary material: Polyolefin/aramid
Physical shape: Reticular string and single string fiber
Specific weight: 0.91 – 1.44 gr/cm3
Tensile strength: 2800 MPa
Length: 19 mm and 50 mm
Color: Yellow, black, yellowish brown and gray
Melting point: 100-427 °C
Resistant on acidic and alkaline environment.

In this research, 19 mm polyolefin Aramid fiber, 50 mm filamentous polyolefin fiber and 0.91-1.44 gr/cm3 specific mass have been used (Yoo et al. 2015).

Table 2
The preliminary mix design of LECA concrete

Mixes No.	Cement (kg)	Sand (kg)	Wate r (kg)	Micro silica jell (kg)	Stone powder (kg)	LECA (kg)	Specific weight of fresh concrete (kg/m^3)	Compressive strength of cubic sample 7 days (MPa)
1	400	715	180	20	120	320	1750	18/6
2	400	780	180	20	120	300	1800	19/6
3	400	850	180	20	120	270	1840	21/8

3.2.8 Glass fiber

It is a kind of hybrid fiber of two mixed fiber which is designed to reinforce the concrete. It reduces the plastic condensation and hardening of concrete and increase the tensile, bending strength and longevity to reduce maintenance and repairing fees. The specific hybrid of this fiber includes of polyolefin Aramid fiber and glass (Wang et al. 2014; Alberti et al. 2015; Majumdar 1970).

The physical properties of Physical properties (Yoo et al. 2015; Hamad 2015) include:
Primary material: Glass, polyolefin aramid
Physical shape: Reticular string and single string fiber
Specific weight: 1.4 – 2.7 gr/cm3
Tensile strength: 1500 Mpa
Length: 19 mm
Color: Yellow, black, white

3.3 Preliminary mix design

Three preliminary mix designs have been provided in order to have an optimum mix design (ACI 1991; Neville 1981; Ardakani and Yazdani 2014). The following table presents the preliminary tests for LECA concrete (Ardakani and Yazdani 2014). The specific weight is not a calculated specific weight in this table, it is the specific weight per volume of 7 days concrete in water. The unit weight of material is in kg/m^3 (Table 2).

Table 3
The final mix design of LECA concrete

Cement(kg)	Sand(kg)	Water(kg)	Micro silica jell (kg)	Stone Powder (kg)	LECA (kg)	Ratio(w/c)
400	825	180	20	120	280	0/45

3.4 Procedure of preparing the light concrete without fiber

The preparation steps for making concrete include of weighing and mixing the ingredients. In order to reducing the negative effect of water absorption in mixture of concrete by light weight aggregate (LWA), pre-wetting of LWA has been done before mixing the materials. Therefore, the certain amount of water equal to 10% weight of the LECA LWA. This amount of water is considered in calculation of effective water cement ratio and reduce it from water in mixture (ACI 213R-87 1999; ASTM C330 2004).

The Laboratory betoniere is used to mix the material . The concrete was mixed for one minute before casting, it cause to be a uniform. To mix three materials, first LWA and natural aggregate add in mixture then cement add into them, they blend in 30 minutes. Two third of water for concrete is added to the mixture while the mixure is rotating. The rest is blended with Micro Silica gel completely then add mixture. The total concrete mix design takes around 10 minutes from casting until its discharge (Cement Concrete & Aggregates Australia 2004).

After mixing, part of concrete are used for slump test. The result of slump test is illustrated in Table 4.

Table 4
LECA concrete Slump test result

Design	Slump (cm)
L1	6/5
L2	8/3
L3	12
Lf	10

3.5 How to make a LECA concrete

In this concrete, polyolefin aramid fiber or infusion glass fiber add in concrete after the indicated materials and Micro Silica gel. Although, the mixing time would be minimized to avoid the fiber damage due to stones abrasion after adding fiber (Alberti et al. 2018).

This concrete is poured in clean and lubricated 15x15x15 cm cubes in two layers and prismatic frames in three layers then they are compensated with density hammer by hand (BS 1881 1983). After compacting, the samples keep in frame for 24 hours with wetted Tarpaulin. Then they bring out precisely without any damage and impact to the frame and they keep between 20+2c until testing (BS 1881 1983; ASTM C 192 2002).

