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Pumice Aggregates for Lightweight Cement Mortars

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***Abstract*—This paper presents an experimental study on cement mortars with different originated pumice aggregates (PA) in order to investigate PA effects on some properties of mortars. Natural sand (NS) was also used to prepare control mortars as reference mix. With this purpose, experiments for aggregate characterisation were conducted and additionally compressive strength, flexural and splitting tensile strength tests were performed on mortars. Results obtained throughout experimental study were analyzed and compared. Replacement of PA with NS led to decreases in mechanical properties of mortars. However, these reductions were differentiated due to the different properties of aggregates. The investigation undertaken also demonstrated the possibility of pumice aggregates in production of structural lightweight mortars.**

***Keywords*—pumice aggregate, compressive strength, tensile strength; lightweight mortar**

I. Introduction

There are many types of aggregates available that are classed as lightweight and their properties cover wide ranges. Elastic properties, compressive and tensile strength, time-dependent properties, durability, fire resistance, and other properties of structural lightweight aggregate concrete are dependent on the type of lightweight aggregate utilized in the cementitious materials [1]. Pumice aggregates are also used as a lightweight aggregate in construction, lightweight concrete, precast concrete, concrete block manufacture, etc. These aggregates are relatively light in weight due to their cellular nature. The cells are elongated and parallel to one another and are sometimes interconnected [2]. Pumice can exhibit acidic or basaltic properties depending on its SiO2 and CaO/MgO contents [3]. The color of basaltic pumice is dark and its specific weight rather more than acidic pumice. Hossain [4] reported the results of investigation to assess the suitability of volcanic ash and pumice powder to be used as cement additives due to their pozzolanic activity. This study recommended the use of 20% volcanic ash or pumice powder as a cement additive. Rashiddadash et al. [5] used pumice to reduce the porosity of weak zone between fibers and paste in fiber reinforced concretes. However, replacing pumice into the specimens had negative effect on the mechanical properties results. Sarıdemir [6] presented the results of experimental study on compressive strength and secant modulus of elasticity of high strength concrete (HSC) containing different levels of silica fume, ground pumice and silica fume together with ground pumice. The experimental results clearly reveal the use of silica fume and silica fume together with ground pumice with a very low water–binder ratio in the production of HSC. Zaetang et al. [7] used diatomite (DA) and pumice (PA) as natural lightweight aggregates in pervious concretes. However, PA exhibited higher water permeability. Ayhan et al. [8] determined the effect of basic pumice on morphologic properties of interfacial transition zone in load-bearing lightweight/semi-lightweight concretes. In accordance with the detections, it was concluded that the basic pumice had a high level of potential to contribute to the morphologic properties of interfacial transition zone. Libre et al. [9] improved the ductility of pumice lightweight aggregate concrete by incorporating hybrid steel and polypropylene fibers. The observations provided insight into the benefits of different fiber reinforcement systems to the mechanical performance of pumice lightweight aggregate concrete which is considered to be brittle. Özodabaş and Yılmaz [10] investigated the strength and durability of alkali activated blast furnace slag mortars (AAS) with very finely ground pumice (P) at certain rates. AAS and AAS + P samples of the compressive strength and flexural strength tests and the drying shrinkage values were close to each other, but the durability test values of the AAS + P samples were better than those of the AAS samples.

The objective of this study is to determine the differences in physical and mechanical properties among mortars made with natural limestone aggregate and three kinds of basaltic and acidic pumice aggregates.

II. Materials and Methods Used in the Experimental Study

Cement used in the mixtures was CEM I 42,5R complying with TS EN 197-1 with a specific gravity of 3.06. Pumice aggregates were collected from three different volcanic sites and sieved as they received. Only PA2 coded pumice aggregate was acidic, PA1 and PA3 coded pumice aggregates were basaltic. Natural crushed fine aggregate utilized in the study was limestone sand. Chemical admixture was not used due to the proper consistency achieved by only water. Ordinary tap water was used in this research for mixing and curing all specimens.

Physical properties such as water absorption, specific gravity, rodded and loose bulk density of aggregates were determined by following the test procedures in the relevant standards (Table 1).

