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Effect of type and texture of aggregates on strength properties of sulfur concrete and portland concrete

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Abstract

Concrete is the most widely used materials in construction throughout the world. Among its properties, strength is the most important, controlled with utmost care by engineers and designers. Concrete is made of different materials: aggregate, water, cement and admixture. Aggregate occupies approximately 75% of the concrete mass; as a result it definitely has an important role in the properties of fresh and hardened concrete. In this research, in order to study the effect of different aggregates in sulfur and conventional concrete, 7 types of rock have been selected including River material, Granite, 2 types of Limestone, Coquina , Travertine and expanded clay. Having designed the machine, the aggregate was prepared from these rock types; then the physical and mechanical characteristics of the samples were determined. After selecting an appropriate mix design which could be applied to both types of concrete, samples were prepared and investigation showed that weak aggregates which are not used in conventional concrete, can, with changes in the mix design, be used in sulfur concrete and provide the needed strength(Coquina that gained 17.6 MPa in conventional concrete reach to 43.6 MPa in sulfur concrete). Furthermore, texture and porosity play an important role in sulfur compared to conventional concrete.

Keywords: *Sulfur concrete, aggregate, concrete strength.*

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Extended abstract

1. Introduction

Nowadays, concrete is the most widely used material in construction all over the world; it is made of different phases consisting of cement, aggregate and interfacial zone. Among all its properties, strength is the most important, controlled with high quality by engineers and designers (Alexander, 2005). To make concrete with different strengths there are different ways including changing the water/cement ratio and type of cement, for instance in the latter case, substituting portland cement with sulfur which made concrete named sulfur concrete (ACI 548). In this type of concrete sulfur is an element binding the particles to each other. If pure sulfur is used as a binder, after hardening, some cracks will appear and the samples will be crushed. To resolve this problem, numerous researches have been done leading to the manufacture of several additives (Emery, 1983). Additives disrupt the chain of the recrystallization system and produce tiny crystals that make a plastic material which can maintain its stability over time (Vlahovic et al., 2011; Gannon et al., 1983). Recent studies have demonstrated that concrete made with sulfur has certain chemical and physico-chemical advantages over portland concrete such as chemical stability and high strength in corrosive environments, rapid hardening and achievement of desired properties in 24 hours, the possibility of recycling and finally, production capability in all weather conditions (Mohamed and El-Gamal, 2009). In the present study, 7 types of different aggregates (river material, granite, 2 types of limestone, coquina, travertine and expanded clay) were selected to make concrete. The aim of this study is to examine the effect of different aggregate types on the strength of sulfur and portland concrete. Furthermore, the possibility of using weak aggregate (coquina), which are not normally used in portland concrete, were investigated to make sulfur concrete.

2. Experimental procedure

In this step, by using a crashing machine, aggregates with the same grading were prepared form different rock types including river material, granite, 2 types of limestone, coquina and travertine. Expanded clay, because if broken loses its strength, was used in its original form. In this paper the 2 types of limestone are identified from each other by suffixes of 1 and 2.

Aggregates were graded based on the ASTM C136 and the fineness modulus calculated for the aggregate is 2.9. The maximum size of the aggregate is 19 mm.

Physical properties such as aggregate porosity, bulk density, moisture absorption, impact test and crushing value were evaluated through lab testing.

In order to investigate the effect of the aggregate on both concretes, having a fixed volume of aggregate is inevitable. Several mix designs were used and specimens were made and the best mixed design was selected which could be applied to both sulfur and portland concrete.

3. Results and discussion

Concrete samples were made and tested 7, 14 and 28 days after being made based on the ASTM C39-01. Results are shown in Figs. 1 to 2.