3.6 Compressive strength test for hardened concrete

Generally, two types of compressive tests have been considered such as cube and cylinder test. The cube type is used in UK, German and most of the Europe counties. The cylinder type has been proposed by US, France and Australia. In this research, cubic specimens have been utilized for compressive strength. First, the specimens are placed in steel or cast-iron frame.

Table 5
The sample with LECA compressive strength results

Sample	Test No.	Average resistance 7 days (MPa)	Average resistance 28 days (MPa)
	1	18.4	21.7
L1	2	18.8	21.9
	Average	18.6	21.8
	1	19.9	23.7
L2	2	19.3	23.5
	Average	19.6	23.6
	1	21.5	25.6
L3	2	21.1	26.2
	Average	21.8	25.9
	1	20.7	25.1
L4	2	20.3	24.7
	Average	20.5	24.9

The cubic frame shape, length of side and polishing the surface should be compatible with advised properties (BS 1881, 1983; Hamad 2015). After the processing, the specimens bring out from frame and they have kept in the pool with 20+2 c temperature (BS 1881, 1983; Hamad 2015; ASTM C 192 2002). Before testing, the specimens come out from the pool and their surface has become dry. Then testing cubic specimens have been placed between two surfaces of machine in the direction which sample is in contact with cubic frame. Now, the vertical forced have been applied to the samples with constant velocity until the cube will break due to compressive force. The force which is written in digital screen of machine will be recorded and the compressive strength will be achieved by division of this force to the cube surface (BS 1881, 1983; Hamad 2015).

3.7 Flexural strength test

To calculate the flexural strength, the prismatic samples have been used with 10x10x5 cm according to ASTM C293 standard (ASTM C293 2010). For the processing, after placing the prismatic samples under the flexural strength machine, the load will be increased by hydraulic jack continuously until sample cracked and broken. Then last load have been read from machine screen and have been recorded (Alberti et al. 2014). The corresponding device is the electrical flexural jack machine with 60 ton capacity. This machine is used to find the flexural strength of concrete in the simple concrete beam with center point load (Alberti 2015). The modulus of rupture has been computed as follows: R=3PL/bd2 (1)

Where,

P: Maximum applied load from machine Lb/f (N)

L: Length of span in (mm)

b: The width average of sample in (mm)

d: The depth average of sample in (mm)

R: Modulus of rupture psi (MPa)

4. Results and findings

4.1 Compressive strength

It has been performed base on BS 1881 standard in cubic samples with 150 mm. in this method, axial load test has applied in samples with certain value and it keeps until their failure. The compressive strength have been achieved by division of maximum applied load to the cross section. This test is done on hardened concrete in 7 and 28 days. Thus, 4 samples from each mix design have utilized for compressive test which the result show in Table 5. As it was expected, the compressive strength is enhanced with increasing the light weight concrete density. L3 sample has the high compressive strength with high specific mass concrete.The LECA concrete compressive strength results are mentioned in Table 5 for 7 and 28 days specimens.

4.2 Flexural strength

It is used base on ASTM C293 standard in prismatic samples with 100x10x10 mm for 7 and 28 days specimens. In this method, prismatic samples have placed horizontally under jack between two support and the load has applied in one point in the middle of span until its failure. The flexural strength have been used for 7-days and 28-days hardened concrete. Three number of each fiber and 5 test for each one are considered.

4.3 Poly polyolefin-aramid fiber test results

For the test with polyolefin string fiber and polyolefin aramid fiber, two specimens for each of three fibers and 2 control samples for their 7 days and 3 samples for each of three fibers and three control samples for theirs 28 days have been tested for flexural strength. The results of 7 days flexural strength are indicated in Table 6 and the results if 28 days flexural strength are shown in Table 7. By the way, the flexural strength result of LECA concrete and polyolefin aramid fiber is illustrated in Figure 1 until 3 for 7 days and 28 days specimens.

