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High-Strength Lightweight Concrete Using Leca, Silica Fume, and Limestone

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Abstract This paper determines mix proportions of high-strength structural lightweight concrete (HSSLWC), which reduces the weight of concrete by using expanded aggregate clay (Leca). In order to produce HSSLWC, mineral and chemical admixtures have been used along with limestone that reduces porosity and increases strength. Tests for specific gravity, and compressive, indirect tensile and flexural strengths were carried out on the specimens. The effect of curing on the compressive strength was investigated by keeping some specimens in open air. The results obtained showed that by using Leca, a lightweight structural concrete (LWSC) can be achieved, with dry density in the range of 1,610–1,965 kg/m^3 and compressive strength in the range of 34–67 MPa, based on cube specimens with 100 mm side length. Limestone significantly improved the mechanical properties of concrete whenever mixed with lightweight aggregates.

Keywords Lightweight concrete · Density · Leca · Limestone · Silica fume

الخلاصـه

تحدد هذه الورقة نسب خلط الخرسانة العالية القوة والخفيفة الوزن (HSSLWC) التي تقلل وزن الخرسانة باستخدام ركام الطين الموسع (leca). ولغرض إنتاج (HSSLWC) يتم استخدام مضافات معدنية وكيميائية مع الحجر الجيري الذي يقلل المسامية وتزيد من القوة. ثم إجراء اختبارات عدة مثل اختبار الكثافة النوعية، وقوة الضغط، واختبار الشد غير المباشر واختبارالانحناء على العينات. إن تاثير المعالجة على قوة الضغط تم فحصها بوضع بعض العينات في الهواء المفتوح. وقد أظهرت النتائج أنه باستخدام (leca) يمكن الحصول على خرسانة حقيقية الوزن (LWSC) بكثافة جافة في حدود 1965 -1610كجم/م^3. وقوة ضغط في حدود34-67 ميجاباسكال على عينات مكعبة بقياس 100مم. إن الحجر الجيري قد حسن بشكل ملحوظ الخواص الميكانيكية للخرسانة كلما تم خلطة بالركام الخفيف الوزن.

1 Introduction

The escalating environmental problems, along with the rapid depletion of conventional aggregates simultaneously, have spurred the use of aggregates from by-products and/or solid waste materials from different industries [1]. Lightweight concrete is known for its advantage of reducing the self-weight of the structures and areas of sectional members, thus making the construction convenient.

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Construction costs can be reduced when lightweight concrete (LWC) is applied to structures such as long-span bridges and high-rise buildings. However, LWC requires a specific mixture method that is quite different from conventional concrete. Using conventional mix design methods would result in raised material segregation, as well as reduced strength due the lower weight of the aggregate. To avoid such problems, it is recommended to apply the mix design method of using high-performance self-compacting concrete for the LWC [2].

Since the forces of earthquakes that influence civil engineering structures and buildings are proportional to the mass of those structures and buildings, reduction of the mass of structures or buildings is of utmost importance for earthquake sustainability and cost-effectiveness. One of the ways to reduce the mass or dead weight of a structure is the use of LWC in the construction. Lightweight concrete can easily be produced by utilizing natural lightweight aggregate, i.e., pumice, perlite, and Leca.

Some researchers report that structural lightweight concrete (SLWC) has its obvious advantages of higher strength/weight ratio, better tensile strain capacity, lower coefficient of thermal expansion, and superior heat and sound insulation characteristics due to air voids in the lightweight aggregate.

Furthermore, it has also been reported that the reduction in the dead weight of a construction, by the use of lightweight aggregate in concrete, could result in a decrease in the cross section of columns, beams, plates, and foundations. It is also possible to reduce the need for steel reinforcements [3].

Lightweight aggregate concrete (LWAC) has been used successfully for structural purposes for many years. For structural applications of LWC, the density is often more important than the strength. A decreased density for the same strength level reduces the self-weight, foundation size, and construction costs [4].

