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Effect of Expanded Perlite Aggregate Size on Physical and Mechanical Properties of Ultra Lightweight Concrete Produced with Expanded Perlite Aggregate

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Abstract

In this study, ultra-light weight concrete (ULWC) with heat-insulating properties is produced by using different size expanded perlite aggregates and various admixtures. The compressive strength, 4 point bending strength, freezing and thawing resistance, water absorption, dry unit weight, ultra sound velocities and thermal conductivity of the samples were determined by applying appropriate tests. The effect of different size expanded perlite aggregate on the properties of ULWC were also investigated in this study and it was found that as the expanded perlite aggregate diameter increased, the void volume uniformity, water absorption percentage and freezing-thawing resistance increased while the unit volume weight of ULWC samples, ultrasound speed velocities, thermal conductivity and compressive strength were decreased. The changes in the masses and compressive strength of ULWC samples subjected to freezing and thawing cycles were examined. The compressive strength loss was found to be between 5 % and 47 % while the weight loss was between 1 % and 3.5 % after 15 freezing and thawing cycles. Finally, the effects of the admixtures on the fresh properties of ULWC were examined and it was determined that the use of 4.5 kg of air-entraining material in one cubic meter of concrete mix is the most ideal ratio and the use of more than 0.01 % by volume of polypropylene fiber is caused settlements in fresh concrete mixtures.

Keywords

expanded perlite, thermal conductivity, mechanical and physical properties, ultra lightweight concrete

1 Introduction

Lightweight concrete, which has superior properties compared to normal concrete in terms of heat insulation and unit volume weight, is now being used more and more [1, 2]. In addition to reducing the loads on reinforced concrete structures, the preference for more advanced materials in terms of fire resistance, sound and heat insulation properties is increasing. This leads to increased interest and widespread use of lightweight concrete [3]. Depending on the properties of the thermal insulation materials used in the construction and the general condition of the construction, it is known that energy savings of 25 to 65 % can be achieved in heat-insulated structures [3].

The expanded perlite aggregate is a natural volcanic rock, which is being widely used in the world [4, 5]. The perlite removed as rock is classified by separating it into various dimensions after it is crushed. When this classified perlite is heated to 850–1150 °C, it loses its water content and explodes under the effect of temperature. With this explosion, sizes of the crushed perlite aggregate increases up to 35 times of its original volume. The material subjected to these processes takes the name of expanded perlite. The expanded perlite is white in color with a melting point of 1300 °C. Its density varies between 32–200 kg/m^3 whereas its thermal conductivity is between 0.040–0.055 W/mK [6]. Because of these properties, it is widely used as an insulating material.

In the light of previous research [7–9], state-of-the-art methodologies were used to produce cement based inorganic insulation materials with minimum unit weight and maximum heat insulation. From this perspective, the insulation material was composed of three main materials (aggregate, cement matrix and admixtures). Each material was designed to have maximum heat insulation capacity by itself. The expanded perlite aggregates that have superior characteristics in terms of heat insulation were used to develop the composite insulation material. Since,

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expanded perlite aggregate can be found in different sizes, it is important to find the effect of expanded perlite aggregate size on the mechanical and physical properties of ultra lightweight concrete samples. Therefore, within the scope of this study, the mechanical and physical properties of ultra lightweight concrete samples produced with different size expanded perlite aggregates were determined in order to achieve the best insulation property.

2 Materials and method

2.1 Materials

The particle size distribution of the expanded perlite aggregates varies depending on their origin and grinding conditions. The practical particle size of expanded perlite aggregates used in this study are; 0.3, 1.18, 2 and 3.6 mm (Fig. 1). The mechanical and physical properties of these expanded perlite aggregates are given in Table 1. The chemical, physical and mechanical properties of CEM I 52.5 R white type cement given in Table 2 was used as the binder. The water from the Van city drinking water network was used as the mixing water.

It is a well known fact that fiber reinforced concrete has greater energy-absorbing ability, than normal concrete. Ultra lightweight concrete containing fiber has a promising future for producing different types of building insulation materials since it reduces the formation of plastic shrinkage and improves the durability and toughness of concrete [10, 11]. Therefore, Polypropylene (PP) fibers shown in Fig. 2, is used in this study. The physical and mechanical properties of the Polypropylene fibers used are given in Table 3. A commercially available air entraining admixture is used to reduce the dry unit volume weight of ultra lightweight concretes by providing air bubbles inside the concrete. Copolymer dispersion-based concrete admixture is used as a concrete strengthening agent and as a dust reducing agent. The physical properties of the copolymer dispersion-based concrete admixture are given in Table 4.

