PC/PFA MULTI-BLEND CEMENTS: STRENGH SURFACE ABSORPTION AND ABRASION PROPERTIES

MSc Dissertation

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ABSTRACT

The effect of cement replacement materials on strength development, near-surface absorption and abrasion resistance of composite cements, in accordance to ENV 197-1:1992, containing multiple binders was investigated. Various materials such as pulverised fuel ash (PFA), condensed silica fume (CSF), metakaolin (MK) and limestone (LS) were used as cement replacement in this investigation.

Compressive strength tests were carried out at 2, 7, 28 and 56 days. The strength development of PC/PFA composite cements was found to be slower than that of corresponding control PC mix. Mixes containing blends of PC/PFA/CSF/LS and PC/PFA/MK/LS produced higher strength gain than the other multi-blend mixes. In fact, at 56 days their strength are comparable to the control PC mix for standard water curing (20°C). This is followed by ternary blends consisting of PC/PFA/CSF and PC/PFA/MK respectively. Concretes made from PC/PFA and PC/PFA/LS mixes showed a much slower rate of strength development compared to other blends studied. The strength development of PC/PFA composite concretes were greatly affected by curing temperature as results showed considerably lower strength at the same age, when subjected to cold curing (5°C water cured).

Initial Surface Absorption Test (ISAT) was used to measure the quantity of liquid which the concrete surface absorbed under capillary attraction. The ISA test were carried out after 28 days on specimens subjected to standard water curing (20°C).

The effect of different curing conditions were also investigated for 310 kg/m^3 binder content mixes. Results showed that quaternary blends of PC/PFA/CSF/LS exhibited the lowest absorption properties followed by the PC/PFA/MK/LS concrete mix. The ternary blends of PC/PFA/CSF and PC/PFA/MK showed slightly higher absorption properties than the quaternary blend. The binary reference mix (PC/PFA) and the ternary blend of PC/PFA/LS exhibit more permeable properties. In examining the effect of different curing conditions, specimens water cured at 40°C resulted in concrete with comparatively better absorption properties whilst specimens water cured for one day (20°C) followed by air cure (20°C, 55RH) showed higher absorption properties.

Abrasion test were carried out at 28 days on 285 and 355 kg/m^3 binder content concrete exposed to two curing conditions (20°C water cure and 7 days covered, 20oC/55RH air cure). Results showed good correlation between the abrasion resistance 28 day compressive strength, i.e. concrete with higher strength values exhibit better abrasion resistance. Hence, the quaternary blend concrete showed higher abrasion resistance while the reference and the PC/PFA/LS blend concrete exhibited much lower abrasion resistance.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is the most widely used construction material in the world. Its popularity can be attributed to its comparatively inexpensive cost, availability and its relative ease to use. It can be formed on site into a range of shapes, sizes and finishes and this flexibility has been the key factor for its acceptance in the concrete construction industry. Furthermore, it is inherently durable and can function in a wide range of environmental conditions.

Historically, concrete has been a three component material comprising of cement, water and aggregates. These early concrete composition were based on lime, although the Romans are known for their development of pozzolanic cement and lightweight concrete based on pumice. Many of the early structures have withstood the test of time very well and the domed roof of the Pantheon is testimony to the durability of this material (Mays, G. 1992). However, the growing awareness on the limitation of this three component concrete particularly with respect to performance in very aggressive environment led to the development and use of additions in concrete. In many cases, such additions bring economic as well as environmental benefits. These are effectively additional constituent materials which can be introduced to mixes to achieve desirable effects on both the fresh and hardened concretes. These concrete consisting blends of Portland cement (PC) and one or more binder materials are termed as blended or composite cements. In recent years, the use of composite cements containing multiple binders become recognised. This is mainly to obtain specific hydration properties (usually control heat of hydration), strength and durability performance.

The use of composite cement which normally comprises a blend PC with pozzolanas or latent hydraulic materials, has increased remarkably in recent times due to the resulting benefits in terms of substantial energy savings, economy, environmental and conservation as well as improved durability of concrete to various types of physical and chemical attacks (Swamy, R.N. 1986, Mehta, P.K. 1989 and Sersale, R. 1991).

Production of Portland cement (PC) is very energy-intensive. In 1990, the average energy consumed in the United States in order to produce 1 tonne of cement using a dry-process was 5.7M kJ. Modern plants, in Austria however, use only about 2.9M kJ (Neville, A.M. 1995). This energy consumption amounts to some 1.9M kJ per annum per head of population. Many cement replacement materials such as fly ash, slags and silica fume are industrial by-products and require little or no energy for processing. For example, pulverised fuel ash (PFA) is a waste product from the burning of fossil fuels in coal powered power stations and condensed silica fume (CSF) is a by-product produced during the manufacture of silicon or ferro-silicon.

It has been reported that an energy saving of approximately 75% can be made in cement production through the use of such addition (Mehta, P.K. 1980). The use of additions in mass concrete structures for example can also be economically beneficial and at the same time heat of hydration controlled. For example, of the 72,000m^3 of concrete used in Normandy Dam, 10,000 tons was PFA which reduced cement requirements by 6,600 tons and approximate cost saving of $225,000 (Lane, R.O. and Best, J.F. 1982). CSF was used in the construction of one of the world's tallest buildings in Chicago in 1990, where savings were made in tonnage of reinforcing steel (3,000 tonnes) and in quantity of concrete placed (7,650 m^3) (Elkem Ltd., 1994).

The use of multi-blend / composite cements would help to alleviate environmental problems associated with disposal of industrial by-products. Stockpiling of such products can cause air pollution, similarly alternative disposal in ponds and streams may release toxic metals which are usually present in small amount. Low-value applications such as land-fill are also potentially hazardous, because toxins may leached into ground water and watercourses. Hence, their use in concrete production offers a convenient (sometime profitable) way of disposing them in an environmental friendly way.

Perhaps the major benefits of using blended cements are better control of concrete rheology during delivery, improved cohesiveness, lower heat of hydration, reduced shrinkage, higher resistance to sulfate attack and alkali/aggregate reactions, strength enhancement, and lower permeability (Mehta, P.K. 1989, Roper, et al 1986, Maage, M. 1987 and Ramakrishnan, et al 1981).