The studies of Norokshchenov and WhitComb have shown that it can be possible to make lightweight concrete with compressive strength 70.5 MPa and density 1,860 kg/m^3 by using Leca, 520 kg/m^3 cement and 20 % silica fume (% by cement weight) [5].

Some researches have shown that it can be possible to produce lightweight concrete with 90 days compressive strength, 43.8 MPa and dry density 1,860 kg/m^3 by use of basalt-pumice aggregate, 450 kg/m^3 cement, and 10 % silica fume (% by cement weight) [3]. Another investigation has shown that lightweight concrete can be produced with 28 days compressive strength, 53.6 MPa, and dry density of about 1,605 kg/m^3 by using Brazilian's LWC [4].

Malhotra has produced LWC of 365 days compressive strength, 70 MPa, and dry density 2,000 kg/m^3 by using Leca. Malhotra found that the best mix proportion was produced when 500 kg/m^3 of cementation material is included and cement type III ASTM, fly ash, and suspense silica fume are used [6].

Lightweight aggregate concrete has been used successfully for structural purposes for many years. For structural applications of lightweight concrete, the density is often more important than the strength. A decreased density for the same strength level reduces the self-weight, foundation size, and construction costs. With the rapid development of concrete technology in recent years, higher-performance concrete can be produced more easily. High-performance lightweight concrete is an ideal construction material in many countries such as Brazil because of weather conditions and low cost. However, very little information is available on the mechanical properties of high-performance lightweight concrete with Brazilian lightweight aggregate (lightweight expanded clay) [7,8]. Lightweight concrete is an ideal material for construction in the hot coastal environment because of its thermal insulation characteristics [9].

There is worldwide environmental, economic, and technical impetus to encourage the structural use of LWAC [10,11]. LWAC has been used successfully for structural purposes for many years. For structural applications of lightweight concrete, the structural efficiency is more important than only a consideration of strength.

There are a number of methods to produce lightweight concrete. In one method, the fine portion of the total concrete aggregate is omitted, which is called "no-fines". Another way of producing LWC is to introduce stable air bubbles inside concrete by using chemical admixtures and mechanical foaming. This type of concrete is known as "aerated", "cellular or gas concrete". The most popular way of LWC production is by using lightweight aggregate. Such aggregates, natural or artificial, are available in many parts of the world and can be used in producing concrete in a wide range of unit weights and suitable strength values for different fields of applications [11].

The results reported (http://www.leca.ir/LECACONCRETE.pdf) show that making building components from lightweight Leca concrete is possible. In fact, it is more economical to use Leca concrete rather than ordinary concrete in constructing building, since lighter weight of building also includes: easy transportation, less reinforcement use and reduction in dimensions of foundation. Usually, with increasing density of Leca concrete its strength gets higher; this kind of concrete is used for sloping drainage and thermal resisting elements with low density (400–1,000 kg/m^3), nonstructural elements with medium density (1,000–1,300 kg/m^3) and load-resisting structural elements with high density (1,300–1,800 kg/m^3). Leca concrete for structural elements must have a design compressive strength of at least 15 MPa and density of at most 1,800 kg/m^3. Structural components made of Leca concrete have been used in America for the past 50 years. Leca concrete with compressive strength of higher than 7.0 MPa is considered usable in building construction. For Leca concrete with density of less than 1,841 kg/m^3, compressive strength of 63.3 MPa has been reported. Leca concrete, compared with other lightweight concrete, possesses a very high strength to density ratio. Lightweight concrete can be used to make structural elements and save money, especially in high-rise building, building on a low strength soil and also where there is a not sufficient coarse aggregate mine. Leca concrete like the ordinary one can be prepared by mixing aggregate (Leca or Leca and sand), cement, and water. In Leca concrete, instead of using ordinary aggregates, one uses Leca aggregate or Leca and ordinary sand. Heating wet and formed clay soil at 1,300 °C in a kiln produces Leca aggregate. In the heating process, the gases are produced, condensed, allowed to escape from the aggregate and finally cause voids inside the aggregates. The production of Leca aggregate is accomplished by different methods. In Iran, they are produced by expansion of moist clay soil in a rotary kiln. LECA aggregates are produced according to the ASTM C330 & C331 and LECA concrete shall meet the guideline of ASTM 211.2 & 318.