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Specific gravity and water absorption of fine aggregates were determined according to ASTM C 128. Aggregates were tested in oven-dry condition utilizing the shoveling and rodding procedure to determine the unit weight (loose and rodded) and void content according to ASTM C 29-97.

Pumice aggregates were completely replaced with natural limestone sand. All replacements were made in volume. All sample preparations were processed in a similar manner according to European Standard EN 196-1. The mortars were cast into 40x40x160 mm prismatic and 50x100 mm cylindric moulds and kept for 24 h. The hardened mortar specimens were then demoulded and maintained under lime-saturated water at 20 ± 2 ^{o}C until the age of testing 28 days.

The bulk density, water absorption and porosity values were obtained by testing 40x40x160 mm prism specimens according to ASTM C 642. The flexural and compressive strength of hardened mortar specimens were determined in accordance with EN 1015-11. The flexural strength of a hardened mortar was evaluated by three point loading of a 40x40x160 mm prism specimen, subsequent to the failure and breakage of this specimen the compressive strength was determined on each half of the prism specimen. The splitting tensile strength of 50x100 mm cylindrical specimens was measured in accordance with ASTM C 496. Three specimens of each formulation were prepared for each test.

III. Results Obtained Throughout Experimental Study

Table 1 shows the physical properties of natural and pumice sands. NS exhibited the lowest water absorption and the highest specific gravity and bulk density owing to its dense micro structure. However, PA2 had the lowest values for specific gravity and bulk density, however it had the highest water absorption percentage. PA2 was acidic pumice and as previously stated, its specific weight rather less than basaltic pumice [3]. Furthermore, PA3 showed higher specific gravity and bulk density and lower water absorption between basaltic pumice aggregates due to its granulometry. When considering the gradation of aggregates which is not presented in this paper, PA3 had the lowest fineness modulus.

TABLE I. PHYSICAL PROPERTIES OF AGGREGATES

Aggregates	Water Absorption (%)	Specific Gravity (kg/dm^3)	Rodded Bulk Density (kg/dm^3)	Loose Bulk Density (kg/dm^3)
NS	1.74	2.74	1.79	1.62
PA1	6.99	2.28	1.05	0.92
PA2	13.03	2.03	1.08	0.98
PA3	11.25	2.31	1.20	1.10

Oven dry unit weight of all mortars were lower than 2000 kg/m^3 (Figure 1). Especially mortar with acidic pumice PA2 was the lightest specimen and its unit weight values were lower than 1870 kg/m^3 for both oven dry and saturated surface dry conditions.

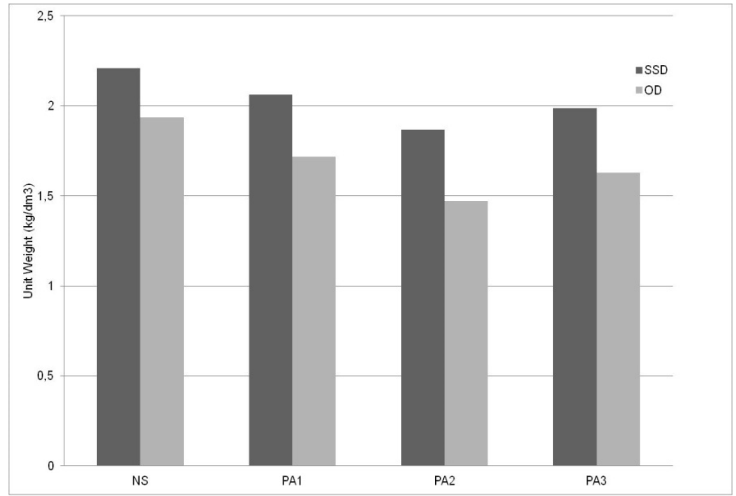

Figure 1. Unit weight of mortars

In the case of tensile strengths, the lowest values were obtained by PA2 mortar for both flexural and splitting tests (Figures 2 and 3). This result can be attributed to the porous nature of the acidic aggregate.