2.2 Method

2.2.1 Experimental design of ultra lightweight concretes produced with expanded perlite aggregates

Firstly, ultra lightweight concrete samples were prepared at different unit weights using the P05 expanded perlite aggregate, that has a particle size of 1.18 mm. Secondly, based on the results of experiments conducted with P05 expanded perlite aggregate, the effects of different size expanded perlite aggregates (P2 (< 300 micron), P05 (1.18 mm), P12 (2 mm) and P14 (3.6 mm)) on the properties of ultra lightweight concrete were investigated and an optimum aggregate gradation was developed. The design method of the ultra lightweight concrete produced in this study is given in Table 5.

Fig. 1 Different size expanded perlite aggregates used in this study

Table 1 Chemical composition and some of the physical properties of different size expanded perlite aggregates used in this study

Chemical Composition	P05 (Aggregate Size) (1.18 mm)	P0, P1, P2 (Aggregate Size) (<300 micron)	P12 (Aggregate Size) (2 mm)	P14 (Aggregate Size) (3.6 mm)
SiO_2	72.4	73.5	72.5	72.9
Al_2O_3	13.5	12.4	12.9	13.4
K_2O	5.54	5.12	5.35	5.24
Na_2O	3.4	3.61	3.54	3.15
MgO	0.16	0.14	0.14	0.15
CaO	0.9	0.87	0.9	0.89
Fe_2O_3	0.76	0.64	0.66	0.74
TiO_2	0.09	0.09	0.09	0.09
Loss of ignition	3.25	3.65	3.92	3.44
Dry unit weight (kg/m^3)	45	110	55	75

Table 2 The physical and chemical properties of cement used in this study

Chemical Composition	CEM-I 52.5 R
CaO	65.70
SiO_2	21.60
Al_2O_3	4.05
Fe_2O_3	0,26
MgO	1.30
SO_3	3.30
K_2O	0.35
Na_2O	0.32
TiO_2	0.33
Loss on ignition	2.79
$SiO_2 + Al_2O_3 + Fe_2O_3$	25.91
Density (g/cm^3)	3.06
Blaine Fineness (cm2/^{g})	4600
Volume Expansion (mm)	1.00
Size > 90 µm (%)	5.18
Size > 45 µm (%)	22.22

Table 3 Physical and mechanical properties of polypropylene fibers

Diameter (µm)	Length (mm)	Tensile Strength (MPa)	Modulus of Elasticity (GPa)
20	12–14	684	3.7

Table 4 Physical properties of copolymer dispersion-based concrete admixture

Structure	Modified polymer dispersion
Color	White
Density	1.1 kg/m^3
pH	8.5
Application temperature	+5C – +35C

Fig. 2 Polypropylene Fibers used in this study

Fig. 3 Production of ultra lightweight concrete samples using expanded perlite aggregates

Table 5 The design of ultra lightweight concrete experiments

Experiment Number	The method used in experiments (Trial and Error Method)
1	First experiment was carried out to investigate the fresh concrete workability for constant W/C ratio (W/C = 2.5).
2–7	These experiments were conducted to determine the effect of the amount of air entraining additive on the physical and mechanical properties of produced ultra lightweight concretes (All other materials in the mixture were kept constant and the copolymer dispersion-based admixture was not used).
8–13	These experiments were conducted to determine the effects of the ratio of copolymer dispersion-based admixture and air entraining admixture on the properties of ultra lightweight concrete samples produced in this study.
14–20	The effect of W/C ratio as well as amount of air entraining admixture on the dry unit weight of ultra lightweight concrete samples was determined by these experiments.
21–32	These experiments were conducted to determine the effect of different size expanded perlite aggregates (P2, P05, P12 and P14) and their gradation on the properties of ultra lightweight concretes.
32–38	The effect of the amount of polypropylene fibers on the properties of fresh and hardened ultra lightweight concretes were determined with these experiments.

2.2.1.1 Preparation of ultra lightweight concrete samples using expanded perlite aggregates

Ultra lightweight concrete specimens with different size expanded perlite aggregates were prepared in five stages as shown in Fig 3. First, the mixing water and cement binder material was poured into the mixer bowl and then mixed. After the cement is fully dispersed in the mixing water, the air entraining admixture is added to the mix for reducing the unit weight.

The air entraining admixture was mixed at high speed and stirred for at least 2 minutes to form air bubbles. As the air-entraining admixture showed its effect fully, the expanded perlite aggregate was slowly poured into the mix. When the desired concrete mix consistency obtained, the copolymer dispersion-based admixture was poured into the mix and the mixture was mixed for at least 2 minutes in order to fully disperse the copolymer dispersion-based admixture. In ultra lightweight concrete specimens produced with fibers, the concrete mix was prepared as defined above and after mixing of copolymer dispersion-based admixture the fibers are added to the fresh mix and the mixture was mixed for 5 minutes with a high speed mixer in order to homogeneously distribute the fibers within the mix.

Finally, the fresh concrete mixtures were poured into molds (10 × 10 × 10 cm; 30 × 30 × 5 cm; 10 × 10 × 40 cm) for mechanical and physical tests. Mix designs of ultra lightweight concrete specimens produced within the scope of this study are given in Table 6 and Table 7.