This investigation has two aims. The first is to produce an applicable LWC with appropriate compressive strength by using Leca. The second one is to study the factors affecting on improvement of the mechanical properties of LWCs; e.g., type and content of cement used, particle size of the aggregate Leca, different replacement levels of Leca, W/B ratio, and limestone. For comparison of curing condition effects, for each of the nine mix designs, five samples were cured in the air and tested after 28 days to determine the compressive strengths.

2 Materials

Previous researchers have shown that LWCs made with cement type II have more compressive strength at early and later ages compared to cement type I. This increment in compressive strength is about 6 MPa [12]. In this study, cement type II with density 3,150 kg/m^3 and Blain's specific area 0.306 m^2/g are used. The initial and final setting times are 175 and 230 min, respectively. This cement also has compressive strengths at 3, 7, and 28 days of 17.4, 21.4, and 34.1 MPa, respectively. The silica fume used in this study has been produced in Iran's iron–silicon industry. The density and Blain's specific area of silica fume are 2,200 kg/m^3 and 20.2 m^2/g, respectively. The silica fume content in previous works has been used in a wide range by cement weight, and it is used in concrete as replacement of cement [13,14]. In this study, silica fume was added to mixes in the powder form. Limestone was used to fill the voids, to improve the strength. Limestone is a very common sedimentary rock of biochemical origin. It is composed mostly of the mineral calcite. Sometimes it is almost pure calcite, but most limestone is filled with lots of other minerals and sand and has the name 'dirty limestone'. Limestone is a sedimentary rock that has been made from the mineral calcite, which came from the beds of evaporated seas and lakes and from sea animal shells. This rock is used in concrete and is an excellent building stone for humid regions. Limestone is an important type of rock. It can be used for building materials, but it is not quite as strong as sandstone and is easily weathered by acidic conditions. Limestone is the primary source of lime for cements. It can be crushed and used as road ballast. Significant quantities of limestone are quarried around the world for these purposes. The rock which contains more than 95 % calcium carbonate is known as high-calcium limestone.

Recrystallized limestone takes good polish and is usually used as decorative and building stone. Limestone has a hardness of 3–4 on Moh's scale, with a density of 2,500–2,650 kg/m^3, compressive strength of 180–210 MPa, and water absorption of less than 1 %. The chemical compositions of silica fume and limestone are given in Table 1.

The chemical composition of Leca is shown in Table 1. Leca is produced by heating clay, in movable furnaces, at high temperatures up to 1,100 °C. It is produced in spherical shapes, has a rough surface, and comes in varying sizes. The inside of the aggregate has a black sponge texture with 73–88 % porosity. The high porosity of the aggregate causes improvement in some properties such as low weight, low heat conductivity, sonic loss, and high resistance against firing. The aggregates have a coating with a thickness of about 50–100 μm. The coating has less absorption compared to the internal texture.

The color of Leca has a high dependency on the mineral materials and the method of its production, as well as production quality.

Table 1 Chemical analysis of Portland cement, silica fume, Leca aggregate, and limestone

Composition (%)	Cement type II	Silica fume	Leca	Limestone
SiO_2	22.00	94.6–96.4	–	0.50
Fe_2O_3	3.20	0.87	66.05	–
Al_2O_3	4.44	1.32	7.10	0.50
CaO	64.92	0.49	16.57	55.4
MgO	1.42	0.97	2.46	–
Na_2O	0.27	0.31	1.99	–
K_2O	0.58	1.01	0.69	–
P_2O	–	0.16	2.69	–
SO_3	1.67	0.10	0.21	–
Extra oxides	1.30	–	0.03	–
Cl	–	–	0.84	0.02
LOI	–	–	–	43.13

