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Investigation of the Mechanical Properties of Lightweight Concrete Containing LECA with Metakaoline Pozzolan Using Polypropylene and Steel Fibers

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ABSTRACT

One of the important problems in designing and implementation of buildings, especially high buildings and large concrete bridges is the significant dead weight of the concrete used in their construction. Therefore, use of a lightweight concrete that has desirable mechanical properties has significant privileges including reduction of concrete sections. These changes will ultimately lead to the reduction of concreting volume and the final price of concrete that has a significant impact on the plan to become more economical. In spite of their benefits, the made concretes by use of lightweight materials, because of porous structure of the aggregates, has less resistance than the normal concretes. In this regard, the role of fibers has been very striking, and especially in lightweight concrete that there is more cavity between its aggregates or grains with lower density are used, utilizing the fibers not only can increase the bonding and interlocking between the grains, but also prevents excessive creation and orifice of the cracks. In this paper, mechanical features of the lightweight aggregate concrete, containing fibers, and with different percentages and same water-cement ratio and same cement content were made, that the made samples, in their ages of 7 and 28 days, were under compressive and flexural strength test, and the results showed that the polypropylene fibers do not have much effect on compressive flexural strength, rather it has effect more on energy absorption capability of lightweight concrete, but steel fibers had significant impact on strength.
KEYWORDS: Lightweight concrete, polypropylene and steel fibers, compressive and flexural strength.

1. INTRODUCTION

Today use of concrete structures in constructing civil projects has developed to a large extent. This feature shows the benefits that this substance has. Alongside these advantages, the concrete has some disadvantages including high bulk density, weakness in carrying the tensile loads, and relatively low ductility. These advantages and disadvantages cause researchers to be diligent in particular applications toward optimization of properties of concrete by use of methods and additive materials. This includes methods of weight loss, aeration techniques and lightweight concrete or pozzolan. To reduce the disadvantage of ductility and tensile, use of different fibers in concrete has had significant development[1, 2].

Use of lightweight concrete, due to economic and other reasons is growing increasingly. The cost of constructing the structures with this concrete is far less than normal concrete. Use of lightweight concrete also reduces the transportation and earthquake load costs. The bulk density of light-concrete structures ranges from 1440 kg/m^3 to 1840 kg/m^3[3]. The behavior of high-strength concrete is like normal concrete. Even, binding between the elements in lightweight high-strength concrete is more than normal concrete[4, 5].

REVIEW OF THE LITERATURE

In a paper, Karahan et al.[6], by examining the effects of 0, 15, and 30% of fly ash with percentages of 0.5, 0.25, 0, 1, and 1.5% of steel fibers found that the percentage 15 gives the best result with 1% of fibers and also, even toward melting and successive ice gives the best result[6]. Balendran[7], by use of 1% of steel fibers found that it has significant effect on flexural and tensile strength of the concrete. By using steel fibers of 0, 0.5, and 1% Sharma [8] found that using the fibers of 1% has led to the increase of all mechanical properties of the concrete.

2. MATERIAL AND METHODS

The aim of the study program is investigation of the effects of steel and polypropylene fibers on lightweight concrete and also comparison of their effects along with pozzolanmetakaolin on compressive and flexural strength of the lightweight concrete that, of course, investigation of these properties is considered in concrete

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with high performance and water-cement ratio of 0.37 because minor changes in water-cement ratio leads to significant changes in resistance properties. In this experiment from each mix design, six block samples of 10×10×10 were made; three of which at the age of 3 days, and the other three samples at the age of 28 days were under the compressive strength test and their mean was presented as the result of the test. Also, from each mix design three samples of 10×10×50 were under flexural strength test in the age of 28 days.

2.1. Raw Materials

2.1.1. Cement

The cement used in this study is Isfahan ordinary Portland cement Type 1, with standard of Iran (ISIRI). Physical features and chemical composition of the cement is given in tables 1 and 2 respectively.

