International Scientific Publications: Materials, Methods and Technologies, Vol. 2
ISSN 1313-2539

INVESTIGATION OF PROPERTIES OF HOLLOW AND LOW STRENGTH CONCRETE MASONRY UNITS WITH PUMICE AGGREGATE

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Abstract

Lightweight concretes can be produced by using different type of lightweight aggregates. The results of investigations on the suitability of using pumice aggregates from Isparta region in Turkey as fine and coarse materials in lightweight concrete masonry production are reported. In this study, pumice aggregate lightweight concrete (PLWC) samples were produced with different sizes of 0-4 mm as fine pumice aggregate (FPA), of 4/8 mm as middle pumice aggregate (MPA) and of 8/16 mm as coarse pumice aggregate (CPA). The pumice aggregates collected from the quarry were first crushed and screened in this study. In order to analyze the role of pumice aggregate ratio on the properties of lightweight concrete masonry for dry mix conditions, a series of preliminary trial batches were first carried out. Trial batches were cast into 100x100x100 mm cube samples with the cement content of 220 kg/m^3 in low water/cement ratio as 0,15. The specimens were analyzed to examine the compressive strength, water absorption and specific porosity of all series. According to the results of preliminary trial batches, it was decided to produce a full scale pumice aggregate masonry block (PAMB) units for the same mixture proportions of the best series in trials. PAMB units were analyzed to investigate their unit weight and the compressive strength for air dry condition at 28 days. The coefficient of thermal conductivity for the blocks was tested based on oven dry. According to experimental results, while dry unit weight has increased, compressive strength of 28 days samples has increased, too for the PLWC dry mix composition. Due to the low strength and thermal conductivity, pumice aggregate lightweight masonry units can be used in constructions for non-load bearing infill walls providing the high isolations.

Key words: *Pumice, lightweight aggregate, hollow blocks, property.*

1. INTRODUCTION

Compressed masonry blocks have traditionally been widely used as a construction material for both structural and non-structural walls. Masonry walls are primarily composed of masonry units (typically concrete blocks or clay bricks) and mortar. In addition to the various options available for masonry units with respect to material composition, further options relate to the geometry of the units and to their percentage of hollow volume. Furthermore, mortar can be composed of several materials and aggregate types and its workability may be adjusted by varying its water content. All these features naturally have a considerable effect on the mechanical characteristics of masonry walls [1].

The capacity of masonry in compression is strongly related to the compressive strength of the masonry units (stone, brick, and block), as well as mortar strength, bonding pattern and many other factors. Though other parameters, such as density, frost resistance and water absorption, may be specified in design, compressive strength has become a basic and universally accepted unit of measurement to specify the quality of masonry units. The relative ease of undertaking laboratory compressive strength testing has also contributed to its universality as an expression of material quality [2].

Masonry wall construction has a number of advantages the first of which is the fact that a single element can fulfill several functions including structure, fire protection, thermal and sound insulation, weather protection and sub-division of space. Masonry materials are available with properties capable

ISSN 1313-2539

of meeting these functions, requiring only to be supplemented in some cases by other materials for thermal insulation, damp-proof courses and the like. The second major advantage relates to the durability of the materials which, with appropriate selection, may be expected to remain serviceable for many decades, if not centuries, with relatively little maintenance. From the architectural point of view, masonry offers advantages in terms of great flexibility of plan form, spatial composition and appearance of external walls for which materials are available in a wide variety of colors and textures [5].

Concrete masonry blocks come in a much greater variety of sizes and formats (solid, cellular and hollow). Also, materials that used in making of masonry block such as aggregate are affected to physical and mechanical properties of blocks. In the production of masonry units, lightweight aggregates are used for reduce the unit weight of material [3].

Increasing utilization of lightweight materials in civil structuring applications is making pumice stone a very popular raw material as a lightweight rock. Due to its having a good ability for making the different products based on its physical, chemical and mechanical properties, the pumice aggregate finds a large using area in civil industry as a construction material. In order to design an initial stage of a building project, the construction material properties should be well evaluated. Therefore, the need arises to analyze the materials to be used in construction experimentally in detail [4].

In this study hollow and non-load bearing masonry units were designed with pumice lightweight aggregate. Physical and mechanical properties of masonry blocks were investigated.