Table 2 Mix proportions for cube samples (kg/m^3)

Mix no.	*C* (kg)	SF (kg)	SP (l)	*W* (kg)	*W*/*B* (–)	Sl (mm)	RS (kg)	LS (kg)	Leca (kg)	Leca size (mm)
1	450	50	9.0	200	0.40	40	660.4	–	355.6	2.00–4.00
2	450	50	9.0	200	0.40	50	660.4	–	355.6	1.00–2.00
3	450	50	9.0	200	0.40	65	660.4	–	355.6	0.50–1.00
4	495	55	11.0	176	0.32	250	639.1	–	273.9	2.00–4.00
5	495	55	11.0	176	0.32	260	485.1	220	207.9	1.00–2.00
6	540	60	9.0	192	0.32	250	434.8	180	234.2	0.00–4.00
7	495	55	6.6	154	0.29	100	553.6	165	234.2	0.00–4.00
8	495	55	6.6	192	0.35	75	474.5	165	312.2	0.00–4.00
9	495	50	12.5	192.5	0.35	–	474.5	165	443.8	2.00–4.00
10	450	45	6.75	153.4	0.31	–	669.3	–	482.0	0.50–1.00
11	495	55	7.2	154	0.28	–	554	176	238.8	0.00–4.00

C cement, *SF* silica fume, *SP* super plasticizer, *W* water, *B* C + SF = binder, *Sl* slump, *RS* river sand, *LS* limestone

Leca is usually brown in color. These aggregates are used in loaded LWC as fine, coarse, and mix modes with density of 1,120, 880, and 1,040 kg/m^3, respectively. In this study, fine modes of Leca have been used, with absorption percentages of 13.5 and 29 % for soaking periods of 0.5 and 72 h, respectively.

The sand used is river sand with a sand equivalent (SE) and fineness modulus (FM) of 70 and 3, respectively. The particle size analysis (PSA) of the sand is based on ASTM. The super plasticizer (SP) used in all mixtures is sulfonate naphthalene formaldehyde.

3 Mix Proportions

Leca aggregate has a low weight and it may be a reason for segregation in the concrete. Higher slumps increase this segregation. To overcome this problem, Leca can be used with silica fume and an appropriate SP. In all the mixes, 10 % silica fume was used as cement replacement along several varying of SP were used, so as to obtain a normal consistency. Mix proportions of 11 mixtures are given in Table 2. Mix no. 1, 2, and 3 have the same details except with varying Leca sizes. In the three mixes, there are 35 % of Leca (based on whole aggregate Leca + sand). The Leca used has a discrete PSA with sizes 2–4, 1–2, and 0.5–1.0 mm. In the mix no. 4 and 5, in order to achieve higher strength, less water and more cement have been used and the Leca content is 30 % of the whole aggregate. The highest content of cement has been used in mix 6 with continuous PSA for Leca. The mix no. 7 and 8 have been designed to obtain the highest compressive strength and lowest specific gravity. Determination of the optimum mixtures; i.e., mix 7, is based on strength viewpoint and is shown in Fig. 1.

3.1 Curing Regimes of the Samples

In this investigation the specimens were cured in two forms as curing in open air; i.e., cuing in the air out of concrete lab, and water cured. In Fig. 3 without curing and with curing mean curing in air and water cured, respectively. Based on the figure it is evident that all the mixtures have higher strengths when the specimens