2.2.2 Tests conducted on the ultra lightweight concrete specimens

The unit weight and water absorption of ultra lightweight concrete specimens were determined according to ASTM C642 [12] standard (Fig. 4 and Fig. 5). The flexural and compressive strength of ultra lightweight concrete specimens were determined according to ASTM C495 [13] and ASTM C78 [14], respectively (Fig. 6 and Fig. 7). Prismatic testing specimens with the dimensions of 100 × 100 × 100 mm for all of these tests except for flexural strength test in which 100 × 100 × 400 mm specimens were used.

The freezing and thawing resistance of the ultra lightweight concrete specimens is one of the main parameters that defines its durability. Therefore, freezing and thawing test following the procedures prescribed in national TS EN 15304 [15] standard was conducted (Fig. 8).

Fig. 4 Determination of dry unit weight of ultra lightweight concrete specimens

Fig. 5 Tests conducted to determine water absorption of ultra lightweight concrete specimens

Fig. 6 Tests conducted to determine flexural strength of ultra lightweight concrete specimens

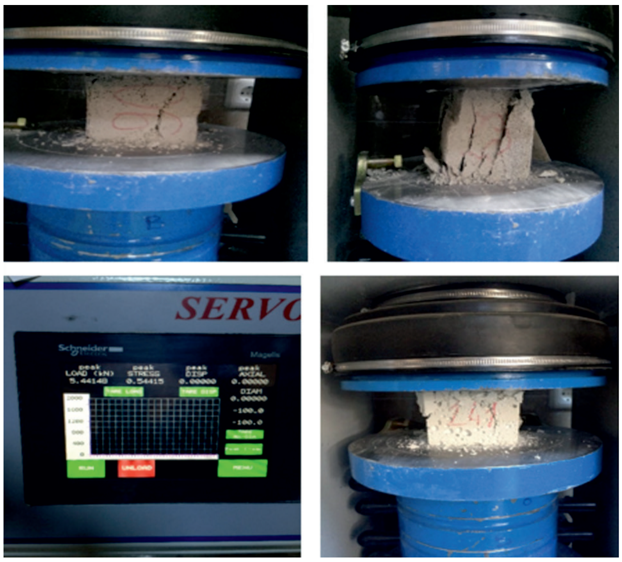

Fig. 7 Tests conducted to determine compressive strength of ultra lightweight concrete specimens

Finally, the thermal conductivity of the ultra lightweight concrete specimens developed in this study was determined following the procedures in TS EN 12667 [16] using thermal conductivity testing machine (Fig. 9).

Table 6 Mix design and dry unit weight of ultra lightweight concrete specimens produced with P05 aggregate

Specimen Number	Cement (kg/m^3)	Water (kg/m^3))	Expanded Perlite (kg/m^3))	Air entraining admixture (kg/m^3))	Copolymer dispersion-based admixture (kg/m^3)	W/C	DUW (kg/m³)
1	112.1	280.3	52.7	22.4	11.2	2.5	257.0
2	204.2	510.5	96.0	0	0	2.5	468.0
3	83.3	208.3	39.2	2.1	0	2.5	191.0
4	90.3	225.8	42.4	4.5	0	2.5	207.0
5	89.9	224.7	42.2	6.7	0	2.5	206.0
6	74.2	185.4	34.9	7.4	0	2.5	170.0
7	65.4	163.6	30.8	13.1	0	2.5	150.0
8	146.2	365.4	68.7	3.7	7.3	2.5	335.0
9	143.1	357.8	67.3	3.7	7.2	2.5	328.0
10	71.6	178.9	33.6	14.3	3.6	2.5	164.0
11	277.8	694.4	130.6	6.9	27.8	2.5	382.0
12	116.5	291.2	54.8	5.8	11.6	2.5	267.0
13	102.1	255.2	48.0	10.2	10.2	2.5	234.0
14	199.4	299.1	93.7	39.9	19.9	1.5	457.0
15	157.1	235.6	73.8	31.4	15.7	1.5	360.0
16	207.2	310.0	97.4	41.4	20.7	1.5	475.0
17	168.4	336.8	79.2	4.2	16.8	2.0	386.0
18	116.1	232.1	54.5	5.8	11.6	2.0	266.0
19	157.5	236.3	74.0	3.9	15.8	1.5	361.0
20	170.2	425.4	80.0	8.5	17.0	2.5	390.0

Table 7 Mix design and dry unit weight of ultra lightweight concrete specimens produced with different size expanded perlite aggregates