Table 1. Physical properties of the cement used in this study

Property	Density (g/cm^3)	Specific Surface, Blain (cm^2/g)	28-Day Compressive Strength (MPa)	Heaped Density (g/cm^3)
Content	3.05	3420	44.5	1.7

Table 2. Chemical analysis of cement

Forming Oxides	SiO2	Al2O3	Fe2O3	CaO	MgO	SO3	Na2O+K2O	LOI
Portland Cement	21	4.6	3.2	64.5	2	2.9	1	1.5

2.1.2.Metakaolin

Metakaolin is an amorphous aluminum silicate with pozzolanic properties that based on ASTM C618 Standard is in pozzolan class N category (raw or calcined natural pozzolan) and like other pozzolans, reacts with calcium hydroxide caused by cement hydration and produces Calcium Silicate Hydrate (C-S-H). The incoming raw material in production of Metakaolin is kaolin clay that by this mineral clay Metakaolin is obtained during a controlled heat treatment at a temperature of 650-800°C. This temperature will remove the chemical water of kaolin and destroys its crystalline structure[9].Kaolin is very fine white mineral clay that has been traditionally used in production of china (Fig. 2). In table 3 the physical features of the used Metakaolin are given.

Fig. 2.

Table 3. Physical characteristics of Metakaolin

Particle Size	Between 0.2 to 1.5 micron
Specific Surface	10000-29000 (kg/m^2)
Bulk Density	2.6 (g/cm^3)

2.1.3. Lightweight aggregate (LECA)

The term LECA is derived from Light Expanded Clay Aggregate. Usually, raw materials that are used to make these lightweight aggregates are formed from sedimentation of the natural materials like clay, shale, and slate that contain a lot of silica. These aggregates are prepared by use of two ways of rotatory furnaces and sedimentation. In both methods, the raw materials are so heated to become expanded. In the process of expansion, the heat will continue until the internal gases of the materials are released and materials become soft and flexible, but will not completely melt. In this stage, the bubbles of internal gases cause pores among the pasty materials. Therefore raw expanded materials and aggregates with a lower bulk density are achieved. [ASTM C78][10] Bulk density of LECA concrete (that is entirely made of LECA) in its compact state is 950 kg/m^3. In table 4, the density of lightweight aggregates is given separately. The low weight of the grain is because of the empty space inside them that based on gradation occupies between 73 to 88 % of the total space. In this research work, the LECA used is directly prepared from Iran LECA company, located in Saveh.

Table 4. The density of lightweight aggregates of LECA

Sample Type	LECA with gradation of 0-4	LECA with gradation of 4-10	LECA with gradation of 10-19
Density	0.99	0.67	0.5

2.1.4. Sand

In this study the sand used is washed river sand 0-5 that is prepared from the Soffe Mountain of Isfahan. Bulk weight of this sand equals to 2590 kg/m^3, also its fineness modulus is 2.81.

2.5.1. Super plasticizer

The super plasticizer used is Polycarboxylate with 40% solid material and true bulk weight of 1081.73 made in Abadgaran Company. The percentage of super plasticizer was set based on fluidity and high performance of the mix design.

2.1.6. Water

The water used in this research is municipal tap water.

2.1.7. Polypropylene and steel fibers

Denir is unit of measuring the mass density of fibers that is defined as the mass in grams to 9000 meters.

Table 5. Properties of Polypropylene fibers

Item	Content	Unit
Type of Material	100% pp	-
Type of Finishing	Hydrophilic	-
Color	White	-
Melting Point	165	Centigrade
Acid and Salt Resistance	High	-
Length	6	Millimeter

Table 6. Properties of steel fibers

Length	Width	Thickness
25 mm	2 mm	0.6 mm

3. Mixing method

The mixer used in this study is of a gyratory type with a maximum volume of 50 liters.

Method of mixing materials is as follows:

First, dry materials were completely mixed together in the mixer for two minutes. Then 50 percent water and the total cemented materials were also added and mixed for three minutes and finally a solution is made from the rest of the water and super plasticizers that would be added to the cement, and let them to be completely mixed together for 5 minutes. Then, the concrete was poured into the intended molds and after 24 hours the samples were removed from the molds and were placed in a water basin with 23°C.

3.1. The Mix Design

The mix design details are shown in table 7. The ratio of water to cemented material is considered to be 0.37 for all combinations, that for each design 1% of the cement volume is selected. Also, for accurate comparison of compressive strength, the ratio of water to cemented materials and the percentage of super plasticizers are kept constant.

S_0: is the control plan of lightweight concrete.
S_1: is the design of 1% polypropylene fibers in lightweight concrete.
S_2: is the design of 1% steel fibers on lightweight concrete.
S_3: is the design of 1% polypropylene fibers with 10% Metakaolin in lightweight concrete.
S_4: is the design of 1% steel fibers along with 10% Metakaolin in lightweight concrete.