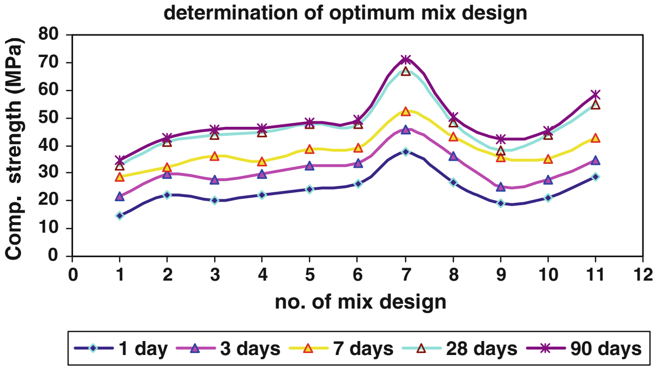

Fig. 1 Optimum mixture based on compressive strength viewpoint

Table 3 Leca PSA and density for cube samples (kg/m^3)

Mix no.	PSA of Leca (mm)					Density at 28 days	
	2.00–4.00	1.00–2.00	0.50–1.00	0.25–0.5	0.0–0.25	Wet	Dry
1	355.6	–	–	–	–	1,658 ± 29	1,610 ± 13
2	–	355.6	–	–	–	1,700 ± 23	1,653 ± 18
3	–	–	355.6	–	–	1,766 ± 26	1,675 ± 34
4	273.9	–	–	–	–	1,769 ± 26	1,727 ± 36
5	–	207.9	–	–	–	1,862 ± 29	1,810 ± 28
6	35.1	128.8	42.1	16.4	11.8	1,810 ± 23	1,759 ± 39
7	35.1	128.8	42.1	16.4	11.8	1,984 ± 25	1,965 ± 21
8	46.8	171.7	56.1	21.9	15.7	1,757 ± 24	1,720 ± 29
9	443.8	–	–	–	–	1,753 ± 18	1,652 ± 20
10	–	–	482	–	–	–	1,622 ± 22
11	47.76	47.76	47.76	47.76	47.76	–	1,890 ± 26

are cured in the water. It is also clear that the optimum mixture; i.e., mix 7, has the highest strengths whenever the specimens are cured in the air compared to the other mixtures at the same conditions; the reason is related to the mix proportion of mix 7.

Since Leca aggregates are very light, air voids can remain in fresh concrete, even after vibration. In the mixtures, it has been observed that although the mixes have been properly vibrated, some air voids remain in fresh concrete. After vibration, visual examining of the surface showed air voids. Therefore, to obtain a homogenous texture in concrete for reducing porosity, in the mix no. 5 to 8, limestone was used. The mix proportions for cube samples are shown in Table 2.

Compressive, indirect tensile, and flexural strengths were used for cube with a side 100 mm, cylinder with 100 mm diameter and 200 mm length, and prisms with dimensions 100 mm × 100 mm × 150 mm, respectively. Compressive strengths were determined at 1, 3, 7, 28, and 90 days and for each age six specimens were used. The tensile and flexural specimens were tested at 28 days with three samples for each test. All specimens were demolded after 24 h and then cured in water of 20 ± 2 °C until test day. In order to study the effect of curing on 28 days compressive strength, for each of the nine mixtures, five cube samples were cured in air with (60 ± 15) % relative humidity (RH) until test day. The PSA of Leca and specific gravity for cube samples are given in Table 3.

4 Results and Discussion

4.1 Compressive Strength

The results obtained in this study show that it is possible to achieve the desired compressive strength by using Leca. It has been shown that the specimens without limestone had some voids after testing, but the voids were reduced in specimens with limestone. Moreover, the specimens including limestone had smoother external