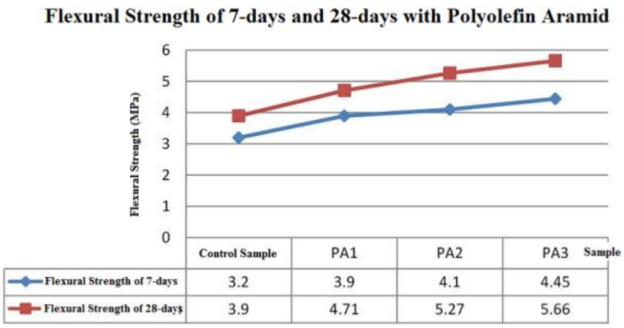

Fig. 1. Comparison graph of the flexural strength in 7-days and 28-days of LECA concrete and polyolefin aramid.

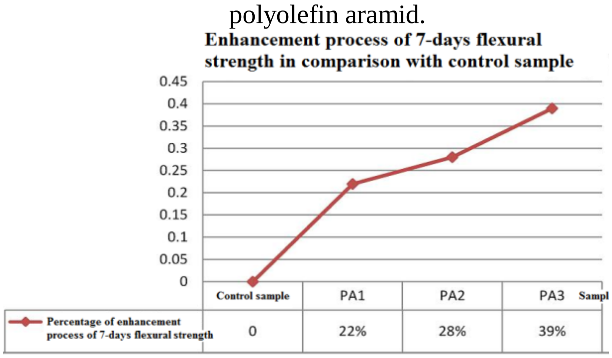

Fig. 2. The enhancement process of 7-days flexural strength of LECA concrete and polyolefin aramid in comparison with control sample.

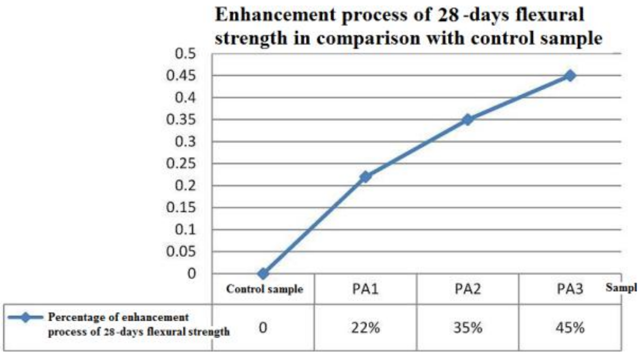

Fig. 3. The enhancement process of 28 days flexural strength of LECA concrete and polyolefin Aramid in comparison with control sample.

Table 6
Flexural strength test result for 7-days LECA concrete and polyolefin aramid

Average (MPa)	Modulus of rupture (MPa)	Sample high (mm)	Sample length (mm)	Sample width (mm)	Sample	19 mm polyolefin Aramid fiber (kg/m3)	Filamentous polyolefin fiber with 50 mm (kg/m3)	Design
3/9	3/8	100	300	100	1	0/5	2	PA1
	3/94	100	300	100	2			
4/1	4/2	100	300	100	1	1	4	PA2
	4	100	300	100	2			
4/45	4/53	100	300	100	1	1/5	6	PA3
	4/37	100	300	100	2			
3/2	3/26	100	300	100	1	0	0	Control Sample
	3/14	100	300	100	2			

Table 7
Flexural strength test result for 28-days LECA concrete and Polyolefin aramid

Average (MPa)	Modulus of rupture (MPa)	Sample high (mm)	Sample length (mm)	Sample width (mm)	Sample	19 mm polyolefin Aramid fiber (kg/m3)	Filamentous polyolefin fiber with 50 mm (kg/m3)	Design
	4/73	100	300	100	1			
4/71	4/64	100	300	100	2	0/5	2	PA1
	4/76	100	300	100	3			
	5/19	100	300	100	1			
5/27	5/33	100	300	100	2	1	4	PA2
	5/29	100	300	100	3			
	5/78	100	300	100	1			
5/66	5/52	100	300	100	2	1/5	6	PA3
	5/68	100	300	100	3			
	4/02	100	300	100	1			
3/9	3/77	100	300	100	2	0	0	Control Sample
	3/91	100	300	100	3			

According to the results, it displays that polyolefin fiber results in enhancing the flexural strength. As it is shown in Figure 3, there is 45% enhancement for 6 kg/m^3 polyolefin string fiber and 1.5 kg/m^3 polyolefin Aramid fiber.