2. EXPERIMENTAL STUDY

2.1. Materials

Isparta / Turkey region volcanic pumice was used for this study. Particle density and bulk density of pumice were 2.24 and 760 kg/m^3, respectively. Ordinary Portland cement (CEM I 42.5R) was used for the production of the LWC and blocks. Surface area by Blaine, specific gravity and 28 days compressive strength of cement were 386 m^2/kg, 3.07 and 48.5 N/mm^2, respectively. The chemical analyses of materials used in this study were determined in Acme Analytical Laboratories Ltd. in Canada and results were given in Table 1.

To define the optimal mix proportions and to obtain satisfactory mechanical properties of masonry units, the pumice LWA was divided into three different size ranges: smaller than 4 mm, 4 to 8 mm and 8 to 16 mm. The aggregates in these size ranges were combined in different proportions to obtain the optimum granulometry in five grading curves properly to TS 1114 EN 13055-1 [6] as Grade 1, Grade 2 and Grade 3, Grade 4 and Grade 5. Aggregate ratios in the mixes were designed that as fine aggregate (FA) has been reduced from 60 % to 40 % while that of medium aggregate (MA) was increased from 20 % to 40 % by a ratio of 5 %. Coarse aggregate (CA) was kept at a ratio of 20 %. Sieve analyses of pumice aggregates were given in Figure 1.

ISSN 1313-2539

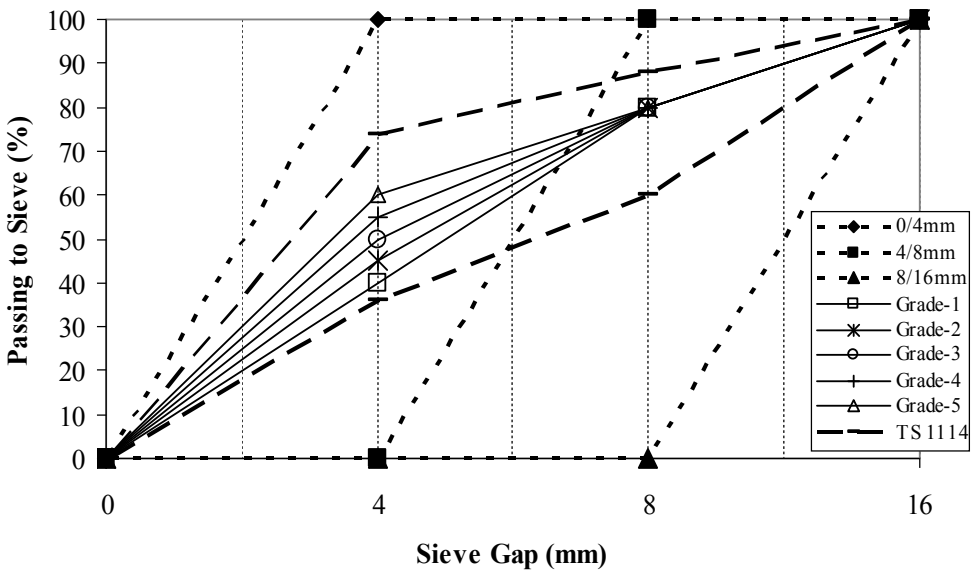


Figure 1. Sieve analyses of aggregates

Table 1. Chemical analysis of cement and pumice

COMPONENT (%)	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	SO_3	K_2O	L.O.I.
Cement	19,3	5,57	3,46	0,86	63,56	0,13	2,91	0,80	2,78
Pumice	56,85	16,72	4,66	1,84	5,39	4,61	-	5,19	2,8

2.2. Mix Proportions and Test Program

Before production of masonry blocks, trial batches were produced for defining of optimum aggregate granulometry that supplying to the best properties on masonry units. The all mixtures were designed at 220 kg/m^3 cement content and at 0.15 actual water/cement ratios (w/c). The pumice aggregates were absorbed water in 30 min before adding the mix because of high porosity of aggregates [7]. In the trial batches, the prepared lightweight aggregate concrete (LWAC) as damped was filled in 100 x 100 x 100 mm cubic moulds by vibration-compression machine in 20 % compression ratio. The specimens immediately demoulded and cured in air (in laboratory condition) at 20±2 ^{o}C for 7, 28 and 56 days. On the trial specimens, compressive strength was defined according to TS EN 12390-3 [8] by 2000 kN compressive machine with a rate of loading controller. Unit weight (UW), specific porosity (SP) and water absorption (WA) were calculated aged in 7 and 28 days specimens according to Archimedes principle by the weight measurements of saturated specimens in air and in water, and the dry weight (oven drying at 105°C to constant weight). In the best granulometry, masonry blocks were produced in same cement content and w/c (Fig. 2). Three types of masonry blocks were designed as one-order hollow, two-order hollow and three-order hollow in size of 135 x 190 x 190 mm, 150 x 340 x 190 mm and 190 x 340 x 190 mm, respectively. Also, the production method was same with trial batches.