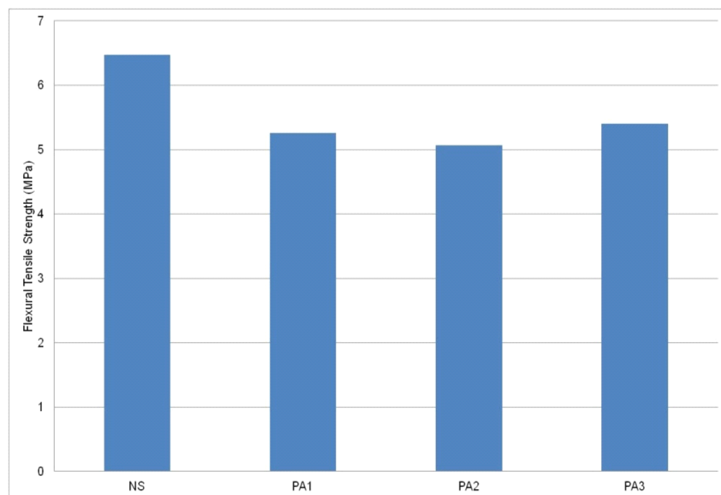

Figure 2. Flexural tensile strength of mortars

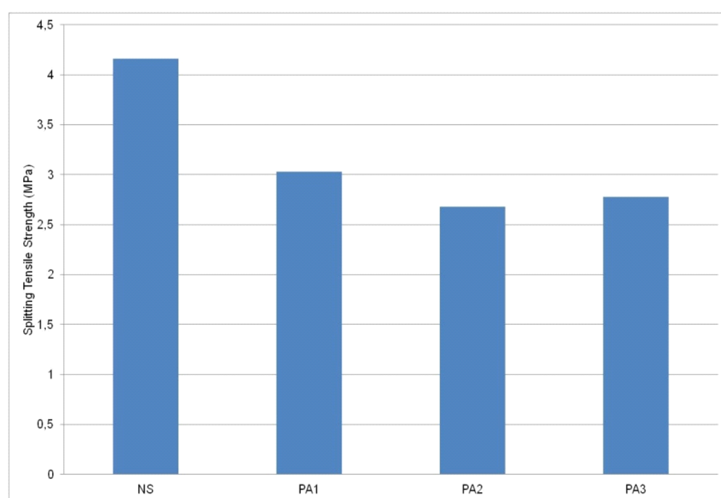

Figure 3. Splitting tensile strength of mortars

Although basaltic pumice aggregates showed similar behavior, PA3 mortar showed the best performance in flexural tensile strength whereas PA1 mortar had the highest value in splitting tensile strength among lightweight aggregates.

Compressive strength values of mortars are shown in Figure 4. Mortar prepared with NS had the highest compressive strength whereas PA3 mortar exhibited the lowest compressive strength. PA1 and PA2 mortars had close compressive strength values.

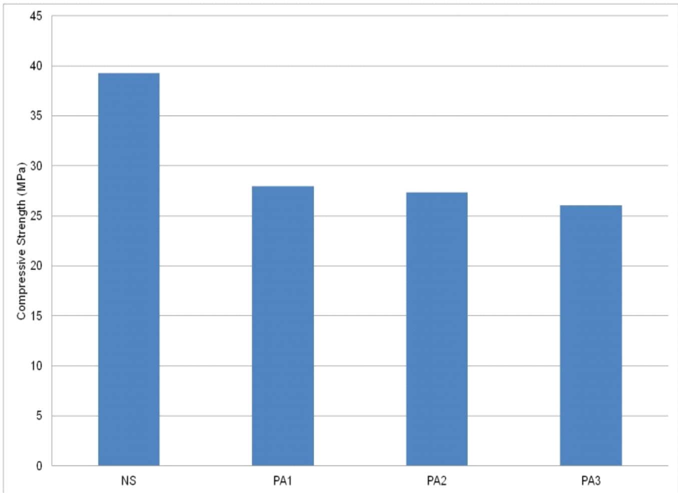

Figure 4. Compressive strength of mortars

IV. Conclusions

Based on the experimental results, following conclusions can be drawn:

Utilisation of pumice aggregates as sand in mortars led to reduction in weight and strength. However, the strength values of pumice aggregate mortars were admissible for structural and non-structural applications. Although the strength reductions were similar, the differences took place mostly due to the pumice type, porosity, sorption behavior, pore-size distribution and particle size distribution.

Acknowledgment

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