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INFLUENCE OF NATURAL LIGHTWEIGHT AGGREGATES ON THE PROPERTIES OF CONCRETE

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Abstract: As a result of the developing technology, the construction industry has also gone to a great interest to discover new materials. A lot of literature research has been done for the lightweight aggregates used in the construction industry. In this study, different types of lightweight aggregates are used for porous lightweight concrete production. For this reason, 8-15 mm pumice and expanded perlite were obtained from Ankara region, 4-8 mm pumice was supplied from Manisa Salihli, volcanic tuff aggregate was obtained from Antalya and expanded clay was supplied from Holland. Before lightweight concrete production, aggregates were separated into adequate particle classes by sieve analysis in diameter with 4-8 mm, 8-11.2 mm and 11.2-15 mm. The expanded clay had a size of 0-4 mm and was separated into 0-1 mm and 1-4 mm sizes. The fresh concrete properties are determined by slump and flow table tests. Hardened composite properties are evaluated by unit weight, ultrasound pulse velocity, and compressive strength tests on 15x15x15 cm cubic specimens. According to test results structural lightweight concrete can be produced with those aggregates. Expanded clay and perlite reduced the workability of the fresh concrete. Volcanic tuff and pumice provided to reach compressive strength values over 25 MPa.

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INTRODUCTION

Concrete is a type of artificial stone which can be produced by a mixture of aggregate, water, and cement. There are various types of concrete can be found in the market due to the desired structural properties. Lightweight concrete (LWC) is one of the most important types of concrete owing to its unit weight and insulation properties against temperature and voice. The LWC gains these properties with the increased porosity of the composite. This porosity can be obtained by using gas-generating agents or lightweight aggregates. The most important factor that affects the compressive strength of the lightweight concrete is the water/cement ratio [Bilgiç, 2009]. Concretes whose unit weights are significantly lower than normal concretes are called as LWC. In general, concretes with a unit weight of less than 1800 kg/m^3 are classified as lightweight concrete. Lightweight concretes can be grouped by unit weight, strength and purpose of its use [Ulusu, 2007].

Currently, lightweight concrete is preferred especially for reducing the dead load of a structure and reducing the cross-sectional areas of reinforced concrete structural elements to be used. Accordingly, it plays an active role in increasing the effective use areas and openings of high-span structures. In addition, lightweight concretes are used for the production of the structural members such as wall panels and blocks, roof floors, bridge decks, *etc*. [Sarı and Paşamehmetoğlu, 2005].

Aerated and Foam Concretes

These types of concretes can be produced using fine aggregate and gas-generating agent. Autoclaved aerated concrete (AAC) is a well-known lightweight concrete and consists of a mixture of sand, lime, cement, gypsum, water, and expanding agent. AAC can be molded and cut into precisely dimensioned units and cured in an autoclave. Air is entrapped artificially by the addition of metallic powders, such as Al and Zn, or foaming agents. The chemical reaction caused by the addition of aluminum makes the mixture expand to about twice its volume, resulting in a highly porous structure [Karakurt *et al*., 2009].

Foam concrete is another kind of cellular concrete; it is produced by aeration of cement mortar using foaming agents. Controlling the ratios of cement, sand, water and foaming agent, a wide range of densities achieved, depending on its application [Namsone *et al.,* 2017]. In previous studies, researchers developed dry density values between 240 to 1800 kg/m^3 and compressive strength for 28 day from 0.2 to 91.3 MPa [Amran *et al.,* 2015].

Lightweight Aggregate Concrete

The most popular way of achieving structural LWC is by using artificial or natural lightweight aggregates. Utilization of lightweight aggregate (LWA) in concrete is mainly to reduce the self-weight of concrete, which leads to reduce the dimension of foundation and that result in cost saving [Hama, 2017]. The main natural lightweight aggregates such as diatomite, pumice, volcanic cinders, scoria, tuff and artificial lightweight aggregates such as expanded clay, shale, slate, perlite and vermiculite have been used as construction materials [Aslam *et al.,* 2017].

Lightweight aggregates usually have a very high water absorption compared with normal aggregates, which is ascribed to its numerous inner voids. Due to the porous structure, lightweight aggregates could easily absorb the free water, which significantly deteriorated the workability of fresh lightweight concrete unless the lightweight aggregates (LWA) were adequately pre-wetted [Zhu *et al.,* 2017]. The unit weight of lightweight aggregates are given in Table 1.

Table 1: Unit weight of aggregates [Kaldı, 2011].