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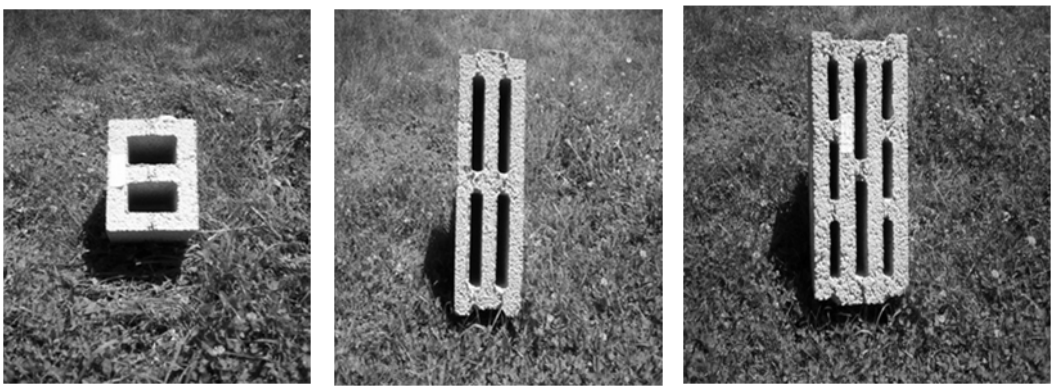


Figure 2 Masonry blocks produced with pumice LWA

Also, compressive strength and unit weight are defined on the masonry blocks. The thermal conductivity of masonry blocks was determined by the ‘‘hot box method” according to ASTM C1363 [9] on the aged 28 days specimens. For the all tests, arithmetic average of three specimens has been used.

3. RESULTS AND DISCUSSION

To investigate the influence of porous aggregate on the physical and mechanical properties of masonry units, natural lightweight aggregate as pumice has been used. Pumice lightweight aggregate concrete (PLWAC) was produced in low w/c ratio by vibration – compression method and they have been tested in 7, 28 and 56 ages.

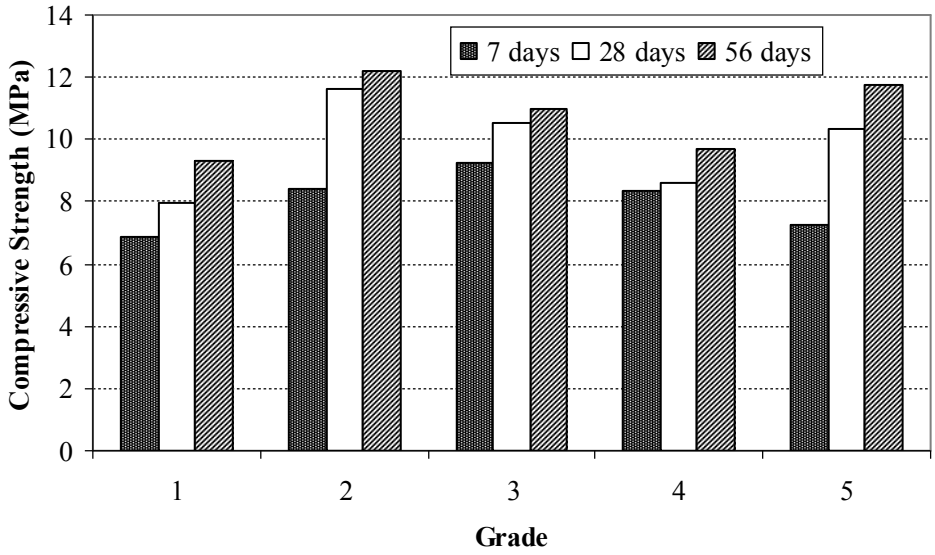


Figure 3 Compressive strength of PLWAC in different ages and gradations

Compressive strength of PLWAC was compared in Figure 3 depending on specimen age. Generally, the compressive strength of LWC has increased by rising of concrete age. Developing of strength in PLWAC was the highest in Grade-2 and Grade-5, Grade-1 and Grade-4, respectively. Of course, the

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strength development in lightweight concrete is limited by the inherent strength of aggregate [10]. The strength development was reduced by increasing of concrete ages from 28 to 56 days due to evaporation of free water that affect to hydration of cement. Besides, the highest compressive strength of PLWAC was obtained in Grade-2 as 12 N/mm^2. The compressive strength of PLWAC has changed between 7 - 12 N/mm^2 for 7 – 56 aged specimens.

