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The effects of pumice aggregate/cement ratios on the low-strength concrete properties

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Abstract

Lightweight concretes can be produced by using processed natural material, processed by-product or unprocessed porous materials, depending upon the requirements of density and strength levels. The present study covers the use of pumice lightweight aggregate (PLA) to produce the lightweight concrete (LWC) for use in construction of load-bearing or non-load bearing elements. In this study, pumice aggregate lightweight concrete (PALWC) blocks were produced with different sizes of 8–16 mm as coarse pumice aggregate (CPA), of 4–8 mm as medium pumice aggregate (MPA) and 0–4 mm as fine pumice aggregate (FPA). According to the preliminary trial batch results, the optimum grade of aggregates was determined as 25% FPA, 25% MPA and 50% CPA by weight for the mixture compositions. The pumice aggregates were obtained from a pumice quarry in Isparta region, Turkey. To analyse the effects of CPA, MPA and FPA/cement ratios on the non-structural concrete engineering properties, the range of different pumice aggregate/cement (A/C) ratios of 6:1, 8:1, 10:1, 15:1, 20:1, 25:1 and 30:1 by weight and cement contents of 180, 137, 110, 72, 52, 40 and 32 kg/m^3 were used to make PALWC mixture testing samples with a slump of from 2 to 4 cm.

The properties of PALWC with the range of different pumice aggregate/cement ratios were evaluated by conducting comprehensive series of tests on workability, compressive strength, elasticity modulus, bulk density, wetting expansion, drying shrinkage, water absorption and thermal conductivity. Experimental test results showed the PALWC up to 25:1 A/C ratios has sufficient strength and adequate density to be accepted as load-bearing block applications. Further, higher than 25:1 A/C ratio has sufficient strength, adequate density and the thermal conductivity to be accepted as non-load bearing infill blocks for insulation purposes. PALWC showed the design flexibility and substantial cost savings by providing less dead load due to its lower density values. The properties, which increase in value and indicate the increasing quality with lower A/C ratios (high cement contents), are compressive strength, modulus of elasticity and density. Properties, which decrease in value, with higher A/C ratios are water absorption, wetting expansion, drying shrinkage and thermal conductivity. It was experienced that lowering the A/C ratios increases strength quality of PALWC. But, increase of the A/C ratio increases the thermal insulation property. Basically, the research showed that non-structural lightweight concrete can be produced by the use of fine, medium and coarse pumice aggregates mixes without using any additions or admixtures.

Keywords: Pumice; Lightweight concrete; Aggregate; Compressive strength; Thermal conductivity

1. Introduction

Pumice stone has been used for centuries in the world. Pumice aggregate can be found in many places around the world where volcanoes are and have been present. Although it has been used successfully in many countries finding new and improved ways to build with pumice is becoming widespread. Due to its toughness and durability, pumice is a well known lightweight concrete aggregate for over 2000 years. Pumice aggregates combined with Portland cement and water produces a lightweight thermal and sound insulating, fire-resistant lightweight concrete for roof decks, lightweight floor fills, insulating structural

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floor decks, curtain wall system, either prefabricated or in situ, pumice aggregate masonry blocks and a variety of other permanent insulating applications [1–3].

Increasing utilisation 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 analyse the materials to be used in construction experimentally in detail. This forms the backbone of any material analysis models in engineering applications [4]. Lightweight concrete is used in civil engineering field, as filler or for the manufacture of heat and sound insulation elements such as panels, masonries, partitions as well as load bearing structural elements [5].

It is a common use to apply lightweight concrete (LWC) for both structural and non-structural applications. As a structural material it should have specific characteristics to meet the strength and performance requirements for the application. Thus, naturally, before recommending any material for a specific application (whether structural or non-structural) there is a need to study the mechanical characteristics to establish its suitability [6].

Lightweight concrete characteristics depend on the aggregate water content prior to mixing. Excessive water content causes lack of adherence between the aggregate and mortar, while low aggregate water content causes the aggregate to soak up part of the mortar water, thus causing a cement sub-hydration and consequent reduction of the concrete shape alteration capacity. Both cases result in lower resistance characteristics than when the aggregates are moderately soaked just prior to concrete preparation. The pumice aggregates were soaked in water for 30 min prior to mixing so as to allow them to absorb the water which they would have absorbed in the mixing phase [7]. Therefore the water used during mixing was only the reaction water. It has shown that to give the best results as to resistance and workability characteristics.

The use of lightweight aggregate with low thermal conductivity in the production of lightweight concrete blocks can provide an alternative cost-effective solution. Lightweight aggregate can be processed natural material, processed by-product or unprocessed material. With large number of voids in the aggregate, lightweight aggregate concrete possesses a relatively higher thermal insulating efficiency than the normal concrete. Therefore, lightweight concrete has superior properties such as lightness in weight, and good thermal insulation, but has a disadvantage of low mechanical properties which makes them suitable only as non-load bearing walls [8].

Due to the high porosity and low bulk density, pumice was used as a natural lightweight aggregate in the production of low-strength concrete such as masonry units making purposes.

The compressive strength of lightweight concretes depends on a variety of factors. These are the sort of coarse, medium and fine aggregates, the concrete composition, conditions of hardening etc. Positive factor in lightweight concretes is also the ''compatibility'' of elastic properties for porous aggregate and mortar as strength and elastic modulus of aggregates in heavy concretes are several times than those of mortar [9].

The production of lightweight concrete block is in most countries a highly mechanised industry based on great automation and accuracy. 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 focus on utilising pumice aggregates in Turkey as the most popular natural lightweight aggregate in the manufacturing of lightweight concrete blocks. Pumice aggregate can be used as aggregates in concrete that meets all these requirements.

Pumice lightweight concrete blocks (PLWCB) are made of pumice, cement and water which are used in construction of non-load bearing infill walls and slabs. The outstanding physical properties of PLWCB have been demonstrated over the years. The concrete block process is perceived to be one of the most labour intensive aspects of construction today. Since these must be handled and placed one-by-one, increased mason productivity is the key to effective management of masonry construction. In tests conducted both in the field and at the University Research and Development Laboratory, it has been dramatically shown that the size and weight of LWC blocks are primary factors influencing the speed at which blocks can be laid [7].

One of the most effective ways to reduce the dead load in multi storey buildings is to lighten the weight of the structure. PLWCB can be manufactured from a density range of 400–1300 kg/m^3.

This paper is basically focused on the development of pumice aggregate lightweight concrete blocks for used in construction of load-bearing and non-load bearing walls. The aim of this study is to examine the effects of pumice/aggregate cement ratios on the low-strength lightweight concrete properties for masonry blocks.

2. Experimental study

2.1. Workability assessment

The experimental program was carried out in order to determine the workability of pumice fine, medium and coarse aggregates to produce low-strength lightweight concrete and to produce mix design data for lightweight concrete masonry units.

2.1.1. Materials used in the research

The pumice aggregate samples were taken from Golcuk region of Isparta in Turkey (Fig. 1). Pumice aggregates