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The effects of hydrophobe clay on some physical and mechanical properties of the low-strength concrete blocks produced with pumice aggregate

Pomza agregası ile üretilen düşük dayanımlı beton blokların bazı fiziksel ve mekanik özelliklerine hidrofob kilin etkileri

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ABSTRACT

Light-weight concrete blocks (LCB) can be produced by using processed natural material or unprocessed porous materials. The present study covers the use of pumice lightweight aggregate (PLA) and hydrophobe clay to produce the LCB for use in construction of load-bearing or non-load bearing structural members. Pumice aggregate (PA) were supplied from Erzurum-Pasinler region. Some physical and mechanical properties of the specimens produced were investigated in this study. According to experimental results, while dry unit weight varies between 855 and 1040 kg m^{-3} with water absorptions between 15%-22%, 28-day compressive strength ranged from 4.75 to 8.5 MPa. Experimental test results showed that the specimens produced with 10% hydrophobe clay addition have sufficient strength and lower water absorption to be considered load-bearing block applications. Due to low unit weight, such specimens can be used to build earthquake-resistant agricultural structures in rural areas.

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***Anahtar Kelimeler*:**

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Hafif agrega
Hafif beton
Hafif beton bloklar

ÖZ

Hafif beton bloklar, işlenmiş doğal malzeme veya işlenmemiş gözenekli malzemeler kullanılarak üretilebilir. Bu çalışma, taşıyıcı veya taşıyıcı olmayan elemanların inşasında kullanılan hafif beton blokların yapımı için pomza hafif agregası ve hidrofob kilin kullanımını kapsamaktadır. Bu makalede pomza agregası Erzurum-Pasinler yöresinden temin edilmiş ve düşük dayanımlı beton blokların bazı fiziksel ve mekanik özellikleri incelenmiştir. Deney sonuçlarına göre, kuru birim ağırlığı 855 ve 1040 kg m^{-3}arasında değişmekte iken, su emme % 15-% 22 arasında, numunelerinin 28 günlük basınç dayanımı 4,75 den 8,5 MPa arasında değişmektedir. Araştırmadan elde edilen sonuçlar, % 10 hidrofob kil katkısı ile üretilen örneklerin yük taşıyıcı uygulamalarda kabul edilebilecek yeterli dayanım ve düşük su emmeye sahip olduğunu göstermiştir. Düşük birim ağırlığından dolayı üretilen örnekler kırsal alanlardaki tarımsal yapıların yapımında depreme dayanıklı olmalarını da sağlamak için kullanılabilir.

1. Introduction

Lightweight concrete (LC) has been widely used in buildings as masonry blocks, wall panels, roof decks and precast concrete units. Reduction in weight by the use of lightweight aggregate concrete is preferred, especially for structures built in seismic zones. LC manufactured either from natural or from artificial aggregate is classified by ACI Committee 213 into three categories with regard to strength and density (ACI Committee 213 1970). The first category is termed low-strength, corresponding to low density and is mostly used for insulation purposes. The second category is moderate-strength and is used for filling and block concrete. The third category is structural LC and is used for reinforced concrete. Pumice concrete blocks of Turkey, can be classified in the second category. Pumice is principally an alumina-silicate of volcanic origin formed by rapid cooling of molten lava. It is a natural lightweight aggregate with a sponge like structure and found in granulated form (Sari and Pasamehmetoglu 2005).

The use of lightweight aggregate with low thermal conductivity in the production of lightweight concrete blocks can provide an alternative cost-effective solution (Al-Jabri et al. 2005). Natural or artificial lightweight aggregates are available in many parts of the world and can be used to produce concrete with wide range of unit weights and strengths 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 (Topcu 2001; Demirboga et al. 2005). Lightweight aggregate can be processed from natural materials, by-products or unprocessed materials. With large number of voids in the aggregate, lightweight aggregate concrete possesses a relatively higher thermal insulating efficiency than the normal concrete. Therefore, LC has superior properties such as lightness in weight, and good thermal insulation (Al-Jabri et al. 2005).

