Near surface characteristics of concrete containing supplementary cementing materials

H. Abdul Razak , H.K. Chai, H.S. Wong

It is an undeniable fact that concrete is the most widely used man-made construction material in the world today, and will remain so for decades to come. The popularity of concrete is largely due to the abundance of raw material, low manufacturing and maintenance cost, excellence in compression, durability to weathering and fire hazards, versatility in forming various shapes and its unlimited structural applications in combination with steel reinforcement. However, the cement industry is also highly energy intensive, and the emission of carbon dioxide during cement manufacturing has created enormous environmental concerns. There has also been an increase in the number of incidents where concrete structures experienced severe deterioration in extreme environments. All these factors have contributed pressures from various quarters to reduce cement consumption, and to intensify research in exploring the possibilities of enhancing strength and durability through the use of pozzolans as supplementary cementing materials. The utilization of calcined clay in the form of metakaolin (MK) as a pozzolan for concrete has received considerable interest in recent years. This interest has been focused on the consumption of calcium hydroxide (CH) produced by cement hydration which is associated with poor durability. Thus the use of metakaolin enhances long-term strength and durability. In addition, it is also possible to obtain early strength enhancement through the filler effect [1].

In this study, high reactivity metakaolin prepared by

calcining refined local kaolin, is investigated for its viability as a pozzolanic microfiller for high-performance concrete in comparison with a trade silica fume.
The study also investigates the effect of different curing regimes on the durability of concrete incorporating metakaolin or silica fume as supplementary cementing materials. Curing is essential for concrete to fully realize its potential properties [2]. The curing becomes more important for concrete incorporating pozzolan, in hot and dry environments [3]. The near surface durability performance, particularly the flow of water into metakaolin and silica fume concrete at various ages subjected to four different curing regimes are evaluated.
These include air (no curing), plastic membrane, wet burlap and water.

Experimental work

Materials

Ordinary Portland cement equivalent to ASTM C 150 Type 1, commercially available densified silica fume and metakaolin were used. Metakaolin was obtained by calcining refined kaolin at 700 _C for 7 h using a laboratory rotary furnace. Physical and chemical properties of the cementitious materials are presented in Tables 1 and 2 respectively. The specific surface (nitrogen adsorption) for silica fume is approximately 21.3 m_2/g, which is much higher than that for cement (4.2 m_2/g) and metakaolin (9.5 m_2/g). X-ray fluorescence analysis shows that its main chemical constituent is silica (92%) with 2.5% loss on ignition. Chemical analysis shows that the metakaolin is principally composed of silica (57%) and alumina (35%).

Siliceous sand and crushed granite stone were used as fine and coarse aggregates respectively. The physical properties of the aggregates used are summarised in

Table 3. A polycarboxylic ether based superplasticizer was used as a chemical admixture. The dark brown liquid admixture had a 20% solids content and specific gravity of 1.05 at 20 _C. Mixing and curing water was taken directly from tap supply.

Mixture proportions

The mixture proportions are summarised in Table 4. The study covered three concrete mixtures that is control (C), 10% silica fume replacement (SF) and 10% metakaolin replacement (MK), which were designed in accordance to the Sherbrooke mix design method [4] for non-air entrained high-performance concrete. The asreceived aggregates were not in saturated and surface dry condition and water corrections were made to the mixture proportions. Additional water contributed by the superplasticizer was also taken into account.

Testing procedures

The durability was measured in terms of the initial surface absorption (ISAT), water absorption and sorptivity. The testing programme and types of specimen prepared are summarised in Table 5. For these tests, specimens were subjected to four different initial curing regimes that is water (W), burlap (B), plastic sheet (P) and air (A). The curing regimes and duration are described in Table 6. Durability tests were then conducted at ages 7, 28, 56 and 90 days after the initial curing of 28 days. Prior to testing, all specimens were dried in a laboratory oven until constant mass was achieved, taken as when the difference between two successive weights performed in an interval of 24 h was not more than 0.1% of the initial mass. The specimens were then taken out from the oven and left to cool overnight under laboratory conditions of 27 ±2 _C and 85 ± 5% RH before conducting the tests.

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ISAT was performed by measuring the absorption of water from a pressure head of 200 mm into the concrete from the top surface. The flow, in ml/m2/s was calculated at intervals of 10, 30, 60 and 120 min. The water absorption test was conducted by completely immersing dried cube specimens in water at 25 _C for 96 h. The sorptivity test was carried out by placing the cylindrical specimens on glass rods in a tray such that their bottom surface up to a height of 2 mm is in contact with water kept under laboratory conditions at 27 ± 2 _C and 85 ±5% RH. This procedure was considered to allow free water movement through the bottom surface. The total surface area of water within the tray should not be less than 10 times that of the specimen cross-sectional area. Specimens were removed from the tray and weighed at intervals of 5, 10, 30, 60, 120 and 180 min. The volume of water absorbed per unit cross-sectional area at each time interval was evaluated and the sorptivity determined from the slope of the graph of the water absorbed against the square root of time. For each test, measurements were obtained from three specimens and the average values reported with coefficient of variation ranging from 4% to 12%.

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