Sari et. al. [11] investigated to the effects of gradation and admixture on the pumice LWAC. The specimens were cured at a temperature of 20-25 ^{o}C and a relative humidity of 50-55 %. Compressive strength of the specimens was determined as between 3.5 - 7 N/mm^2 for 28 and 56 ages. Babu et. al. [12] investigated to the performance of lightweight EPS aggregate concretes containing fly ash over a wide range of concrete densities of 500 - 2200 kg/m^3. The compressive strengths of the specimens have varied between 1.1 and 18.4 N/mm^2 for 28 ages.

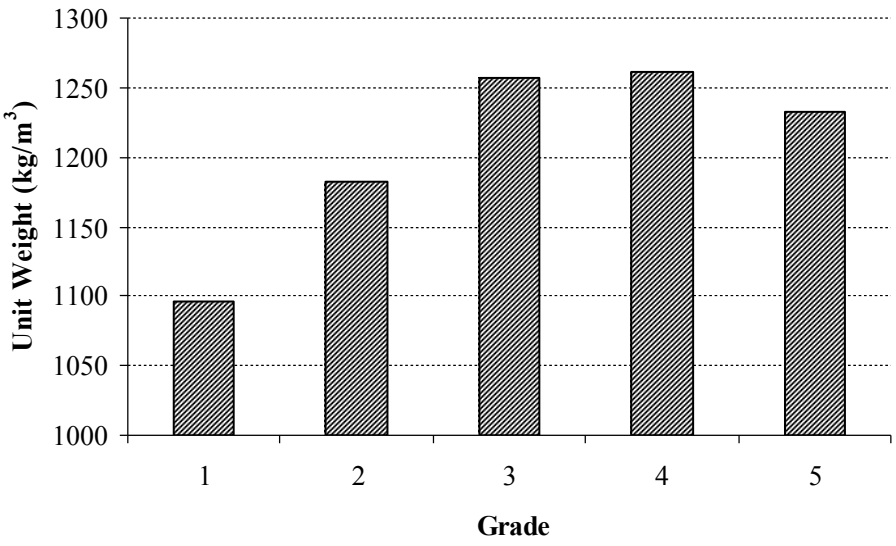


Figure 4. Unit weight of 28 aged PLWAC

As known from the literature, LWACs are categorized according to compressive strength and unit weight of them (Figure 4). Generally, the PLWAC for 28-56 days can be categorized as moderate strength LWC because of their strength in between 7 – 12 N/mm^2 and unit weight in between 1100 - 1260 kg/m^3. The grading effects to unit weight of LWAC as seen in Fig. 4. The lowest unit weight was obtained on the specimens that produced with Grade-1 while the highest unit weight was obtaining on the specimens produced with Grade – 4.

Figure 5 illustrates the specific porosity (sp) and water absorption (wa) of pumice LWAC. The specific porosity and water absorption of pumice LWAC have ranged between 15 % - 25 % and 12 % and 23 %, respectively. They have decreased until Grade-3 and then again increased by increasing of surface area of aggregate depending on fine material and in cubic meter. Pumice LWAC has higher "sp" and "wa" value than normal strength concrete due to properties of aggregate such as pore structure. The specific porosity and water absorption of LWC depends upon the raw material used for making them.

Even tough the lowest porosity and water absorption were obtained in the specimens that produced with Grade-3, the highest compressive strength and improper unit weight was obtained on the specimens produced with Grade-2. Hence, masonry units in this study were produced in Grade-2. Geometrical, physical and mechanical properties of three type's masonry blocks are presented in Table

ISSN 1313-2539

2. Compressive strength of masonry units is different depending on hollow ratio on surface or totally surface area, and it has changed between 3.77 – 5.11 N/mm^2. In the same cement and w/c ratios, three-order hollow masonry blocks more proper than other units due to strength and thermal conductivity.