Specimen Number	Cement (kg/m^3)	Water (kg/m^3)	Air entraining admixture (kg/m^3)	Copolymer dispersion-based admixture (kg/m^3)	P05 (kg/m^3)	P2 (kg/m^3)	P12 (kg/m^3)	P14 (kg/m^3)	PP Fiber (kg/m^3)	PP Fiber (%V)
21	142.9	357.1	7.1	13.0	0.0	0.0	0.0	107.14	0.0	0
22	142.9	357.1	7.1	13.0	0.0	0.0	78.57	0.0	0.0	0
23	131.6	328.9	6.6	12.0	0.0	0.0	36.18	49.34	0.0	0
24	142.9	357.1	7.1	13.0	0.0	78.57	0.0	53.57	0.0	0
25	142.9	357.1	7.1	13.0	32.14	0.0	0.0	53.57	0.0	0
26	125.0	312.5	6.3	11.4	14.06	34.37	17.18	23.43	0.0	0
27	142.9	357.1	7.1	13.0	16.06	39.28	0.0	53.57	0.0	0
28	142.9	357.1	7.1	13.0	16.06	0.0	0.0	80.35	0.0	0
29	131.6	328.9	6.6	12.0	14.80	0.0	54.27	0.0	0.0	0
30	131.6	328.9	6.6	12.0	5.92	0.0	21.70	59.21	0.0	0
31	131.6	328.9	6.6	12.0	11.80	0.0	21.70	49.34	0.0	0
32	131.6	328.9	6.6	12.0	17.76	0.0	21.70	39.47	0.0	0
33	131.6	328.9	6.6	12.0	0.0	0.0	36.18	49.34	1.32	0.140
34	131.6	328.9	6.6	12.0	0.0	0.0	36.18	49.34	0.28	0.033
35	131.6	328.9	6.6	12.0	0.0	0.0	36.18	49.34	0.55	0.066
36	131.6	328.9	6.6	12.0	0.0	0.0	36.18	49.34	0.83	0.100
37	131.6	328.9	6.6	12.0	0.0	0.0	36.18	49.34	0.09	0.010
38	131.6	328.9	6.6	12.0	0.0	0.0	36.18	49.34	0.20	0.020

Fig. 8 Freezing and thawing tests of ultra lightweight concrete specimens

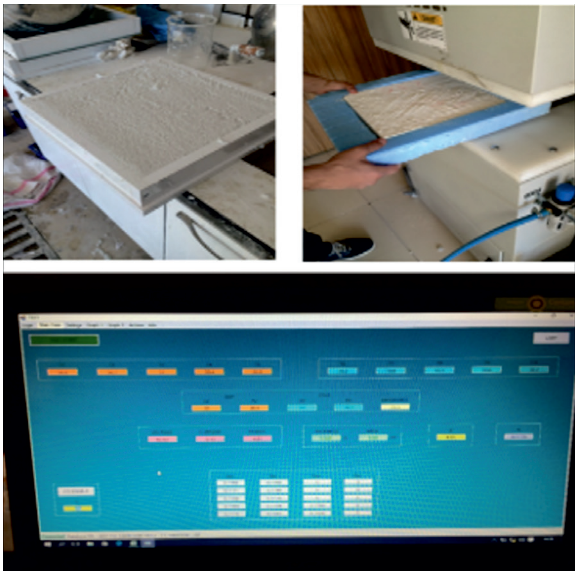

Fig. 9 Thermal conductivity tests of ultra lightweight concrete specimens

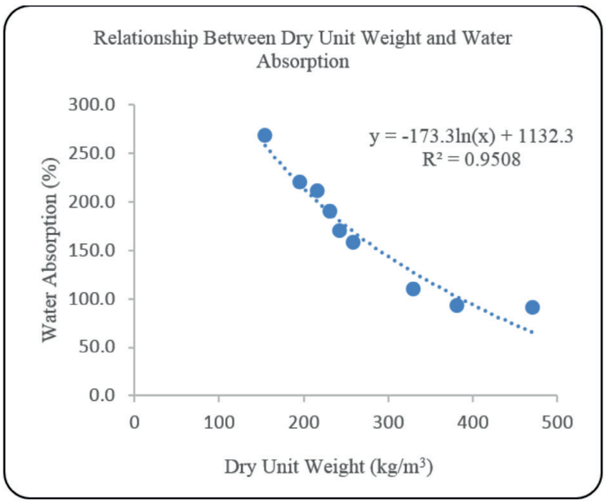

Fig. 10 The relationship between dry unit weight and water absorption characteristics of ULWC specimens produced with P05 aggregate

3 Results and discussion

The experimental test results of ultra lightweight concrete samples prepared at different unit weights using the expanded perlite aggregate, named P05 that has a particle size of 1.18 mm, is given in Table 8 whereas the experimental results of concrete specimens prepared with different size expanded perlite aggregates (P2 (< 300 micron), P05 (1.18 mm), P12 (2 mm) and P14 (3.6 mm)) are given in Table 9. As shown in Table 8 and Table 9, the unit weight of concrete can be reduced substantially by using expanded perlite aggregates. Weight reduction of concrete elements that leads to reduction of the total weight of the building results in reduced cross sections and less amount of reinforcement which is important for economical aspects.

