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The Usage of Perlitic Pumice from İzmir-Menderes (Turkey) in the Production of Low-Strength Lightweight Concrete

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Lightweight aggregates, used to produce cavity blocks in the construction sector, vary according to their technical properties and thus, technical analyses should be performed on lightweight aggregate specimens. Lightweight aggregates, like pumice, are widely employed for the production of construction elements, used as light masonry units. In literature there are studies related to applications of various lightweight aggregates, such as volcanic slag, ignimbrite and expanded clay, in addition to pumice, to produce porous cavity blocks. This study investigates the usability of perlitic pumice formations, present around Menderes, İzmir (Turkey), as lightweight aggregate. Many experiments were conducted to investigate this possibility and to determine the optimum mixing ratios of aggregate. Based on the results, for 10% of cement by volume, the optimum aggregate mixing ratio was 40% 0–4 mm and 60% 4–8 mm.

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1. Introduction

Structural members of various types can be produced from lightweight concrete. Cavity blocks, hollow blocks and insulating plates are the most important products among them. Industrial development has been seen in Turkey, especially in the production of cavity blocks [1]. The use of light cavity blocks decreases the weight of multi-storey buildings. Moreover, in Turkey, because heat insulation has become obligatory in buildings, and a mandatory energy performance certificate is required for buildings, the insulating construction elements, such as porous light wall blocks, have become more important. Lightweight aggregates, like pumice, are widely used for the production of construction elements, used as light masonry units. Porous cavity blocks, using pumice, are also called "lightweight concrete masonry blocks".

In literature, there are studies related to the application of various lightweight aggregates, such as volcanic slag, ignimbrite and expanded clay, in addition to pumice, to produce porous cavity blocks [2, 3]. This study investigates the usability of perlitic pumice formations, present around the district of Menderes in İzmir province, in the production of light cavity blocks, as lightweight aggregates.

Perlitic pumice formations are located in the southern part of Menderes County, the former name of which was Cumaovası, at a distance of 20 km from the city center of İzmir. The mining field consists of young volcanic cones formed along fractures. The field has different rock types and a quiet rough morphology with deep valleys to the west [4]. The depth of ore deposits is between 25 to 90 m. Deposits are lying discontinuously along the Murat Hill and Karadağ for 10 km [5]. Although perlite and pumice bedding stratifications are known to exist, there is also a transitional rock called perlitic pumice.

Perlitic pumice is a natural and porous rock type. This rock, obtained from the zone between perlitic bedding stratifications, shows lightweight aggregate characteristics due to its lightness and porosity. In macroscopic investigations, done on perlitic pumice samples, a spongy and porous structure is observed. The existence of a large and non-uniform porous structure in large aggregate particles has been noted. On the other hand, fine-sized and non-uniform porous structures are observed in small-sized particles. The most effective component of this acidic rock is SiO_2. In macroscopic and microscopic investigations of samples, it shows some characteristics of both the perlite and the pumice, since it is a transitional rock. Therefore, it is named as perlitic pumice [1].

In this study, optimum mixture ratios were determined by casting concrete samples using perlitic pumice components, having different particle size distributions.

2. Experimental method

This study has employed specimens of perlitic pumice with the dimensions from 0 to 4 mm and from 4 to 8 mm, obtained from mineral deposits of Menderes, İzmir. The results of chemical analysis of the perlitic pumice and the cement are shown in Table I. CEM-1 32.5 cement was selected for experiments because the subject of the study is related to production of low-strength, lightweight concrete.

In the research, lightweight concrete specimens were prepared based on the TS 3234 standard [7]. Within this scope, lightweight concrete specimens having 6, 8,

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TABLE I

Chemical composition of İzmir-Menderes perlitic pumice and composition of the cement [6].

Component	Perlitic pumice [%]	Cement [%]
SiO_2	72.63	20.74
Al_2O_3	12.14	4.12
Fe_2O_3	0.89	3.56
CaO	0.27	64.18
Na_2O	1.62	0.63
K_2O	5.99	0.72
MgO	0.01	1.59
TiO_2	0.03	–
MnO	0.07	–
P_2O_5	0.003	–
Mass loss	5.17	2.69

and 10% of cement by volume were prepared in the vibration and pressing unit as dry mixtures, by using aggregates at various mixing ratios. Fifteen different concrete mixtures, having five aggregate combinations, were prepared to determine the optimum mixing ratio of fine and coarse aggregates (Table II). Materials were subjected to natural curing after casting and then stored. Dry unit weight and uniaxial compressive strength values were determined after a 28-day curing process.

TABLE II

Amounts of materials used for 1 m^3 of mortar.

Mixture No.	Aggregate mixing ratios	0–4 [kg/m^3]	4–8 [kg/m^3]	Cement [kg/m^3]
M1	100% 0 to 4 mm	1130	–	78
M2		1106	–	104
M3		1082	–	130
M4	60% 0 to 4 mm 40% 4 to 8 mm	678	392	78
M5		664	374	104
M6		649	366	130
M7	50% 0 to 4 mm 50% 4 to 8 mm	565	478	78
M8		553	468	104
M9		541	457	130
M10	40% 0 to 4 mm 60% 4 to 8 mm	452	573	78
M11		442	561	104
M12		473	549	130
M13	100% 4 to 8 mm	–	955	78
M14		–	935	104
M15		–	914	130

3. Results and discussion

For low-strength, porous cavity block production, lightweight concrete specimens having 6, 8, and 10% of cement by volume were prepared using perlitic pumice aggregates with particle size of 0–4 mm and 4–8 mm. Dry unit weight, uniaxial compressive strength and water absorption values of the samples of 15 mixing groups, after twenty eight days of curing, are shown in Table III. Variation of the uniaxial compressive strength and dry unit weight with the amount of cement and for different aggregate mixing combinations are shown in Figs. 1 and 2.