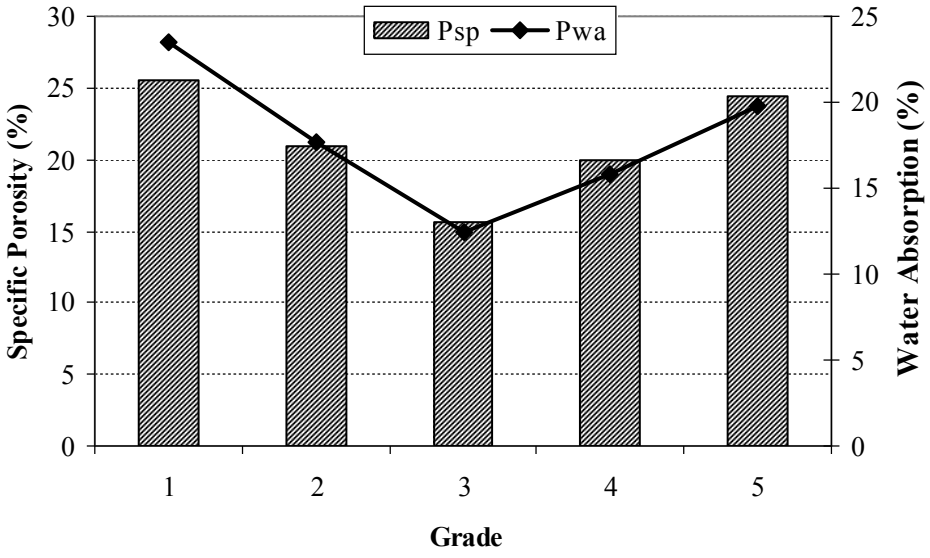


Figure 5. Specific porosity (sp) and water absorption (wa) of 28 aged PLWAC

Table 2. Properties of Masonry Blocks

Property	Masonry Block Type		
	135x190x190	150x340x190	190x340x190
Total surface area (cm^2)	256,5	570	710,64
Total hollow surface area (cm^2)	75	150,12	169,96
Total full surface area (cm^2)	181,5	419,88	540,68
Hollow ratio on surface (%)	29,24	26,34	23,92
Fullness ratio on surface (%)	70,76	73,66	76,08
Total volume (cm^3)	4874	10944	13502
Total hollow volume (cm^3)	1350	2732	3059
Total fullness volume (cm^3)	3524	8212	10443
Volumetric hollow ratio (%)	27,70	24,96	22,66
Volumetric fullness ratio (%)	72,30	75,04	77,34
Block weight (kg)	4,06	9,31	12,07
Dry unit weight (kg/m^3)	833	851	894
Masonry number in 1 m^2	28	13,5	13,5
Compressive strength (N/mm^2)	3.77	3.66	5.11
Thermal conductivity (W/mK)	0.237	0.214	0.203

ISSN 1313-2539

Thermal conductivity is depends upon the pore structure of the lightweight aggregates, density of concrete and the cement paste matrix [13]. Other words, the thermal conductivity is increases with increasing of density of concrete. Also, according to Kim et al. [14], aggregate volume fraction and moisture condition of concrete are revealed as mainly affecting factors on the thermal conductivity of concrete. The thermal conductivity of masonry units has decreased by increasing of volumetric hollow ratio and thermal conductivity of masonry blocks has ranged between 0.203 - 0.237 W/mK.

Al-Jabri et. al. [15] studied to block element for hot climate region. The blocks were produced from two indigenous materials: vermiculite (VerBlock) and polystyrene beads (PolyBlock1) which were used as lightweight aggregates with different proportions in the mix. The mechanical properties of the two types of blocks were compared and compressive strength of these blocks has changed between 2.2-15 N/mm^2.

Uysal et.al. [13] a study has conducted on thermal conductivity coefficients of concretes made up of mixtures of pumice aggregate (PA) and normal aggregate, and they were reported that when 25%, 50%, 75%, and 100% PA ratios were used in place of normal aggregate by volume, PA decreased the density and thermal conductivity of concretes up to 40% and 46%, respectively.

As seen, the masonry blocks produced with pumice aggregate has lower thermal conductivity than normal concrete and brick used in constructions.

4. ACKNOWLEDGEMENT

Authors thank to The Scientific & Technological Research Council of Turkey (TUBİTAK) for financial support throughout this study by project of 104.M.391.

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