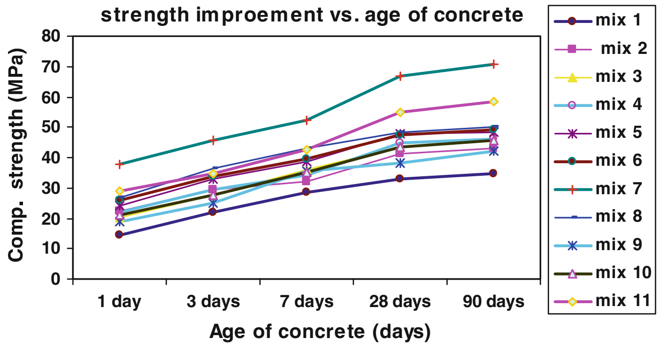

Fig. 2 Compressive strength versus the age of concrete specimens

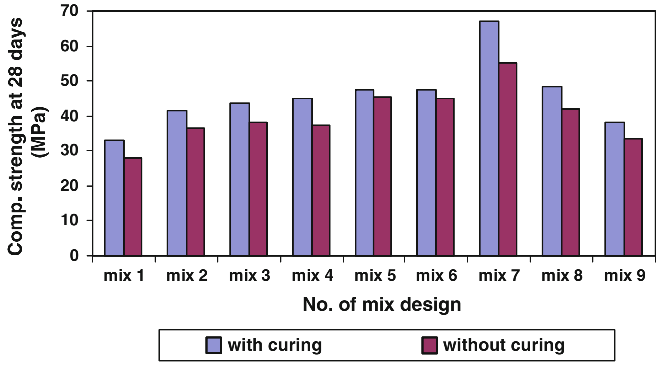

Fig. 3 Effect of curing condition on compressive strength at 28 days

surfaces. It was concluded that reducing the voids caused a noticeable improvement of the strengths. Compressive strength versus curing age is shown in Fig. 2.

The effect of curing on compressive strength at 28 days is shown in Fig. 3. It is clear that for all mixtures, compressive strengths of samples cured in air was reduced by about (5–18) % when compared with those cured in water. Variations in PSA of Leca affect compressive strength. Based on mix no. 1, 2, and 3, it is clear that a greater fineness of aggregate size results in an increase in compressive strength. It is observed that whenever the aggregate size is changed from 2 to 4 mm to 1 to 2 mm and 0.5 to 1 mm, compressive strength is increased about 20 and 27 %, respectively. Standard deviation for compressive strength at 1, 3, 7, and 28 day ages are (2–10), (2–9), (5–8), and (4–8) %, respectively. The ratios of 1, 3, and 7 days compressive strengths to 28-day compressive strength for the samples cured in water are (44–51), (63–75), and (76–94) %, respectively.

4.1.1 Determination of the Optimum Mixture

From Fig. 2 and based on the given data in Table 2 and comparison of the strengths obtained for different mixtures especially the mix no. 7 and 11, it can be said that water–binder ratio is the most important factor of the strength improvement. The ratio is 0.29 and 0.28 for the mix no. 7 and 11, respectively. The Leca contents and their grain size distribution are the same for both the mixtures. It can also be seen that the values of slump for both the mixtures are 100 mm and 0, respectively; this may be because the limestone content of mixture 11 is more, about 7 %, than that of mixture 7. It should be noted that more limestone results in more absorption. Also, the contents of cement, silica fume, and water used in both the mixtures are the same. Moreover, it can be seen that the grain size distribution of Leca in mixture 7 is not uniform, whereas it is uniform in mixture 11. Sand–binder ratio is also an important factor that is the same for both the mixtures. Finally, it can be expected that the strengths of mixture 7 are higher than those of the other mixtures.