3.1 Influence of dry unit weight of ULWC specimens on water absorption characteristics

The relationship between the dry unit volume weights of the samples and the water absorption percentages is given in Fig. 10. The rate of water absorption was found to be higher due to the high void ratio in the samples with less unit weight. By increasing the expanded perlite aggregate content, the total porosity of the concrete, which is reflected by the reduction of the unit weight of the concrete samples, is also increased and resulted in higher water absorption. A significant relationship between the water absorption percentages of the test samples and the dry unit volume weight was observed. It is seen that the approximate value of the water absorption percentage of the samples with known dry unit volume weight can be determined by using this empirical formula obtained from this relationship and shown on the graph (for dry unit volume range of 150 kg/m^3 – 468 kg/m^3).

3.2 The relationship between dry unit weight and compressive strength of ULWC specimens produced with P05 aggregate

Regardless of the mix design, the compressive strength of the concrete samples decrease with a decrease in unit weight of concrete specimens, which can be attributed to the high content of air in the expanded perlite aggregates. The relationship between the dry unit weight and the compressive strength of the ultra lightweight concrete specimens with heat insulation properties are given in Fig 11. Although a significant relationship between the dry unit weights and the compressive strength cannot be observed (i.e. $R^2 = 0.6932$), the compressive strength increases as the dry unit weight of the specimens increases due to the fact that the void ratio decreases as the dry unit weight of the specimen increases.

Table 8 Test results of ultra lightweight concrete specimens produced with P05 aggregate

Experiment Number	Compressive Strength (MPa)	Dry Unit Weight (kg/m^3)	Ultrasonic Pulse Velocity (m/s)	Flexural Strength (MPa)	Thermal Conductivity (W/mK)	Water Absorption (%)	Freeze-Thaw Resistance
1	0.38	257.0	936.0	0.045	0.064	267.7	Adequate
2	0.87	468.0	1756.0	0.450	0.120	76.9	Adequate
3	0.15	191.0	1112.0	0.114	0.056	189.2	Inadequate
4	0.20	207.0	914.0	0.018	0.059	219.9	Adequate
5	0.26	206.0	930.22	0.066	0.059	213.2	Adequate
6	0.30	170.0	855.49	0.039	0.041	231.9	Adequate
7	0.13	150.0	791.76	0.024	0.039	242.3	Adequate
8	0.50	335.0	1462.0	0.300	0.083	109.7	Adequate
9	0.50	328.0	1244.0	0.066	0.083	211.1	Başarısız
10	0.17	164.0	836.37	0.030	0.039	235.0	Adequate
11	0.50	382.0	1712.0	0.150	0.095	92.4	Adequate
12	0.50	267.0	1131.0	0.162	0.057	157.9	Adequate
13	0.30	234.0	1065.0	0.111	0.067	170.4	Başarısız
14	0.84	457.0	1770.11	0.359	0.113	82.7	Adequate
15	0.50	360.0	1460.99	0.300	0.079	133.1	Adequate
16	0.80	475.0	1827.47	0.380	0.134	73.3	Adequate
17	0.50	386.0	1541.0	0.260	0.095	119.6	Adequate
18	0.50	266.0	1161.43	0.162	0.065	182.0	Adequate
19	1.00	361.0	1464.0	0.305	0.083	132.6	Adequate
20	1.10	390.0	1555.0	0.330	0.092	117.5	Adequate

Table 9 Test results of ultra lightweight concrete specimens produced with different size expanded perlite aggregates

Experiment Number	Compressive Strength (MPa)	Dry Unit Weight (kg/m^3)	Ultrasonic Pulse Velocity (m/s)	Flexural Strength (MPa)	Thermal Conductivity (W/mK)	Water Absorption (%)	Freeze-Thaw Resistance
21	0.65	313.5	1529	0.348	0.085	110	Adequate
22	0.41	251.7	1220	0.273	0.062	170	Adequate
23	0.64	251.8	1229	0.384	0.062	167	Adequate
24	1.33	357.4	1541	0.745	0.100	96	Adequate
25	0.45	283.4	1276	0.324	0.084	149	Adequate
26	0.58	284.7	1495	0.253	0.081	147	Adequate
27	0.61	292.5	1441	0.333	0.087	144	Adequate
28	0.56	275.1	1431	0.186	0.078	134	Adequate
29	0.32	264.4	1221	0.267	0.084	151	Adequate
30	0.38	235.4	1344	0.330	0.058	136	Adequate
31	0.58	255.1	1441	0.189	0.059	140	Adequate
32	0.37	247.0	1229	0.132	0.062	154	Adequate
37	0.68	217.3	1106	0.270	0.059	81	Adequate