Pumice aggregate concrete mixture design has special characteristics related to mixture water content. In general, lightweight concrete mix design is determined the water/cement ratio (W/C) of a mixture considering the aggregates to be in the position of saturated surface dry. Due to high water absorption capacity of pumice, the total mixture water requirement of pumice concrete mixture can be extremely high. The loss of strength at early ages can be attributed to the high water demand of pumice aggregates due to their porosity. Highly porous aggregate structure may absorb a significant portion of mixing water which reduces the workability of fresh concrete to a great extent (Khandaker and Hossain 2004). When concrete is made with lightweight aggregate that has low initial moisture contents and relatively high rates of absorption, it may be desirable to mix the aggregates with one-half to two-thirds of the mixing water for a short period prior to the addition of cement (ACI Committee 211.2-91 1992). Therefore, the aggregate can be pre-wetted and the saturated surface can be dried before casting of concrete. However, this process will also cause an increase in W/C ratio and results with strength loss and increase in the fresh density of concrete block.

Lightweight masonry blocks are produced in most countries in a highly mechanized fashion. This production has to match strict standards that describe properties specified for the products. These may include denotations on sizes, strength, weather resistance, insulating properties and fire resistance. In recent years, there has been a focus on utilizing pumice aggregates (PA) in Turkey as the most popular natural lightweight aggregate in manufacture of lightweight concrete blocks. Pumice lightweight concrete blocks are made of pumice, cement and water which are used in construction of non-load bearing in fill walls and slabs (Gunduz 2005). One of the most effective ways to reduce the dead-load in multi-story buildings is to lighten the weight of the structure. Lightweight blocks can be manufactured from a density range of 400 kgm^{-3}-1100 kgm^{-3} with an average 40–50% reduction in weight, as compared to conventional slabs (Brown 1990; Gunduz 2008).

The masonry block process is perceived to be one of the most laborious intensive aspects of construction today. Since masonry units (blocks) must be handled and placed one-by-one, increased masonry productivity is the key to effective management of masonry construction (Bomhard 1980; Brown 1990). In test conducted both in field and at the research laboratory, it has dramatically shown that the size and weight of masonry units are primary factors influencing the speed at which blocks can be laid.

This research is basically focused on the development of pumice aggregate lightweight concrete blocks to be used in construction of load-bearing and non-load bearing walls. The aim of this study is to examine the effect of hydrophobe clay (Kurt 2009) on the physical and mechanical properties of low-strength lightweight concrete blocks. In particular, this research was conducted in order to investigate the reduction of water absorption of lightweight aggregate concrete blocks.

2. Materials and Method

2.1. Aggregate, hydrophobe clay and cement

The PA used in this research is obtained from Erzurum-Pasinler province, East of Turkey. It is characterized with a maximum particle size of 16 mm. The pumice aggregates were separated into four groups in fine (0-2 mm and 2-4mm), medium (4-8mm) and coarse sizes (8-16mm). Hydrophobe clay (Fig. 1) used in this study was supplied by the Anka Nanoteknoloji Ltd. company in Erzurum Region. An ordinary Portland cement (CEM II 42.5) complying with TS EN 197-1 standard requirements was used throughout this research. The chemical compositions and physical properties of the cement, pumice and hydrophobe clay are provided in Table 1.

Figure 1. Water droplets escaping out of hydrophobe clay specimen.

Table 1. The chemical composition, physical and mechanical properties of the cement, pumice and hydrophobe clay.

	PC	PA	HC
Chemical composition (%)			
CaO	59.00	1.84	1.71
SiO_2	18.63	71.35	53.28
Al_2O_3	4.48	13.20	20.67
Fe_2O_3	3.41	1.54	6.13
MgO	2.72	0.01	2.82
Na_2O	0.18	3.4	0.02
K_2O	0.52	5.0	0.82
SO_3	2.37	0.04	-
CI	0.009	-	-
LOI	8.11	3.05	14.0
Free CaO	0.41		
Physical and mechanical properties of cement			
Comp. str. 2 days (MPa)	17.9		
Comp. str. 7 days (MPa)	31.7		
Comp. str. 28 days (MPa)	45.9		
Specific gravity	2.94		
Initial setting time (min.)	177		
Final setting time (min.)	233		
Volume stability (mm)	1		
Blaine value (m^2/kg^{-1})	4191		
90 µm passing (%)	98.8		
32 µm passing (%)	88.5		

