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Investigation of properties of low-strength lightweight concrete for thermal insulation

Osman Ünal[a], Tayfun Uygunoğlu[a,*], Ahmet Yildiz[b]

[a]Construction Department, Technical Education Faculty, Afyon Kocatepe University, 03200 Afyon, Turkey
[b]Afyon Kocatepe University, Engineering Faculty, 03200 Afyon, Turkey

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Abstract

In this study, block elements with diatomite, which have different aggregate granulometries and cement contents, were produced and the effect of these parameters on physical and mechanical properties of block elements were investigated. Diatomite samples were taken from the region of Afyon. In the mixes, water/cement ratio was kept at 0.15. Analyses include compressive strength, thermal conductivity, ultrasonic velocity tests, bulk density and specific porosity. According to experimental results, while dry unit weight is varied between 900 and 1190 kg/m^3, compressive strength of 7–56 days specimens ranged from 2.5 to 8 MPa. Materials with a ratio of 30% fine, 40% medium and 30% coarse size have the best compressive strength and thermal insulation in all series. Due to low thermal conductivity, lightweight aggregate concrete with diatomite can be used to prove high isolation in the structure.

Keywords: Diatomite; Lightweight aggregate; Lightweight concrete; Thermal insulating

1. Introduction

Diatomite is a siliceous sedimentary rock, which consists principally of fossilized skeletal remains of diatoms, unicellular aquatic plants related to algae. These microscopic plants have the unique capability of extracting silica from water to produce their skeletal structure. When diatoms die, their skeletons settle to form a diatomite deposit. It is a chalk-like, soft, friable, earthy, very fine grained rock, usually light in color. It is very finely porous and very low in density [1]. As the diatoms are composed of an amorphous form of silica containing a small amount of microcrystalline material, diatomite is chemically stable and inert. Because of the open structure of the diatom skeletons, diatomite is a lightweight rock and yet quite hard. Diatomite is commonly found in volcanic environments, with the deposits forming in lakes in volcanically active areas. There are a large number of diatomaceous deposits in Afyon, Turkey [2–4].

The production of lightweight aggregate concrete has been expanding, and now includes all types—from no-fines concrete of low density, mainly for block production, with densities from 300 to 1200 kg/m^3, to structural concrete with densities from 1000 to 2000 kg/m^3 and compressive strengths from 1 to 100 MPa. The production of all types of concrete is closely connected to the availability of lightweight aggregate, and economics dictate the use of lightweight aggregate concrete in place of normal-weight concrete (NWC) [5].

Lightweight aggregates such as 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 such as internal and external walls, inner leaves of external cavity walls, fill panels and isolation of roof decks and floors [6,7].

Aggregates generally constitute about 70–80% by volume of Portland cement concrete. Due to the large volume fraction it occupies in concrete, aggregates exert a

*Corresponding author. Tel.: +90 272 228 13 11/345; fax: +90 272 2281319.
E-mail addresses: unal@aku.edu.tr (O. Ünal), uygunoglu@aku.edu.tr (T. Uygunoğlu), ayildiz@aku.edu.tr (A. Yildiz).

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major influence on the elastic modulus of concrete and can be expected to have an important influence on other properties as well [8].

Apart from the density of the aggregates, the density of the concrete also depends upon the grading of the aggregates, their moisture content, mix proportions, cement content, water-to-binder ratio, chemical and mineral admixtures, etc. Besides the material, it also depends upon the method of compaction, curing conditions, etc [9].

Lightweight concrete (LC) is generally used to reduce the dead weight of a structure as well as reduce the risk of earthquake damages to a structure because the earthquake forces that will influence the civil engineering structures and buildings are proportional to the mass of those structures and buildings. Thus, reducing the mass of the structure or building is of utmost importance to reduce their risk due to earthquake acceleration [10].

Highly absorptive, light weight and free-flowing nature are characteristics of diatomite aggregates. Diatomite was apparently used by the ancient Greeks as an abrasive and in making lightweight building bricks and blocks [11]. Because of these unique properties of diatomite, the production of LC with diatomite for high thermal isolation and reduction of dead load of construction was aimed at.

Fig. 1. Diatomite deposits in Seydiler region of Afyon, Turkey.

2. Experimental program

2.1. Materials

The diatomite samples were taken from Seydiler region of Afyon in Turkey (Fig. 1). The chemical analyses of diatomite were determined using ICP–MS (Inductive coupled plasma–mass spectrometry), at the ACME analytical laboratory, Canada. The results of chemical analyses of diatomite and cement are given in Table 1. Seydiler diatomite can be used as an insulation and filtration material according to the quality criteria of diatomites and results of chemical analyses [4].

The particle density of the lightweight aggregate was 2.45 kg/m^3. Ordinary Portlant cement (OPC 42.5) was used for the production of the LC. The diatomite aggregates were separated into three groups in sizes of 0–4 mm (fine), 4–8 mm (medium) and 8–16 mm (coarse).

2.2. Mix proportions

In order to investigate the effect of different aggregate granulometry and cement content on physical and mechanical properties of block elements, mixtures were prepared in four different aggregate granulometries (Table 2) and in four different cement contents as 250, 300, 350 and 400 kg/m^3. The water/cement ratio of all mixtures was kept at 0.15. The diatomite aggregates were absorbed in water before adding to the mix, because high porosity of diatomite does not absorb to mix water. The aggregates were added in the mix by compacted saturated bulk density (CSBD). CSBD of aggregates are given in Table 2.

Aggregate ratio in the mix, which was designed as fine aggregate (FA) was reduced from 45% to 30% while that of medium aggregate (MA) was increased from 25% to 40% by a ratio of 5%. Coarse aggregate (CA) was kept at a ratio of 30%. The series were coded as A: 45% FA + 25% MA + 30% CA; B: 40% FA + 30% MA + 30% CA; C: 35% FA + 35% MA + 30% CA and D: 30% FA + 40%

Table 2
Ratio and CSBD of aggregates

Size of aggregate	CA	MA	FA
CSBD (kg/m^3)	860	910	1400

Table 1
Chemical analyses of Seydiler diatomite and OPC 42.5

Content (%)	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	SO_3	K_2O	LOI
Diatomite	67.20	10.09	2.74	0.63	1.36	0.36	—	0.67	8
Cement	19.3	5.57	3.46	0.86	63.56	0.13	2.91	0.80	2.78