Aggregate Type	Dry Unit Weight (kg/m^3)
Clinker	720-1040
Sintered ash	779-960
Expanded clays	320-960
Expanded perlite	80-120
Expanded vermiculite	60-160
Pumice	480-880
Diatomite	450-800
Timber sawdust	320-480

Excessive water content of LWA would cause an increase in the amount of total water and thus might cause lack of cohesiveness between the aggregate and mortar, which affected the strength and durability of LWC. On the other hand, low LWA water content would lead the aggregates to absorb part of the mix water, which influenced the workability of LWC [Gündüz, 2008].

In this study, pumice, expanded clay, expanded perlite, and volcanic tuff are used as LWA in order to produce LWC mixtures. The physical and mechanical properties of the LWC specimens were investigated by experimental studies.

MATERIALS AND METHOD

Materials

The experimental studies are performed in the Bilecik Seyh Edebali University, Materials Science Laboratory. The raw materials for the LWC production were obtained from different sources. The CEM I 42.5 R type Portland cement was supplied from SANÇİM cement factory. Pumice aggregate was obtained in two different particle size with 4-8 and 8-15 mm from Salihli and Ankara respectively (Figure 1).

Figure 1: 4-8 and 8-15 pumice aggregate.

Expanded clay was supplied from Plagron factory in Netherlands with a particle size as 8-16 mm. The other processed aggregate expanded perlite was supplied from Ankara in diameter with 3-6 mm. Volcanic tuff was obtained from Antalya in dimension with 4-15 mm. The expanded clay and perlite aggregates are given in Figure 2.

Figure 2: Expanded clay and perlite.

Method

Before the production of the LWC, the particle size distribution of aggregates are determined by sieve analysis. The unit weight and water absorption tests were performed on oven for dry aggregate specimens. Mix designs of the specimens are performed according to the characterization results of the ingredients. The workability of the fresh LWCs are determined by slump test and flow table tests (Figure 3). The water/cement ratio of the mixtures were prepared as 0.48 for all LWC mixtures (Table 2).

Figure 3: Workability tests.

Hardened concrete properties are determined on 150×150×150 mm cubic specimens. These specimens were cured in lime saturated water at 20±3°C for 3, 7 and 28 days. The pore structures of the LWC specimens are evaluated by ultrasound pulse velocity (UPV) test. Compressive strength test is also performed on LWC specimens by using uniaxial compression test apparatus.

TEST RESULTS

Aggregate Analyses and Design

The granulometry curve of the LWA specimens is given below in Figure 4. Expanded perlite and tuff aggregates are the finest aggregate types when compared with expanded clay and pumice.

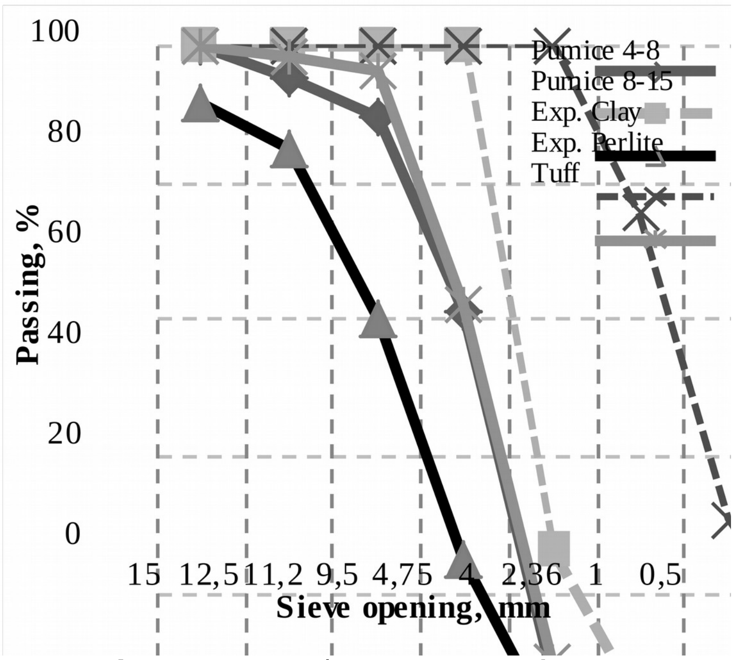

Figure 4: Granulometry curve of LWA**.**

Table 2: Mix design of the LWC specimens.