Table 7. Mix designs

Mix Name	S0	S1	S2	S3	S4
The Percentage of Fiber	0	1	1	1	1
The Percentage of Metakaolin	0	0	0	10	10
Cement (kg/m^3)	500	500	500	450	450
Metakaolin (kg/m^3)	0	0	0	50	50
LECA Sand	260	260	260	260	260
LECA 4-10	110	110	110	110	110
Washed Sand	560	560	560	560	560
Water (kg/m^3)	185	185	185	185	185
Super Plasticizer	5	5	5	5	5
Cemented Water/Material	0.37	0.37	0.37	0.37	0.37
Cemented Plasticizer/Material	1%	1%	1%	1%	1%

4. Compressive Strength Test

For each mix design 6 block samples of 10 Cm were made, all of which were taken out of the mold after 24 hours and were placed in a water basin with temperature of 23 °C and were tested at the ages of 7 and 28 days, and the average of the three samples was recorded as the compressive strength. The compressive strength test on the samples was done by standard press machine with upload controlling of 3.00 Mpa/s. Also, to do flexural strength test, a prismatic sample of 10×10×50 Cm was made and was tested in age of 28 days.

5. LABORATORY RESULTS AND DISCUSSION

The results of compressive and flexural strength tests are given in table 8 and in graphs 1, 2 and 3 in a comparative way.

To determine the flexural strength of the concrete, the method of applying two concentrated loads on beam with simple support was used (JabalAmeli) [11] that its results is given in graph 3 in a comparative way.

Table 8. Results

Item	7-Day Compressive Strength	28-Day Compressive Strength	28-DayFlexural Strength	Density
S0	17.6	21.4	1.9	1790
S1	18	23	2.01	1830
S2	20.1	24.3	2.1	1829
S3	24	28.97	2.9	1888
S4	26.6	31.7	3.2	1890

