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Influence of ground pumice on compressive strength and air content of both non-air and air entrained concrete in fresh and hardened state

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HIGHLIGHTS

- Image analysis can determine air content of hardened concrete.
- Air entrainment improved workability. GP inclusion impaired workability.
- GP inclusion reduced entrained air content, increased trapped air content.
- High strength frost resistant concrete can be produced by inclusion of GP and AEA.

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ABSTRACT

Study investigates the influence of ground pumice (GP) addition on compressive strength and air content of air entrained and non-air entrained concrete. Control Portland cement concrete was prepared by keeping the binder amount at 400 kg/m^3 with water binder (W/B) ratio 0.45. Air entrained Portland cement concrete mixtures were also prepared by addition of 0.025%, 0.05% and 0.075% air entraining agent (AEA) dosages to control Portland cement concrete. All Portland cement concretes mixtures were modified by inclusion of 10%, 15%, 20% and 25% GP as cement replacement in mass basis, and then concretes containing ground pumice were obtained. Air contents of all fresh concretes were measured. Entrained air void area values on cut surface of hardened concrete were determined by image processing technique. Increase in air entraining agent dosage content in fresh concrete exhibited an increase not only in air content but also flow diameter value of fresh concrete. Addition of ground pumice as a cement replacement in concrete caused reduction in air content and flow diameter, however, it increased compressive strength of air entrained concrete. Compressive strength values related inversely with the air contents of fresh concrete as well as air void area values of hardened concrete computed by image processing technique. Air contents of fresh concrete and image processing void area values of hardened concrete has shown a good relationship between themselves. Image processing can be used to measure air content of hardened concrete.

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1. Introduction

It is known and reported by many researcher that addition of pozzolanic materials in concrete improved strength and durability related properties of concrete including compressive and tensile strength, modulus of elasticity, abrasion resistance, drying shrinkage, heat evolution, freeze-thaw resistance, porosity and permeability [1–9]. Laboratory studies regarding utilization of pozzolanic materials in concrete still popular among the researchers to improve rheological, mechanical and durability related properties of concrete.

Porosity and pore structures play a crucial role in durability related properties of concrete, and known to be an important influencing factor for durability concern. Particularly, when a concrete with critical saturation state is subjected to freeze-thaw action, it should be produced with AEA as an air entrained concrete so as not to be harmed by freeze-thaw action. Using AEA in concrete is the best effective way and method to increase freeze-thaw resistance of concrete, since AEA entrains air bubbles, with no connection but with close distance to each other, into fresh concrete with an average diameter of 0.05 mm [10]. Total entrained air amount introduced in concrete with AEA employment, distance between air bubbles, and size of bubbles were investigated by many researchers in terms of their influence on damage caused by freeze-thaw action to concrete [11–14].

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Another favourable contribution of using AEA in concrete is improving workability of fresh concrete. The air bubbles entrained by AEA improve workability of concrete by decreasing friction between solid particles by taking places between them as airbag [15].

Fineness and reactivity of pozzolanic materials used in air entrained concrete affect pore size and pore structure of concrete as well as amount of AEA used, significantly [15]. Pozzolanic materials (fly ash, pumice and slag), generally, have unburned carbon, higher fineness and rough porous structured surface texture [14,16,17]. It is known that while unburned carbon amount and fineness of materials increase required water amount since more water is needed to wet these higher surface [15]. Therefore, efficiency of water in the mixture is reduced resulting with the loss of workability which reduces amount of entrained air, or increases the amount of AEA needed. On the other hand, molecules of AEA can be absorbed by rough porous structured texture or unburned carbon of supplementary cementing materials, thus, it results with lower air entraining or increase in required amount of AEA for a mixture [16–18].

Usage of silica fume in concrete at about 5% and 10% as cement replacement does not influence distribution of entrained air in concrete [18]. However, in some cases utilizing silica fume in concrete more than 10% as cement replacement can cause increase in entrained air amount, if a superplasticizer is used to maintain reduced workability of concrete caused due to extreme water demand of silica fume addition [19].

Fly ashes were widely used as pozzolanic materials in concrete and they generally reduced efficiency of AEA to entrain air in fresh concrete. Zhang [17] reported that in some cases, fly ash containing concrete may require such an air AEA dosage that could be five times higher than that of required dosage for control Portland cement concrete. Some of physico-chemical properties of fly ash are responsible for increasing the dosage and amount of AEA in mixture. In terms of physical look, due to the difference between specific gravities of cement and fly ash, in mass replacement case of fly ash with cement, results with higher amount of powder volume for a mixture, thus, increase in AEA dosage becomes inevitable. In addition, fly ash particles can contain more porous structure than cement particles contains. Therefore, this can increase AEA dosage requirement for fly ash containing concrete for certain or constant amount of entrained air bubbles. In terms of chemical look, unburned carbon content of fly ash can absorb significantly water and AEA, and neutralize efficacy of AEA, thus, it can increase AEA dosage requirement for fly ash containing concrete mixture [14].

