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A preliminary concrete mix design for SCC with marble powders

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ABSTRACT

The marble has been commonly used as a building material since ancient times. Disposal of the waste materials of the marble industry, consisting of very fine powders, is one of the environmental problems worldwide today. However, these waste materials can be successfully and economically utilized to improve some properties of fresh and hardened self-compacting concrete (SCC).

The aim of this study is to find some relationship between properties of the fresh SCC and the hardened SCC containing marble powder. For this purpose, the mix design approach based on monogram developed by Monteiro and co-workers for normal vibrated concrete was adapted to SCC mixes. In order to obtain this monogram, a series of SCC mixes with different water/cement ratios and water/powder ratios were prepared. Several tests such as slump-flow, T_{500} time, L-box, V-funnel and sieve segregation resistance were applied for fresh concrete and tests such as compressive strength and split-tension strength at 7, 28 and 90 days were performed for hardened concrete. In conclusion, the mix design method based on monogram can be suggested for preliminary design in SCC.

1. Introduction

All natural stones that industrially can be processed as cut to size, polished, used for decorative purposes and economically valuable are called as marble. USA, Belgium, France, Spain, Sweden, Italy, Egypt, Portugal and Greece are among the countries with considerable marble reserve [1]. Turkey has the 40% of total marble reserve in the world. 7,000,000 tons of marble have been produced in Turkey annually and 75% of these production have been processed in nearly 5000 processing plants. It can be apparently seen that the waste materials of these plants reach millions of tons. Stocking of these waste materials is impossible.

In marble quarries, the stones are being cut as blocks via different methods (Fig. 1a). These blocks are being moved to processing plants. In these plants, the blocks with 15–20 tons weight are being cut to size as decorative tiles and being polished. During the cutting process, the dust of the marble and water mixes together and become waste marble mud. The material that become dry mud after being refined within the refinement facilities are too big for stocking and becoming harmful for the environment day by day (Fig. 1b). During the cutting process 20–30% of the marble block become dust.

These type solid waste materials should be inactivated properly without polluting the environment. The most suitable inactivating method nowadays is recycling. Recycling provides with some advantages such as protecting the natural resources, energy saving, contributing to economy, decreasing the waste materials and investing for the future [2]. The self-compacting concrete technology has a big potential for this type solid waste materials.

Self-compacting concrete (SCC) is a special very liquid concrete type that can settle in to the heavily reinforced, narrow and deep sections by its own weight, and can consolidate itself without necessitating internal or external vibration, and while providing with these features can keep its cohesion (stability) without leading segregation and bleeding. This concrete type developed in Japan in 1980s with the progressions in the concrete technologies has become widespread in all over the world. Especially the developments in the superplasticizer technology have contributed considerably to formation and progression of the self-compacting concrete [3,4].

Different from the classical concrete design, the self-compacting concrete needs the superplasticizers, viscosity increasing addition and inert or pozzolanic mineral additions in big quantity all together or partly. New experiment techniques, design methods and ergo standards relating the selection of these materials and usage of them in proper ratios in concrete design is being developed [5–10]. The expected performance criteria for the self-compacting concrete are self-compacting when it is fresh, high early age strength that can stand for the early negative effects and durability to the all external effects in hardened situation.

Numerous experimental tests on SCC revealed that the SCC mixes containing inert fine powders such as limestone and chalk have good fresh properties, excellent surface finish and hardening strength higher than expected such as compressive strength and

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splitting tensile strength same as the pozzolanic fine powders such as fly ash, blast-furnace slag and silica fume. This is mainly due to improved particle packing and water retention of the fresh mixes and chemical reactions involving cement hydrates and calcium carbonate [8].

This paper presents a study combining the properties of fresh SCC and hardened SCC in one graph. For this purpose, the mix design method based on monogram devised by Monteiro and co-workers [11] for ordinary concrete was modified to SCC mixes. This method has based on three laws: the Abrams' law [12], Lyse's law [13] and Molinari's law [14]. In the experimental program of the study, a series of SCC mixes with different water-to-cement and water-to-powder ratios were prepared by using three type marble powder: cherry (Rosso Levanto), gold and white. Then, several tests such as slump-flow, T_{500} time test, L-box, V-funnel and sieve segregation resistance were applied for fresh concrete and tests such as compressive strength and split-tension strength at 7, 28 and 90 days were performed for hardened concrete cube specimens. Consequently, a monogram was developed using the data obtained from 47 experimental programs for preliminary design in SCC.