2.2. Mixture proportions and testing procedure

In order to investigate the effects of hydrophobe clay on physical and mechanical properties of samples produced from cement and PA mixtures were prepared in two different cement contents of 250 and 350 kg m^{-3}. Lewis (1966) reported that a common practice for structural and masonry unit concretes is to mix the aggregates and about two thirds of the required mixing water for periods up to 1 min prior to the addition of the cement, and the balance of the mixing water. Mixing is then continued as required for homogeneity, usually four or more minutes for masonry unit mixes. According to the Turkish standard TS 3234 (1978), the pumice aggregates (4-8 mm and 8-16mm) were pre-wetted with the amount of required mixing water for periods up to 1 min prior to the addition of the cement, because high porosity of pumice does not absorb mixed water. To define the optimal mix proportions and to obtain satisfactory mechanical properties, the pumice aggregate was divided into four different size ranges: smaller than 2mm, 2 to 4mm, 4 to 8 mm and 8 to 16 mm. The aggregates in the seize ranges were combined to obtain grain distribution curve, which fall within the grading curves A16 and C16 in TS 706 Turkish Standard Code (TS 706 1980). According to A16, C16 and TS 706 the grading of the pumice aggregate is shown the Table. 2.

Table 2. Cumulative passing for one aggregate grade and for A16-C16 TS706 code.

Sieve size (mm)	Cumulative passing (%)		
	A16	Grade	C16
16	100	100	100
8	60	80	88
4	36	59	74
2	21	37	62
1	12	25	49
0.5	8	14	33
0.25	3	5	18

Aggregate ratios in the mix designed as fine aggregate (0-2mm and 2-4mm), medium aggregate (4-8 mm) and coarse aggregate (8-16 mm) were mixed in 37%, 22%, 21% and 20% by weight, respectively. Hydrophobe clay proportions (0%, 5%, 10%, 15% and 20%) were used by weight in the replacement with material remaining in a range of 0-2mm sieve. The series were coded as, A1, A2, A3, A4, A5, B1, B2, B3, B4 and B5. The content of materials per cubic meter is given in Table 3.

Cube samples of 100x100x100 mm in size, were prepared to determine compressive strength, water absorption, and density. The molds were filled by fresh LC and compacted by using a wide field mallet, and then 25 compaction strokes were performed at two levels. For each mixture, 9 specimens were prepared. After 24 h, the specimens were taken out from the molds and were cured for 28 days in a laboratory curing tank at 21±2 °C, then removed and were put in an oven until constant weight was obtained for the tests. The samples were tested for water absorption, density and compressive strength in accordance with the standards (TS 3624 1981; TS 3114 1990; TS EN 992 1998; TS 2823 1986), respectively. At the same time, the method recommended by Somayaji, (1985) was used to determine water absorption.

3. Results and Discussion

Some physical and mechanical properties of concrete samples for different hydrophobe clay ratios and cement contents are given in Table 4. As it can be seen from Table 4, properties which increase in value, indicating increasing quality with additive of hydrophobe clay, are compressive strength, density and water absorption.

The research study as expected showed that the compressive strength of the concrete composition increases with increasing cement content and hydrophobe clay ratios. The ratio of hydrophobe clay has a positive effect on the strength. The strength increases with increasing hydrophobe clay ratio up to 10% of hydrophobe clay level, then, it begins to decline. The average cube compressive strengths of the concrete tested are presented in Fig. 2. The compressive strength values were determined to be between 4.75 MPa and 8.5 MPa. As it can be seen from Fig. 2, the strength characteristics of specimens show an increasing trend up to a certain value. On the other hand, the analysis shows that the compressive strength of specimens increases for use of hydrophobe clay up to 10% instead of fine aggregate (0-2 mm) as a mineral admixture. Due to water repellent properties of the hydrophobe clay, use of hydrophobe clay ratios more than 10% in mixture caused difficulty in mixing and placing of fresh concrete. Because of this negativeness, porous volume in concrete increased. Therefore, this leads to decrease in compressive strength and unit weight. The dry density values of the same specimens varied from 855kg m^{-3} to 1040kg m^{-3} (Fig. 3). On the other hand, it was determined that water absorption changed approximately between 15% and 22%.