Mixture	Cement kg	Water kg	Sand 0-4 kg	Pumice 4-8 kg	Pumice 8-15 kg	Expanded Clay kg	Expanded Perlite kg	Tuff kg
PMLC	270	130	433	290	409	-	-	-
ECLC	270	130	275	-	-	723	-	-
EPLC	270	130	233	-	-	-	540	-
VTLC	270	130	233	-	-	-	-	840

The physical properties of lightweight aggregates are given in Table 3. According to test results the unit weight of the aggregates are varied between 0.06 to 1.25 g/cm^3. The water absorption ratios are inversely proportional with the unit weight and density of the aggregates.

Table 3: Physical properties of LWA.

LWA	Unit Weight kg/m^3	Specific Gravity	Water Absorption %
Pumice	475	0.80	25
Exp. Clay	50	0.65	18
Exp. Perlite	40	2.20	70
Tuff	1.25	1.90	4

Workability

The workability of the LWC specimens are performed by slump and flow table tests. Test results are given in Table 4. As seen from table EPLC specimen showed the lowest workability due to its higher water absorption ability. Pre-saturation of perlite is very important before the usage of this material in the concrete mixture. It can be clearly concluded that the consistency of concrete reduced with the usage porous lightweight aggregates.

Unit Weight

The unit weight test results of LWC specimens are given in Figure 5. According to test results the unit weight values of the specimens are varied between 1389-1852 kg/m^3. The most effective weight reduction is obtained by expanded perlite used EPLWC specimen. This result can be attributed to the lower specific gravity of this material. Expanded clay concrete specimen (ECLWC) also showed similar unit weight performance as expanded perlite. The highest unit weight values are obtained from volcanic tuff specimens. The curing time of the specimens does not show a significant effect on the unit weight behavior.

Table 4: Workability test results.

Mixture	Slump mm	Flow Table mm
PMLC	100	320
ECLC	80	320
EPLC	10	270
VTLC	120	360

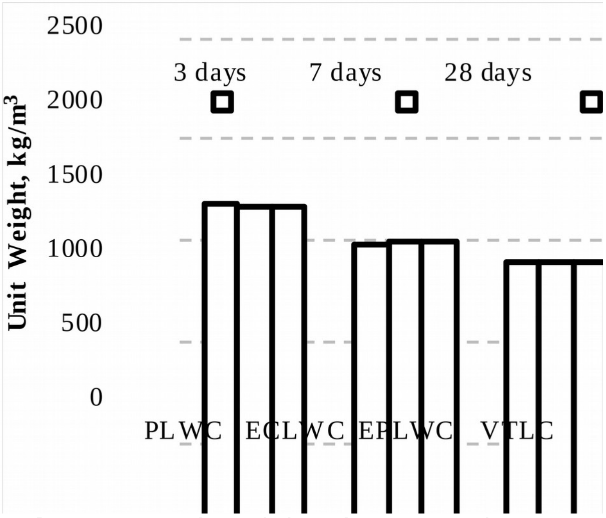

Figure 5: Unit weight of LWC specimens**.**

UPV and Compressive Strength

The UPV and compressive strength test results of the LWC specimens are given in Table 5. According to the test results the UPV values are reduced with reduced unit weights. This phenomenon is related with the increased porosity of the LWC specimens. The compressive strength of the LWC specimens are varied between 3 to 26 MPa due to the type of the LWA and curing time. Volcanic tuff showed the higher strength value depending on the higher unit weight of this specimen. The strength values are related with the porosity of the LWC. The UPV values were also influenced by the unit weight values of the specimens. Volcanic tuff and pumice used LWC mixtures can be used for structural applications. Expanded clay and perlite is more useful for insulation applications in structures.

Table 5: UPV and strength test results.

LWC	UPV km/sec			Compressive Strength MPa		
	3d	7d	28d	3d	7d	28d
Pumice	3.12	3.20	3.18	10	16	21
Clay	2.75	2.80	2.83	6	8	12
Perlite	2.27	2.24	2.30	3	7	9
Tuff	3.74	3.83	3.88	15	22	26

CONCLUSIONS

According to the test results of this study, the following conclusions can be drawn out.

- Production of LWC is easier with volcanic tuff and pumice aggregates rather than expanded clay and perlite.

- The workability of the fresh concrete is adversely affected in PLWC. The reduction of the workability can be reduced with the pre-saturation of the lightweight aggregates before mixing.
- Expanded perlite and clay aggregates are very effective on the unit weight reduction of the LWC.
- The pore structure of the LWC influenced directly with the bulk unit weight of the aggregate type. This porosity also effective on the strength and insulation properties of the final product.
- Pumice and volcanic tuff aggregates can be used for the structural LWC production. Expanded perlite and clay should be more effective on insulation.

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