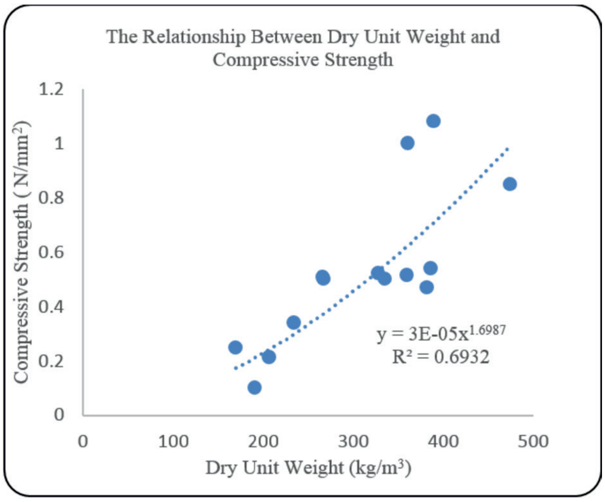

Fig. 11 The relationship between dry unit weight and compressive strength of ULWC specimens produced with P05 aggregate.

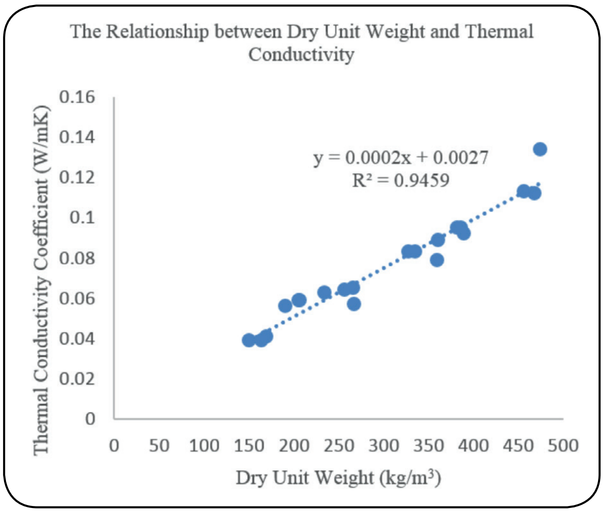

Fig. 12 The relationship between dry unit weight and thermal conductivity coefficient of ULWC specimens produced with P05 aggregate.

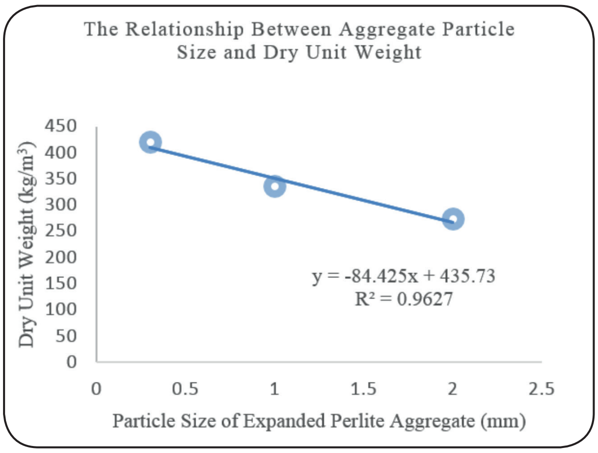

Fig. 13 The effect of different particle size expanded perlite aggregates on the dry unit weight of ULWC specimens.

Table 10 The aggregate particle size distribution, unit weight and water absorption characteristics of the ULWC specimens prepared using different particle size expanded perlite aggregates

Experiment No	Dry Unit Weight (Kg/m³)	Water Absorption (%)	P05 Aggregate (1 mm) (%)	P2 Aggregate (0.3 mm) (%)	P12 Aggregate (2 mm) (%)	P14 Aggregate (3.6 mm) (%)
23	273.6	167.3			0.5	0.5
24	357.4	95.9		0.5		0.5
25	335.0	149.4	0.5			0.5

3.3 The relationship between dry unit weight and thermal conductivity of ULWC specimens produced with P05 aggregate

The relationship between the dry unit volume weight and the thermal conductivity coefficient of ULWC specimens is given in Fig. 12.

As seen in this graph, there is a correct and meaningful relationship between the thermal conductivity coefficient and dry unit volume weight of ULWC specimens produced with P05 aggregate (R^2 value obtained was found to be close to 1). This finding is in good agreement with previous research [17]. In this sense, the thermal conductivity coefficient of the ULWC specimens produced with P05 aggregate with known dry unit volume weight can be determined by using this empirical formula obtained from this relationship and shown on the graph (for dry unit volume range of 150 kg/m³ – 468 kg/m³).