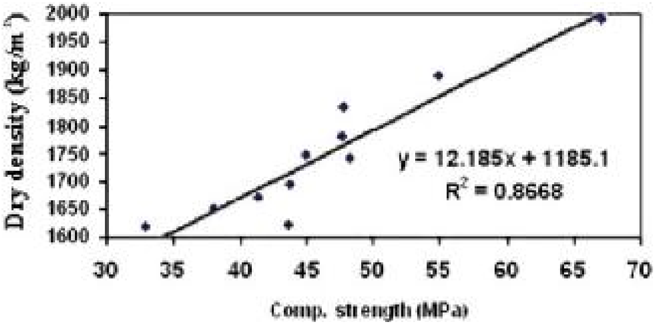

Fig. 4 Relationship between dry density and compressive strength

4.2 Specific Gravity

Average wet and dry specific gravities for mix no. 1 to 9 are shown in Table 3. Wet density means the unit weight of concrete specimens kept in the molds, with a surface dry condition after 24 h. Dry density means the unit weight of concrete specimens after 28 days curing in open air. If 2,400 kg/m^3 is assumed for unit weight of normal concrete, it can be seen that the unit weight of LWC is reduced by about (17–31) %. This result shows that whenever LWC is used, the lateral forces due to earthquake can be reduced, since dead weights of structural elements have been notably reduced. The specific gravity of LWC on incorporating Leca depends highly on the Leca content used. Increasing the Leca content in the concrete causes a greater decrease in specific gravity. In order to study the influence of Leca's PSA on specific gravity of LWC, mix no. 1–3 were made with different PSA. It is seen that by using a greater fineness of Leca, the specific gravity of concrete is also greater. Indeed, by using an aggregate size of 1–2 mm instead of 2–4 mm and 0.5 to 1.0 mm instead of 1 to 2 mm, the specific gravity increased by about 2.7 and 1.3 %, respectively.

In mix no. 4 and 5, there are differences between limestone and Leca contents. It is seen that dry density has been increased from 1,727 to 1,810 kg/m^3. Therefore, it can be deduced that the use of limestone in mixture 5 increases density by about 2 %. Overall, the density is increased by about 0.5 % using 10 % of limestone in each mix. However, it is clear that the slight increase in specific gravity is not as noticeable as other advantages of limestone use in concrete. In mixture 7, the content of Leca used is 30 % and in mixture 8 the content was increased to 40 %. Increasing the Leca content from 30 to 40 % resulted in a 12 % reduction in the specific gravity. In all the mixtures, it was observed that the increase in density caused increase in compressive strength. The relationship between dry density and compressive strength is shown in Fig. 4. From the relationship, the dry density of LWC can be calculated based on an assumed value of compressive strength.

Table 4 Compressive, flexural, and indirect tensile (Brazilian method) strengths at 28 days

Mix no.	Comp. strengths with curing	Comp. strengths without curing	Flexural strength	Indirect tensile (Brazilian method)
1	32.9	28.2	4.44	3.42
2	41.4	36.5	5.28	3.24
3	43.7	38.1	4.36	2.86
4	44.9	37.3	5.43	4.50
5	47.7	45.3	7.17	4.68
6	47.6	44.9	6.76	4.27
7	67.0	55.1	9.71	5.59
8	48.2	41.9	6.89	4.21
9	38.1	33.5	5.63	4.02
10	43.6	–	4.64	3.92
11	54.9	–	8.68	4.97