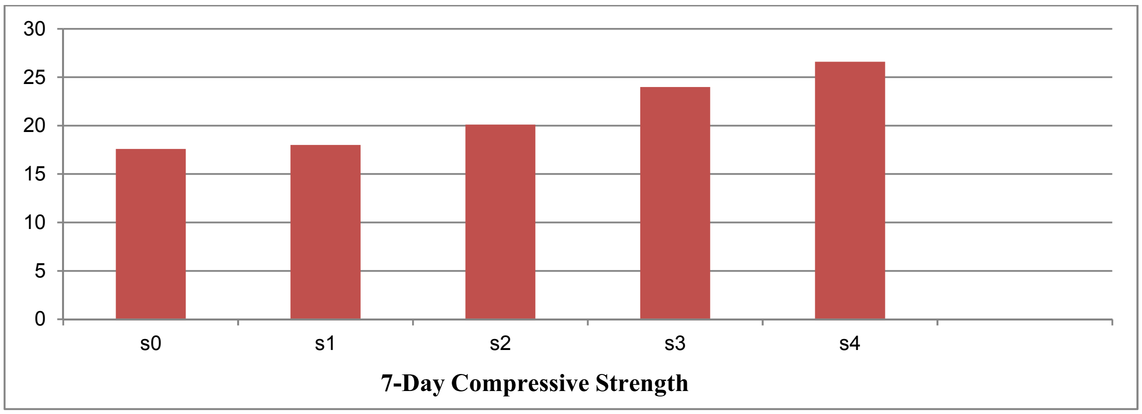

Fig 1. The result of compressive strength

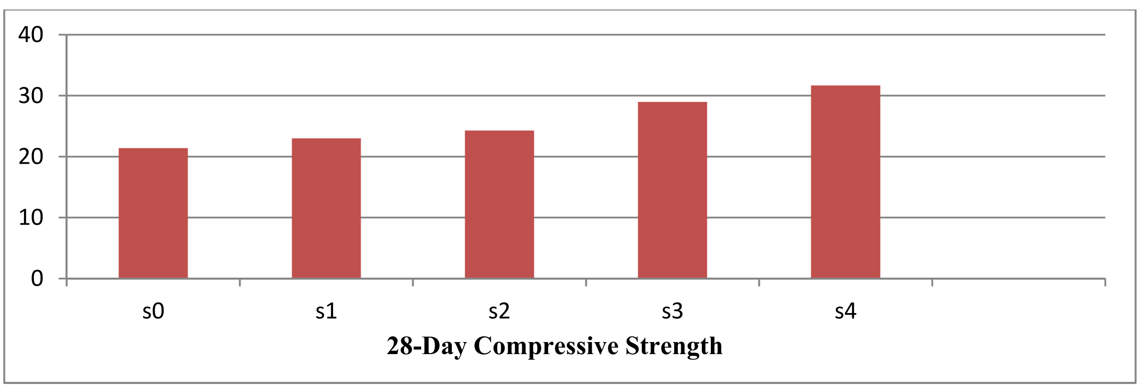

Fig 2. The result of compressive strength

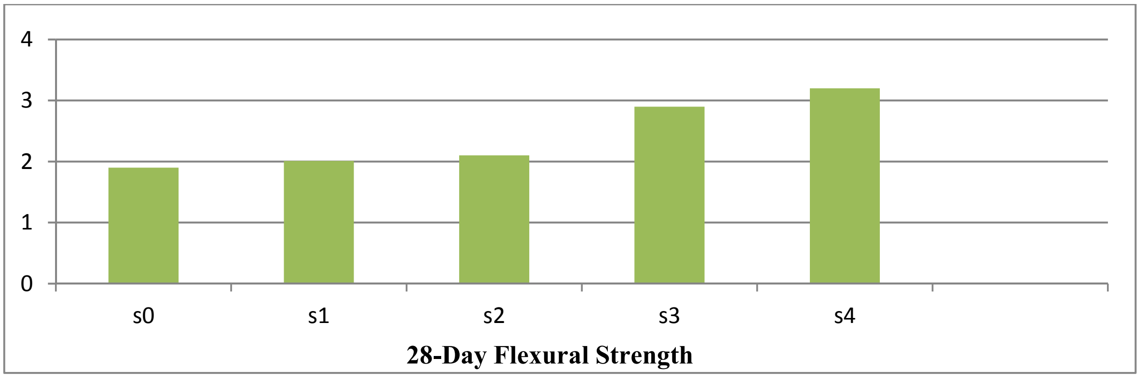

Fig 3. The result of flexural strength

As the table of results and the graphs show:

By adding 1% of polypropylene fibers to its control design, only 2.25% to its compressive strength and 5.7% to its flexural strength will be added, while with the same amount of steel fibers we see 36.3% increase in compressive strength and 52.6% in flexural strength, and these numbers will increase more by adding Metakaolinpozzolanto the control design.

6. CONCLUSION

According to this study, the following conclusions are drawn:

- ❖ 1% adding of steel fibers in lightweight concrete will result in a significant strength increase in its compressive and flexural strength.
- ❖ Adding 1% of polypropylene fibers in lightweight concrete do not have any significant increase in the strength.
- ❖ By adding 10% Metakaolinpozzolan to the concrete, in concretes that contain fibers, we will see increase in strength compared to the effects of pozzolan, alone, in concrete.

REFERENCES

[1] Hasani A. The effect of steel fibers on controlling the tensile cracks of concrete. Maskan Research Center, G Journal. 1999.

[2] Kaivani A. Principle and technology of concrete containing steel fibers: Roodaki Publication; 1990.

[3] Neville AM. Properties of concrete: Longman Group Ltd; 1995.

[4] Mitchell DW, Marzouk H. Bond characteristics of high-strength lightweight concrete. ACI Structural Journal. 2007;104:22.

[5] Mouli M, Khelafi H. Strength of short composite rectangular hollow section columns filled with lightweight aggregate concrete. Engineering structures. 2007;29:1791-7.

[6] Atiş CD, Karahan O. Properties of steel fiber reinforced fly ash concrete. Construction and Building Materials. 2009;23:392-9.

[7] Balendran R, Zhou F, Nadeem A, Leung A. Influence of steel fibres on strength and ductility of normal and lightweight high strength concrete. Building and Environment. 2002;37:1361-7.

[8] Sharma A, Reddy G, Varshney L, Bharathkumar H, Vaze K, Ghosh A, et al. Experimental investigations on mechanical and radiation shielding properties of hybrid lead–steel fiber reinforced concrete. Nuclear Engineering and Design. 2009;239:1180-5.

[9] Zolfaghari A. On the analysis of the role of Metakaoline on increasing the resistencey of concrete. The First National conference on Civil engineering. Gilan2010.

[10] ASTM. Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third –Point Loading).

[11] Jabal. A B. On the analysis of Microsilica on resistancy and durability of on structional lightweight concrete. Third National Conference on Civil Engineering. Sanandaj2011.