3.4 The effect of expanded perlite aggregate size distribution on the dry unit weight of ULWC specimens

In order to determine the relationship between the expanded perlite aggregate particle size and the unit weight of the ULWC specimens, the experiments in Table 10 were carried out. During these experiments, the most suitable gradation was achieved by taking 50% of the expanded perlite aggregate with the P14 size. For this purpose, P12, P05 and P2 expanded perlite aggregates, which have smaller grain diameters in different ratios, were used respectively, while the P14 expanded perlite aggregate amount having the maximum particle diameter was kept constant. As shown in Fig. 13, the density of ultra lightweight concrete specimens increase with decreasing particle diameter of expanded perlite aggregate. SEM analysis of the test specimens obtained using only P05 expanded perlite aggregate showed that the void size was small and the distributions were not homogeneous (Fig. 14). SEM analysis results

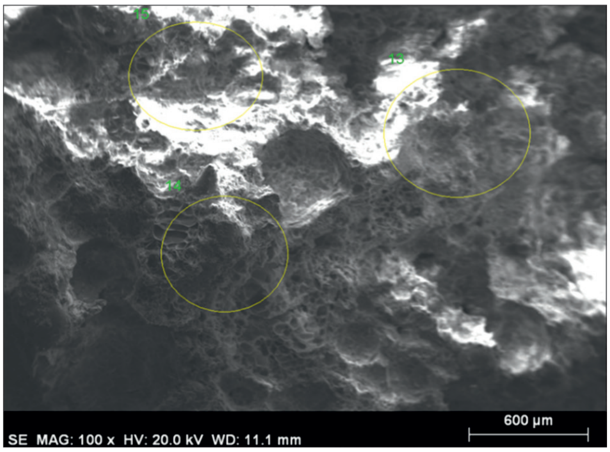

Fig. 14 SEM image of ULWC specimen produced with P05 expanded perlite aggregate

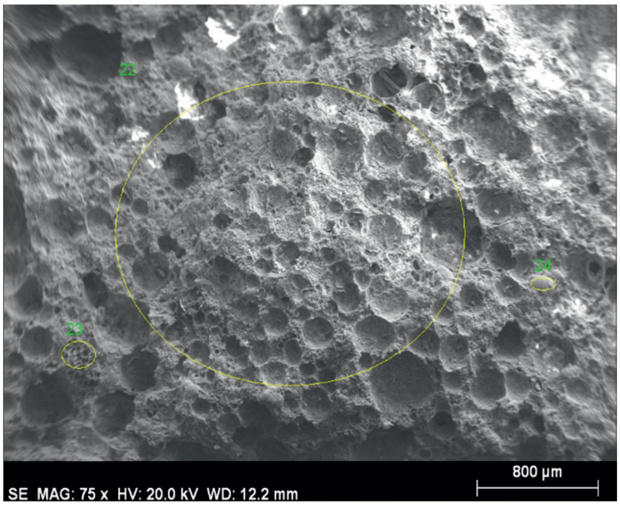

Fig. 15 SEM image of ULWC specimen produced with different size expanded perlite aggregate

of test specimens obtained by using expanded perlite aggregates with different aggregate grain sizes showed larger and homogeneous distribution of void structure (Fig. 15). The void structure of the samples with large particle size diameter is found to be more homogenous and bigger. When the particle size of the expanded perlite aggregate decreases, the void ratio decreases and the homogeneity of the void structure decreases as well. On the other hand, as the expanded perlite aggregate particle size diameter increases, the water absorption percentage increases as well due to the increase of the entrained air in the concrete.

3.5 Effect of Polypropylene Fibers on the Fresh Properties of ULWC specimens

Firstly, ultra lightweight concrete specimen with a fiber volume fraction of 0.14 % was prepared. A serious decrease in the volume of the fresh concrete in the mold during settling process was observed. The reason for such a settlement of fresh concrete can be attributed to the gradual disappearance of air bubbles in ultra lightweight concrete by the fibers. In order to solve this problem, the amount of fiber used decreased gradually and with a fiber volume fraction of 0.011 %, no decrease in the volume of the fresh concrete was observed (Fig. 16).

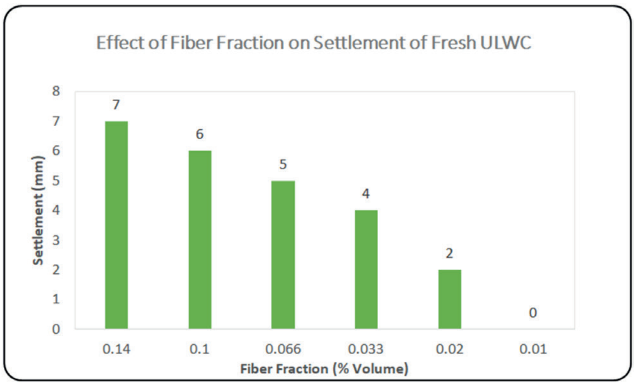

Fig. 16 Effect of fiber volume fraction on the settlement of fresh ULWC specimens