Utilizing slag in concrete reduces efficiency and productivity of AEA used in fresh concrete. When replacement level of slag in concrete is increased, it causes an increase in dosage of AEA to maintain certain amount of entrained air bubble in concrete. Saric and Aitcin [20] reported that AEA dosage is to be increased between 2 and 4 times when 50% slag is replaced with cement for a certain amount of entrained air bubbles.

It is known that using mineral admixtures in mortar or concrete mixture influences workability of fresh concrete and entrained air amount. However, in literature studies carried out utilizing pumice in air entrained concrete mixture is found to be scanty. Pumice is a natural material. Pumice is formed after volcanic activities. It is a durable material. It has a porous and spongy structure. Its spongy and porous structure was formed by trapped gases during molten lava flush. Its content is mostly amorphous and glassy and its porosity is about 75%. When it was finely ground granulated, it shows pozzolanic property due to its amorphous alumina-silicate contents [21].

Hossain [22] stated that pumice have pozzolanic property and it reacts with portlandite known as calcium hydroxide existed due to hydration reaction of alite and belite components of Portland cement. Reaction that takes place between pumice and portlandite forms additional new calcium-silicate-hydrate gel in cement paste, and results with improvement in strength gain and reduction in porosity and pore size which causes upturn in durability related properties. He reported that using powdered pumice as cement replacement up to 50% caused a reduction in workability and compressive strength of concrete. He reported that using 25% replacement of powdered pumice reduced workability 4% compared to control concrete. Reductions in compressive strength were 26%, 26.4%, 22.7% and 24.2% for 1 d, 3 d, 7 d and 28 d curing age, respectively.

Saridemir et al. [23] studied on concrete containing GP. They were replaced cement with GP up to 20% in mass basis. They reported that 5% replacement of GP with cement result with an increase in compressive strength in comparison to control concrete. Other GP concrete made with 10%, 15% and 20% replacement of GP showed lower compressive strength than that of control concrete.

Rashiddadash et al. [24] carried out a laboratory study on pumice and metakaolin containing concrete. They were reported that inclusion of 10% and 15% GP as cement replacement caused a reduction of compressive strength of concrete.

Kabay et al. [25] carried out a laboratory study to investigate properties of concrete made with pumice powder and fly ash as mineral addition in concrete. They replaced pumice powder and fly ash with cement separately as well as in combination. They reported that fly ash replacement did not influence workability of concrete significantly. It was also reported that pumice replacement with cement caused a significant reduction in slump workability. Based on their laboratory findings, replacement of 10% and 20% pumice powder with cement caused 16% and 28% reduction in slump workability of concrete in comparison to control concrete. The reduction of workability was attributed to porous structure and irregular shape of pumice particles. They further reported that utilization of pozzolanic materials (pumice and fly ash) caused a reduction of 7 days short term compressive strength. However, due to pozzolanic reaction, concrete containing pozzolanic materials shows better strength development than that of control concrete in long term. Concrete made with pumice or fly ash exhibited higher relative strength development in comparison to control concrete.

Samimi et al. [26] investigated effects of zeolite and pumice addition on mechanical and durability related properties including permeability and compressive strength of self-compacting concrete. As a result of their study, they reported that concrete made with 10% pumice addition developed higher or equivalent compressive strength to reference concrete, at 28 days of curing time. Moreover, they expressed that same concrete developed 21% higher compressive strength than that of control concrete. The favourable expected effect of using pumice on decreasing capillary water absorption coefficient became marked after 90 days.

Ulusu et al. [27] who blended pumice with cement, carried out a laboratory investigation. They reported that due to porous inner structure of pumice, setting times and water demand of mixture were increased. They also observed that using pumice blend with cement has shown a good performance to reduce or inhibit expansions caused by free CaO and MgO.

On the other hand, air-void performance of air entrained hardened concrete was characterized or verified by microscopic analysis and evaluation in laboratory by obtaining air void parameters, including average size, number of air void, and average distance between air-void system. Currently, image information's collected using high resolution camera and scanner can be transformed to more palpable digital information. With digital image analysis, visualizing and selecting air void in concrete, determination and

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