Light-weight aggregate concrete used for insulation purposes may provide strength as low as 0.5 MPa and a density of less than 1450 kg m^{-3}. Strength requirements for building blocks are most commonly set at 2.5 MPa for filler block and 5.0 MPa for load bearing blocks. Insulating masonry block elements are usually made with low-strength aggregates such as pumice. These aggregates have an average compressive strength of 3.5 MPa, but this value can be increased up to 7.0 MPa. The average density of a masonry block is 978 kg m^{-3} (Chandra and Berntsson 2002).

The properties of some traditional building materials such as clinker bricks and hollow concrete blocks, and gas concrete are shown in Table 5 (Sahin et al. 2008).

Table 3. Content of materials in 1 m^3.

Cement content (kg m^{-3})	Series	Lightweight aggregate(kg)				Hydrophobe clay(kg)	Water(l)
		0-2mm	2-4mm	4-8mm	8-16mm		
250	A1	382	167	158	133	-	286
	A2	363	167	158	133	19	286
	A3	344	167	158	133	38	286
	A4	325	167	158	133	57	286
	A5	306	167	158	133	76	286
350	B1	373	162	155	130	-	270
	B2	354	162	155	130	19	270
	B3	335	162	155	130	38	270
	B4	316	162	155	130	57	270
	B5	297	162	155	130	76	270

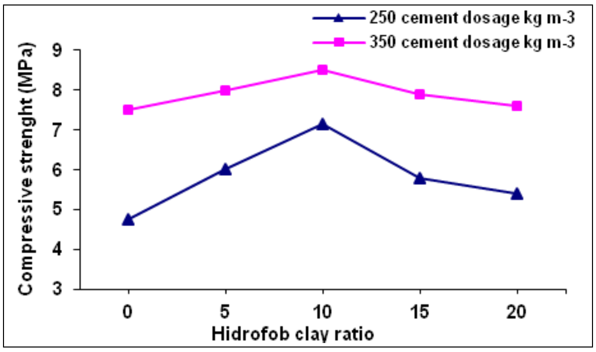

Figure 2. Compressive strength of specimen aged for 28 days.

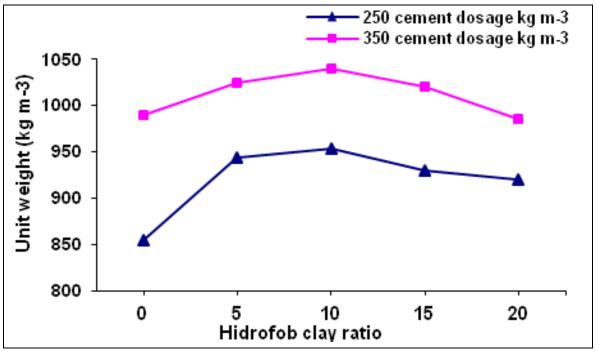

Figure 3. Unit weight of specimen aged for 28 days.

The Turkish standard (TS 2823 1986) gives an average compressive strength of pumice concrete filled blocks as between 2.5 MPa-15 MPa and states that no blocks should have a compressive strength less than 2.5 MPa. It can be seen that the compressive strength of produced samples were between the values given in the standards. In this study, the highest compressive strength of samples (A3 and B3) has been achieved with 10% hydrophobe clay addition. Therefore, these mixture compositions are all suitable for production of load-bearing and non-load bearing blocks.

Al-Jabri et al. (2005) researched the insulation block element for a hot-climate region. The blocks were produced from vermiculite and polystyrene beads used as light-weight aggregates. They found that compressive strength of these blocks changed between 2.2 and 15 MPa.

Table 4. The mix proportions, water absorption, density and compressive strength of specimens.