4.4 Results with glass fiber

For this test, there are two specimens for each three fiber and two control samples for 7 days and three specimens for each three fibers and three control samples for 28 days which are considered for flexural strength test. The results of 7-days flexural strength are shown in Table 8 and theirs 28-days in Table 9. Meanwhile, the result of LECA concrete and glass fiber are illustrated in Figure 4 until 6 for 7-days and 28-days samples.

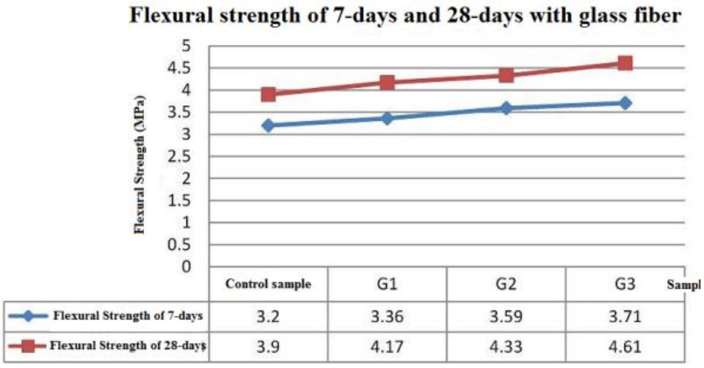

Fig. 4. Comparison graph of the flexural strength in 7 days and 28 days of LW concrete with glass fiber.

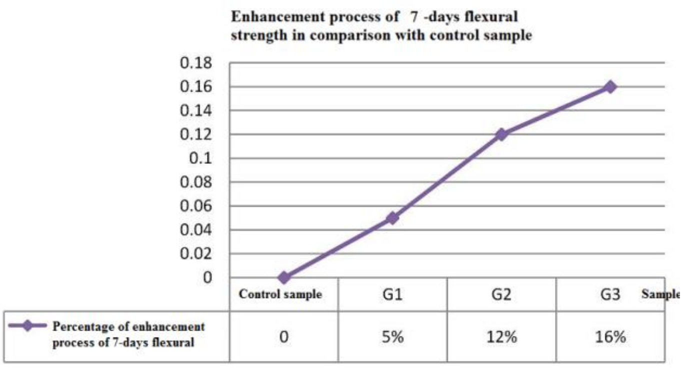

Fig. 5. The enhancement process of 7 days flexural strength of LW concrete with glass fiber in comparison with control sample.

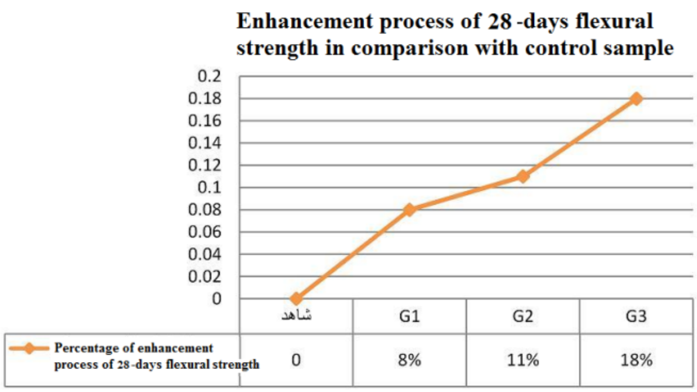

Fig. 6. The enhancement process of 28 days flexural strength of LW concrete with glass fiber in comparison with control sample.