All strengths are in MPa

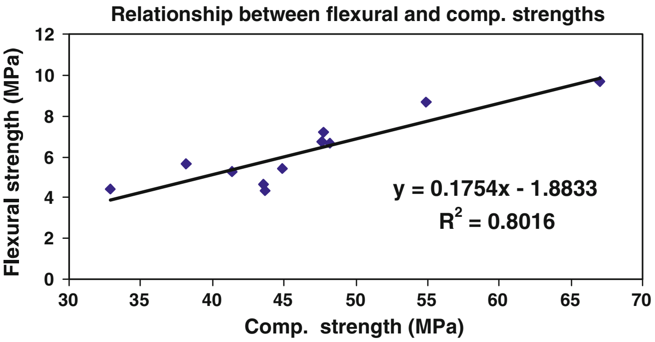

Fig. 5 Relationship between flexural and compressive strengths

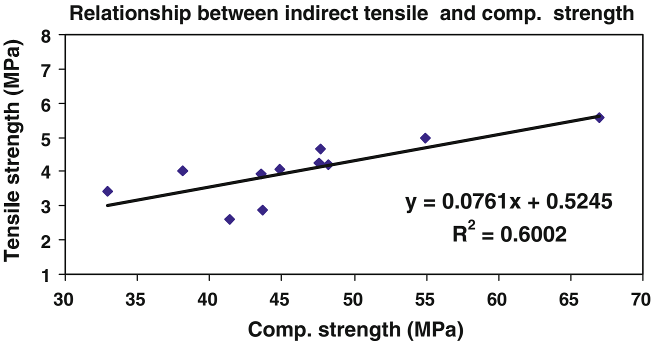

Fig. 6 Relationship between indirect tensile and compressive strengths

4.3 Flexural Strength

This strength for tested specimens at 28 days was determined in the range of 4.36–9.71 MPa. These strength levels are shown in Table 4. Using a regression analysis method shows the relationship between flexural and compressive strengths at 28 days, which was determined as follows:

$$\text{For LWC without the use of limestone: } f_r = 0.76\sqrt{f_{cu}} \quad \text{(a)}$$

$$\text{For LWC with the use of limestone: } f_r = 1.06\sqrt{f_{cu}}; \quad \text{(b)}$$

where f_r and f_{cu} are flexural and compressive strengths of cube samples in MPa. The relationship between flexural and compressive strengths is shown in Fig. 5.

Since limestone fills the voids in concrete, incorporating limestone results in more flexural strength compared to concrete without limestone. Therefore, it can be deduced that the use of limestone in concrete causes improved strength and also gives an apparently smoother surface for concrete.

Based on the results obtained in this study, it can be said that with incorporating of limestone in LWC, the flexural strength is increased by more than 40 %, when compared with that of LWC without the use of limestone. Lo, Cui, and Li proposed the following experimental formula detailing the relationship between flexural and compressive strengths for LWC [15].

$f_r = 0.69\sqrt{f_{cu}}$; where f_r and f_{cu} are flexural and compressive strengths of cube samples in MPa, respectively.

The formula $f_r = 0.73\sqrt{f_{cu}}$ has been proposed by Zhang and Gjorv for the determination of the relationship between flexural and compressive strengths of HSLWC [15], where f_r and f_{cu} are flexural and compressive strengths of cube samples in MPa, respectively.

The experimental formula $f_r = 0.76\sqrt{f_{cu}}$ was produced for LWCs by Short and Kinnburgh [17], where f_r and f_{cu} are flexural and compressive strengths of cube samples in MPa, respectively. Comparison of experimental formulas presented by several researchers and the results obtained based on this experimental work shows that the use of limestone has a significant role in improving the flexural strength of LWCs.

4.4 Tensile Strength

In this investigation, tensile strength has been determined by indirectly using Brazilian's method. The results are shown in Table 4. The relationship between indirect tensile and compressive strengths is presented in Fig. 6. Based on the results obtained in the study, the formulas for LWCs can be proposed as follows.

For concrete without the use of limestone, there is no appropriate relationship, but whenever limestone is used $f_{\mathrm{t}} = 0.4164 \times f_{\mathrm{cu}}^{0.6142}$; with $R^2 = 0.8666$, where f_{t} and f_{cu} are indirect tensile and compressive strengths of cylinder and cube specimens in MPa, respectively.

5 Conclusions

The results obtained from this research allow us to draw the following conclusions:

1. By using the both Leca and silica fume, high-strength lightweight concrete can be obtained.
2. The most important role of silica fume in the production of high-strength lightweight concrete is to fill the voids and improve the compressive strength.
3. The particle size analysis of Leca and its contents has significant role on the density and compressive strength of lightweight concretes. The use of Leca with higher fineness will result in a greater increase in the density and compressive strength of lightweight concretes.
4. The use of limestone has a significant role in the improvement of mechanical properties of lightweight concretes.
5. The use of limestone in lightweight concretes results in the flexural strength increase up to 40 %, without a noticeable increase in the specific gravity.
6. Curing conditions of lightweight concrete have a significant role in the final compressive strength. In this study, it was shown that there was an 18 % reduction in the compressive strength of specimens cured in air compared to the specimens cured in water.

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