TABLE III

Parameters of lightweight concrete specimens for different aggregate mixing ratios.

Specimen No.	Dry unit weight [kg/m^3]	Uniaxial compressive strength [kg/cm^2]	Water absorption [%]	Aggregate and cement mixing ratios
M1	1288	3.60	18.05	100 % 0–4 mm 6%, 8%, 10% PC*
M2	1379	16.50	18.69	
M3	1478	24.65	16.57	
M4	1356	8.15	14.60	60% 0–4 mm 40% 4–8 mm 6%, 8%, 10% PC
M5	1342	9.80	16.16	
M6	1397	14.75	14.53	
M7	1367	6.80	15.65	%50 0–4 mm %50 4–8 mm 6%, 8%, 10% PC
M8	1447	19.45	14.53	
M9	1406	20.80	12.73	
M10	1349	5.80	14.01	40% 0–4 mm 60% 4–8 mm 6%, 8%, 10% PC
M11	1416	14.25	13.43	
M12	1471	25.55	13.56	
M13	1364	7.25	14.29	100% 4–8 mm 6%, 8%, 10% PC
M14	1366	7.10	13.49	
M15	1336	14.40	12.58	

PC (Portland cement)

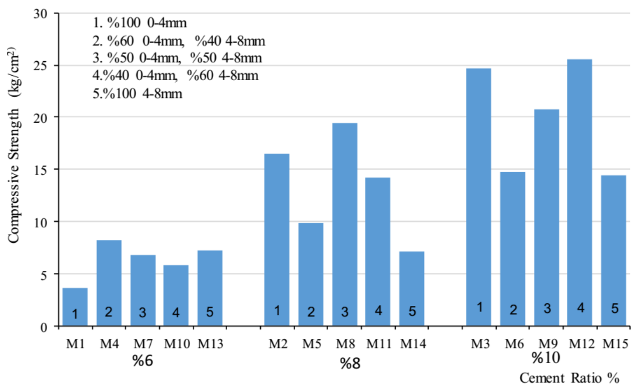

Fig. 1. Uniaxial compressive strength for different combinations of cement amount and different aggregate mixing ratios.

There are two factors of importance for porous masonry blocks: uniaxial compressive strength and dry unit weight. Based on the TS EN-771-3 standard [8], an arbitrary limit value is specified for masonry units intended to be used as non-load-bearing wall members. However, in practice, 28-day compressive strength values of masonry wall members should be 25 kg/cm^2 and unit weight values should be between 600 to 800 kg/m^3 [2].

After examining the uniaxial compressive strength values, the highest strength value in mixtures with 6% of Portland cement (PC), in volume, was 8.15 kg/cm^2. This value was achieved in the mixture of "60% 0–4 mm and 40% 4–8 mm" aggregates.

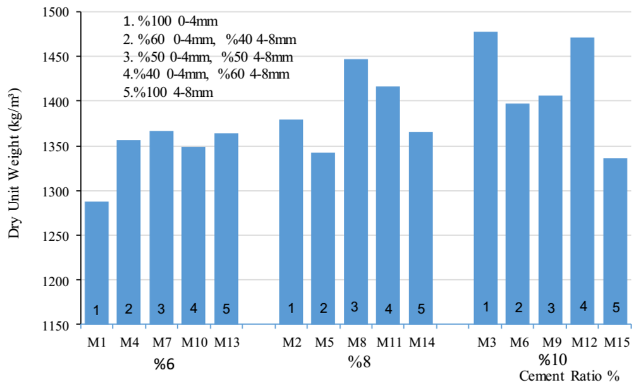

Fig. 2. Dry unit weight for different combinations of cement amount and different aggregate mixing ratios.

The highest uniaxial compressive strength value in mixtures with 8% of PC, by volume, was 19.45 kg/cm^2. It was achieved in the mixture with aggregate combination of "50% 0–4 mm and 50% 4–8 mm".

The highest uniaxial compressive strength value in mixtures with 10% of PC, by volume, was 25.55 kg/cm^2. It was achieved in the mixture with aggregate combination of "40% 0–4 mm and 60% 4–8 mm".

Although low-strength values were obtained at the end of the study, the compressive strength value of 25.55 kg/cm^2, obtained in the mixture M12 is appropriate for production of light wall blocks. Based on these results, for 10% of cement by volume, it can be seen that the optimum aggregate mixing ratio was "40% 0–4 mm and 60% 4–8 mm".

It was found that the dry unit weight values of lightweight concrete specimens were between 1288 kg/m^3 and 1478 kg/m^3. Both values were obtained in the "100% 0 to 4 mm" mixture. The lower limit was obtained at 6% of cement, by volume, while the upper limit was obtained at 10% of cement, by volume. Dry unit weight values were within the standard values and are determined to be in the D 1.4 and D 1.6 group, based on the classification specified in the TS EN 206-1 standard [9].

4. Conclusions

Low-strength values were obtained in the study because of the use of 6, 8, and 10% of cement by volume and because of the employed CEM-1 32.5 type of cement. Despite of using very small cement amounts, the compressive strength value of 25.55 kg/ cm^2, obtained in the mixture M12 is appropriate for the production of pumice concrete unreinforced cavity blocks for light structural members. The highest strength value was obtained from the "10% of cement by volume, 40% 0 to 4 mm and 60% 4 to 8 mm" combination of aggregates.

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