Table 8
Flexural strength test result for 7 days LW concrete with glass fiber

Average (MPa)	Modulus of rupture (MPa)	Sample high (mm)	Sample length (mm)	Sample width (mm)	Sample	19 mm Glass fiber (kg/m3)	Design
3/36	3/3	100	300	100	1	3	G1
	3/42	100	300	100	2		
3/59	3/53	100	300	100	1	4/5	G2
	3/65	100	300	100	2		
3/71	3/74	100	300	100	1	6	G3
	3/68	100	300	100	2		
3/2	3/26	100	300	100	1	0	Control Sample
	3/14	100	300	100	2		

Table 9
Flexural strength test result for 28 days LW concrete with glass fiber

Average (MPa)	Modulus of rupture (MPa)	Sample high (mm)	Sample length (mm)	Sample width (mm)	Sample	19 mm Glass fiber (kg/m3)	Design
	4/1	100	300	100	1		
4/17	4/26	100	300	100	2	3	G1
	4/15	100	300	100	3		
	4/31	100	300	100	1		
4/33	4/47	100	300	100	2	4/5	G2
	4/21	100	300	100	3		
	4/51	100	300	100	1		
4/61	4/62	100	300	100	2	6	G3
	4/7	100	300	100	3		
	4/02	100	300	100	1		
3/9	3/77	100	300	100	2	0	Control Sample
	3/91	100	300	100	3		

According to the results, it shows that fiber glass cause to increase the flexural strength of the samples. As it indicated in Figure 6, there is 18% enhancement for 6 kg/m3 glass fiber.

4.5 Comparison of flexural strength results

In Figure 7 and 8, the LECA concrete with glass and polyolefin fibers are compared in terms of their flexural strength.

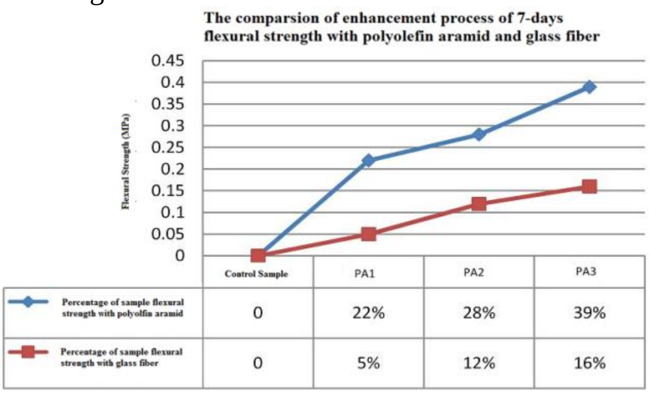

Fig. 7. The enhancement process of 7 days flexural strength with polyolefin aramid and glass fiber.

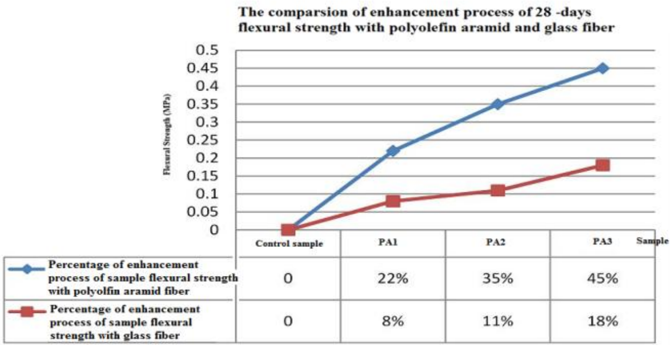

Fig. 8. The enhancement process of 28 days flexural strength with polyolefin aramid and glass fiber.

5. Conclusion

This study investigated the effect of Polyolefin Aramid and glass fiber based on flexural strength of LECA concrete. The amount of used Polyolefin Aramid is 5, 5.2 and 5.7 in each cubic meter and 3, 5.4 and 6 for glass. According to the indicated researches and tests, following results are obtained.

Polyolefin Aramid and glass fiber cause to increase the flexural strength in LECA concrete. Increase strength of LECA concrete directly depends on the length and thickness of used fiber. Using Polyolefin affect on increasing the flexural strength of LECA concrete which enhance around 45%. In addition, the flexural strength will be enhanced by adding the number of fiber. Glass fiber results in increasing the flexural strength of LECA concrete which raise around 18%. Furthermore, the flexural strength will be increased by adding the number of fiber. The flexural strength of samples increase with polyolefin fiber rather than glass fiber because of long length of polyolefin fiber and its material and thickness. Due to 3-D reinforcing the concrete with fiber and distribute the fiber randomly, as long as the number of tests increase, the results will be more accurate.

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