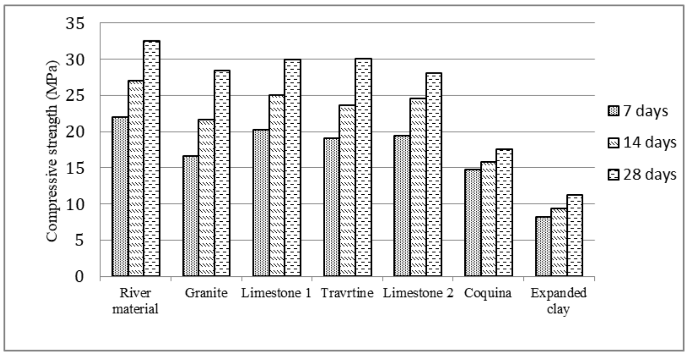

Fig. 1. Portland concrete Compressive strength

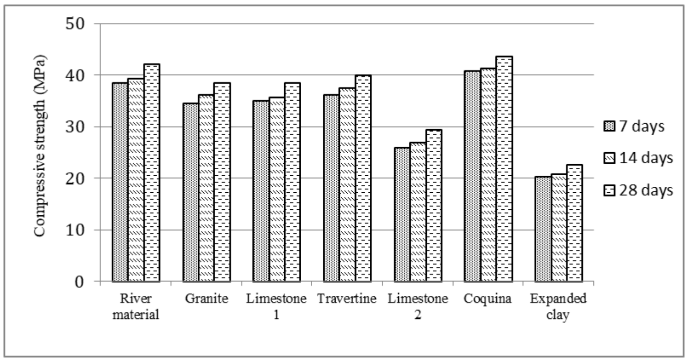

Fig. 2. Sulfur concrete compressive strength

According to the results presented in fig. 1, in portland concrete, aggregates with rough texture made concrete with higher strength. In the case of coquina, because of the cavity texture it has high amount of moisture absorption that makes it gains lower strength. In expanded clay, the rounded shape in conjunction with the smooth texture and inappropriate grading are the reason why it gains the lowest strength among all other aggregates.

Fig. 2 shows that in sulfur concrete, the cavity texture of coquina, which was a negative parameter in Portland concrete, acts as a positive element. The cavity texture lets sulfur cement, which has a lower viscosity than that of the portland cement, penetrate in the pores and increase the strength of both aggregate and contact area and increase the final strength of sulfur concrete. Focusing on the results in fig. 6, it can be seen that in sulfur concrete all aggregates which have a rough texture gain higher strength. Limestone 2, as a result of smooth texture and high flat index, gains lower strength.

Among all, concrete made with coquina aggregate shows the highest increase in strength. In addition to the previous reasons, the amount of cement increased form 21% to 30% was also a determining factor because with the previous amount it would be impossible to make samples. The same amount of cement was also added to the concrete made by expanded clay. The need for extra cement itself shows that part of the cement penetrates through the aggregate. Thus this extra amount of sulfur cement could be another reason of increasing the concrete strength. The reason for the penetration of sulfur concrete in coquina aggregate can be explained by low viscosity of melted sulfur cement.

4. Conclusions

- The surface texture of the aggregate has a significant effect on concrete strength. This effect is more in sulfur concrete. Aggregates with a rough texture increase the strength of concrete. Porous and cavity texture decreases strength of Portland concrete because it makes the aggregate weaker and on the other hand, these textures in sulfur concrete let sulfur cement penetrate into the voids and pores and thus increases the strength of sulfur concrete.

- In both concrete types, the highest strength is related to the concrete whose aggregate has a rough texture and high mechanical properties.
- Sulfur concrete has a higher elasticity modulus than portland concrete but when the amount of sulfur cement increases, the elasticity modulus drops.
- By using sulfur and additive instead of portland cement it is possible to make concrete with acceptable strength form expanded clay and Coquina which are inappropriate aggregates in portland concrete.
- Overall, because sulfur concrete gains higher strength, aggregate characteristics are more effective in this type concrete

References:

Alexander, M., Mindess, S., 2005. Aggregates in Concrete: CRC Press.

Emery, J. J., 1983. Properties of Flexible Pavement Materials: A Symposium: ASTM International.

Gannon, C. R., Wombles, R. H., Hettinger, W., Watkins, W. D., 1983. New concepts and discoveries related to the strength characteristics of plasticized sulfur Properties of flexible pavement materials: ASTM International.

Mohamed, A.-M. O., El Gamal, M., 2009. Hydro-mechanical behavior of a newly developed sulfur polymer concrete. Cement and Concrete Composites, 31(3), 186-194.

Vlahovic, M. M., Martinovic, S. P., Boljanac, T. D., Jovanic, P. B., Volkov-Husovic, T. D., 2011. Durability of sulfur concrete in various aggressive environments. Construction and building materials, 25(10), 3926-3934.

ACI-committee-221., 2007. Guide for Use of Normal Weight and Heavyweight Aggregates in Concrete. American Concrete Institute.