Cement content (kg m^{-3})	Series	Water absorption (%)	Density (kg m^{-3})	28 days Comp. strength (MPa)
250	A1	22.0	855	4.75
	A2	20.5	944	6.00
	A3	18.0	953	7.13
	A4	19.5	930	5.80
	A5	20.5	920	5.40
350	B1	17.0	990	7.50
	B2	16.0	1025	8.00
	B3	15.0	1040	8.50
	B4	15.5	1020	7.90
	B5	16.0	985	7.60

Table 4 summarizes the results of unit weight in 28 days. Addition of hydrophobe clay increased the unit weight of the produced samples. The unit weight of specimens prepared with hydrophobe clay addition varied from 855 to 1040 kg m^{-3} (Fig. 3). According to Turkish standard, the oven-dried unit weight values of pumice concrete filled blocks are to be between 800 and 1600 kg m^{-3}. As can be seen in Table 4, the oven-dried unit weight values are between the values given by the standard. The research results show that the samples comply with the minimum required standard value.

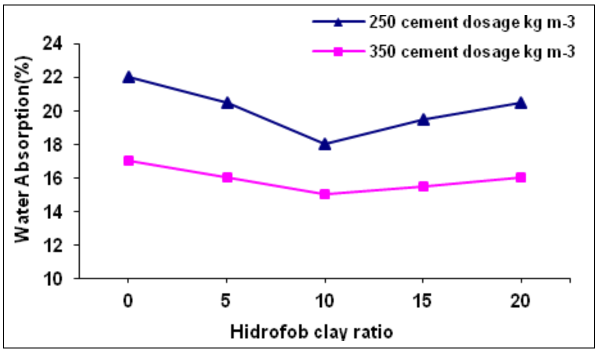

Figure 4. Water absorption of specimen aged for 28 days.

Water absorption was found to vary between 15 and 22% varying with hydrophobe clay ratios and cement content (Table 4). It was observed that the water absorption values are closely related to increasing cement content and hydrophobe clay. However, water absorption is different for mixes, decreasing with increasing cement content and hydrophobe clay ratio. The main cause of the lower water absorption of the samples produced with the pumice aggregate was the effect of hydrophobe clay. This change in water uptake is very apparent in water absorption versus hydrophobe clay ratio relationship (Fig. 4).The water absorption values of produced samples are lower than the values given in the Table 5.

Table 5. The properties of some building materials used in wall making.

Material	Compressive strength (MPa)	Density (kg m^{-3})	Water absorption (%)
Hollow concrete block	2–12.5	500–2200	25–35
Clinker bricks	16	800–1800	18
Gas concrete	2–3.5	800–1400	25–35
Lightweight concrete	17	400–2000	24–50

4. Conclusions

The following conclusions can be drawn from this investigation which is an investigation of physical and mechanical properties of lightweight concrete blocks produced with pumice and hydrophobe clay:

The compressive strength of specimens was determined to be between 4.75 MPa and 8.50 MPa in 28 days. The strengths of samples increase with increased contents of hydrophobe clay. Addition of hydrophobe clay in both cement doses (250 and 300 kg m^{-3}) led to an increase in the strength. The compressive strength of specimens is higher than the minimum required value given in the standards. The research findings show that the maximum increase in compressive strength value is obtained with 10% hydrophobe clay addition.

- Unit weight changed between 855 and 1040 kg m^{-3} for specimens aged for 28 days. Addition of hydrophobe clay to pumice aggregate increases the unit weight of samples. However, the unit weights of all specimens are between the values given by the standard.

- Water absorption of samples, in the present investigation was obtained to be between 15 and 22%.The water absorption of samples produced was found to be less compared to traditional construction materials.

There is a growing demand for construction due to population expansion and shortage of building materials projected for future. The use of local materials for building in rural areas has a positive impact particularly on local economies. Traditional construction materials do not meet our current need due to the engineering properties. Therefore, it is important to improve weaker properties of thin lightweight concrete block. As a result, the use of hydrophobe clay would be beneficial to improve the physical and mechanical properties of lightweight concrete. Lightweight concretes with pumice and hydrophobe clay can be used in constructions to obtain high strengths and reduce self-weight or dead load of construction.

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