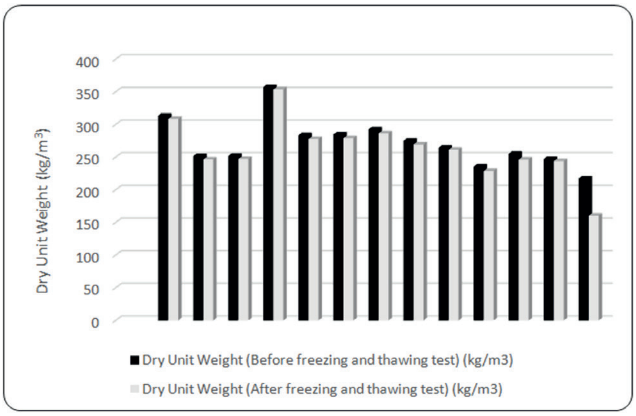

Fig. 17 Mass loss after freezing and thawing cycles

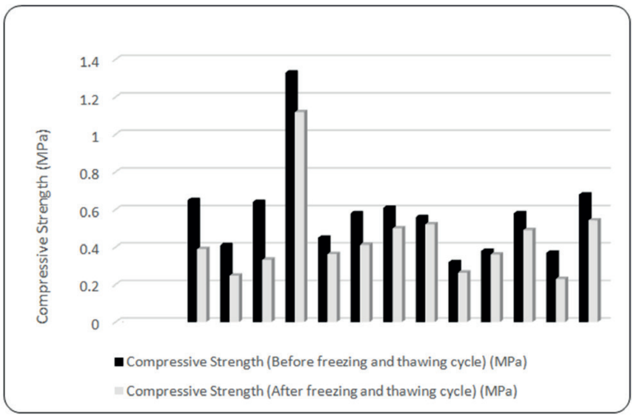

Fig. 18 Effect of freezing and thawing cycles on compressive strength of ULWC specimens

3.6 Effect of freezing and thawing cycles on mass loss and compressive strength of ULWC specimens

The effect of freezing and thawing cycles on mass loss and compressive strength of ultra lightweight concrete specimens prepared with different particle size of expanded perlite aggregates are shown in Fig. 17 and Fig. 18. The mass losses were found to be 1.18 % – 3.44 % whereas the compressive strengths decreased 5 % – 47 %.

4 Summary and conclusions

The present research is aimed at developing an economically and environmentally viable ultra lightweight concrete while improving the mechanical and thermal properties (with very low thermal conductivity and reasonable strength) of ultra lightweight concrete. Therefore, in this study, a detailed experimental program was conducted to develop ULWC specimens using different size of expanded perlite aggregates. The developed ULWC could be a practical solution for economical and sustainable structures due to its excellent thermal properties with reasonable mechanical strength and superior durability properties. Based on the results obtained, the thermal conductivity coefficient of ULWC specimens was observed to decrease with a decrease in dry unit weight. It has been found that, the ultra lightweight concrete samples produced with expanded perlite aggregate with a dry unit weight of 150 kg/m^3 or less have a thermal conductivity coefficient less than 0.040 W/mK, compressive strength of 0.13 MPa and a water absorption percentage of 242.3 %. It has been observed that the decrease in the dry unit volume weight leads to an increase in the water absorption percentage while reducing the compressive strength as well. On the other hand, the compressive strength is expected to decrease as the concrete specimens absorb water and become wet. But simple measures (i.e. water repellent paints etc.) can be taken to make the ULWC specimens watertight.

Within the scope of this study, the effect of the amount of the air entraining admixture on the dry unit weight of ultra lightweight concrete has been examined and it was found that, as the amount of air-entraining admixture used in the test samples increased, its effect on decreasing the dry unit weight of ultra lightweight concrete samples becomes ineffective. In this respect, it has been determined that the use of air entraining admixture in excess of 4.5 kg per cubic meter reduces the effect of unit volume weight and becomes uneconomical.

The amount of fibers used in ULWC concretes was found to directly affect the settlement of fresh concretes due to the gradual disappearance of air bubbles in ultra lightweight concrete by the fibers. A fiber volume fraction of 0.011 % is proposed to be used in order not to have any settlement in the volume of the fresh ultra lightweight concretes.

The effect of freezing and thawing cycles on mass loss and compressive strength of ultra lightweight concrete specimens prepared with different particle size of expanded perlite aggregates was found to be between 1 % – 3.5 % and 5 % – 47 %, respectively.

Finally, SEM analysis of the test specimens showed that by using expanded perlite aggregates with different aggregate particle sizes the dry unit weight of ULWC samples can be decreased due to larger and homogeneous distribution of void structure.

The results of this study shows the practical impact of using expanded perlite aggregates in the production of ultra lightweight concrete building materials. Lower thermal conductivity coefficients of ultra lightweight concrete produced with expanded perlite aggregates would offer important economic and environmental benefits with using ULWC blocks for construction of non-load bearing exterior walls.

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