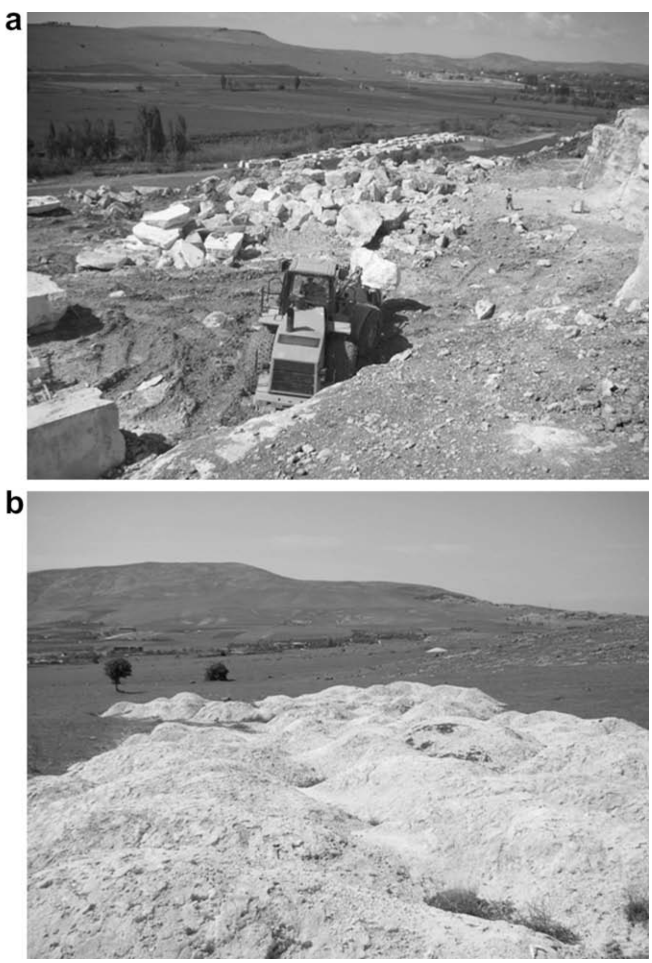

Fig. 1. (a) A marble quarry and (b) marble powder waste.

2. Concrete mix design monogram

There are many methods for concrete mix design with reference to compressive strength. Since it is combining the properties of fresh and hardened cementitious material in one graph, the mix design method proposed by Monteiro and co-workers [11] is highly useful for preliminary design. Fig. 2 illustrates a typical mix design monogram for constant water/cement ratio. This monogram utilizes the three relationships below:

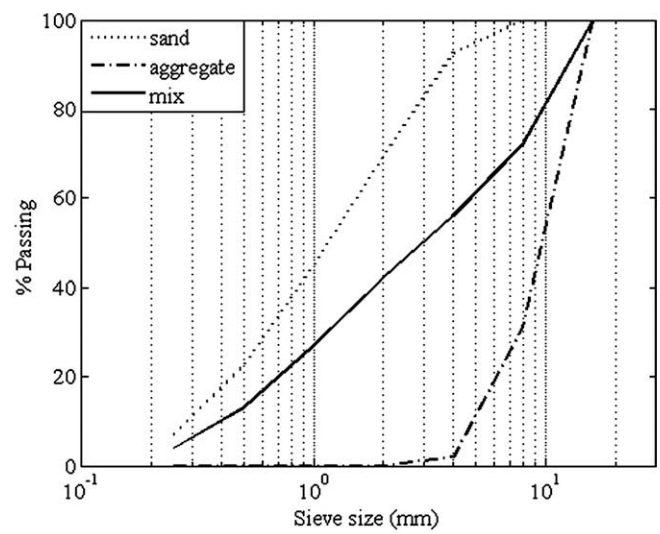

Fig. 3. Gradation curves of granular materials.

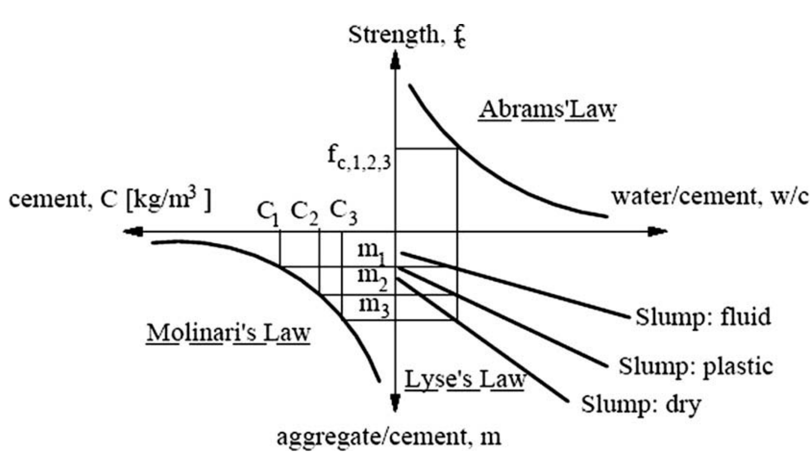

Fig. 2. Mix design monogram for a given water/cement ratio [11].