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CONCRETE AND HIGH PERFORMANACE CONCRETE

Umar Yasin Mir[1], Chitranjan Kumar[2]
[1]PG Student, [2]Assistant Professor
Al-falah School Of Engineering And Technology, Al- falah University Haryana India

ABSTRACT: Construction is one of the significant sectors of Indian economy and is an integral part of the development. Today India's urban population is the second largest in the world and its future development leads to increased demand for housing to cope with this problem India should desperately need to plan for acquisition of land and rapid creation of dwelling units. Construction is a complex process involving basically the areas of Architectural planning, Engineering & Construction. There is growing realization today that speed of construction needs to be given greater importance especially for large housing projects. This is not only essential for the faster turnover of equipment and investment – leading possible to the reduction in the housing cost but also for achieving the national objective of creating a large stock to overcome shortest possible time. Fortunately, some of the advanced technologies catering to faster speed of construction are already available in the country. For e.g. Prefabrication, autoclaved blocks, tunnel formwork, of construction etc

I. INTRODUCTION

Concrete is an extraordinary and key structural material in the human history. As written by Brunauer and Copeland (1964), "Man consumes no material except water in such tremendous quantities". It is no doubt that with the development of human civilization, concrete will continue to be a dominant construction material in the future. However, the development of modern concrete industry also introduces many environmental problems such as pollution, waste dumping, emission of dangerous gases, depletion of natural resources etc. Presently Portland cement and supplementary cementitious materials are cheapest binders which maintain/ enhance the performance of concrete. However, out of these binders, production of Portland cement is very energy exhaustive along with CO2 production. About 1 tonne of CO2 is produced in manufacturing of each tonne of Portland cement (PC). Thus, cement production accounts for about 5% of total global CO2 emissions (Nixon, 2002). On the other side of the spectrum, in order to reduce the rate of climate change, a global resolution to an 8% reduction in greenhouse gas emissions by 2010 was set in the Kyoto Protocol in 1997. Developed countries are much aware for its need and a climate change tax was introduced by them. In this connection UK Government also introduced same kind of tax on 1st April 2001, in order to achieve its target of a 12.5% reduction in greenhouse gas emissions which is the government's domestic goal of a 20% reduction in CO2 emissions by 2010. Therefore, it is evident that, in order to keep its position as a dominant material in the future, the model of concrete industry needs to be shifted towards "sustainability".

AIM AND OBJECTIVES OF THE STUDY

The primary aim of this investigation was to evaluate the influence of high volumes of SCMs on the properties of HPC. More specifically, the research had the following objectives:

- To study the hydration properties and its significance on properties of HPC
- To investigate the effects of various replacement levels of FA (class F), GGBS and SF on compressive strength and durability properties of concrete.
- To evaluate the comparative response of various SCMs on the properties of HPC.

MATERIALS

Concrete can be defined as a stone like material that has a cementitious medium within which aggregates are embedded. In hydraulic cement concrete, the binder is composed of a mixture of hydraulic cement and water (ACI Committee 116). Concrete has an oven-dry density greater than 2000 kg/m3 but not exceeding 2600 kg/m3 (BS EN 206-1:2000).

BINDER

PORTLAND CEMENT FLY ASH (FA)

SILICA FUMES (SF) AGGREGATES

PROPERTIES OF CONCRETE

The workability of concrete is defined in as the "property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated, and finished". The workability of fresh concrete is usually measured by slump test, compacting factor test, Vebe test and flow test.

HIGH PERFORMANCE CONCRETE

The concept of HPC has definitely evolved with time. Initially it was equated to high strength concrete (HSC), which certainly has some merit, but it does not show a complete and true picture. Other properties of the concrete must also be considered, and may even take priority over the strength criterion.

Use of supplementary cementitious materials (SCMs) is necessary for producing HPC. Concretes with these cementitious materials are used extensively throughout the world. In HPC, materials and admixtures are precisely selected and optimised to form higher strengths (early as well as ultimate) and higher durability as compared to normal concrete. HPC is also called "durable" concrete because its strength and impermeability to chloride

penetration improves the service life as compared with that of conventional PCC. Some of the major users of HPCs are power, gas, oil and nuclear industries. The applications of such concretes are increasing with the passage of time due to their enhanced structural performance, environment friendliness and low bearing on energy utilisation (Mehta, 1999).
HPC also provides enhanced mechanical properties (in terms of tensile and compressive strength) in precast industry in addition to strong stiffness. The advantages of HPC cannot be denied in cold areas where durability performance of concrete can resist penetration of chloride present in snow and water. This results in longer life for the embedded reinforcing steel and a reduction in the deterioration processes (Kuennen, 2004). The method of proportioning of fundamental components and the admixtures offer the main difference between HPC and conventional concrete. A high dosage of water reducing admixture may lead to a required low water/cement, leading positive effects on concrete properties.

TESTS
Fineness of cement
Consistence of cement
Compressive strength test of cement
Tests on fresh concrete
WORKABILITY OF CONCRETE
Compressive Strength Test
Flow test

II. RESULTS AND DISCUSSIONS

MIX PROPORTIONS
The final mix proportions were arrived at after having done many trials so as to have a slump between 60-90 mm at a constant water-binder ratio (w/b) of 0.30, coarse aggregate content of 1150 kg/m3 and a constant total binder content of 485 kg/m3. The slump was adjusted by adding different dosages of the SP. This final dosage of superplasticiser for constant slump (between 60 mm to 90 mm) was achieved after having a number of trials (Table 4.1). Keeping in view the actual slump obtained, it can be concluded from the data shown that there is an increase in the trend of superplasticiser dosage with the incorporation of various SCMs, this is due to very high fineness of these materials.

COMPRESSIVE STRENGTH DEVELOPMENT
The compressive strength development of cement pastes containing high volumes of different SCMs for Series A and B are reported in Table 4.2. It can be seen that as expected for both the series, the increase in compressive strength was positively related to the age for all the specimens. The incorporation of high volumes of FA and GGBS in the cement paste mixes produced a lower strength value at the early age but at later ages, the strengths either greater or comparable to the control mix. The improvement in the compressive strength at later ages is mainly due to the pozzolanic reaction. The compressive strength of paste mix containing 15% SF was greater than that of the FA and GGBS paste mixes at all ages. This is due to the micro filler effect of SF in addition to its pozzolanic properties.

COMPRESSIVE STRENGTH
The compressive strength results are reported in Table 4.4. These results are presented in Figs. 4.1 and 4.2 and the changes in compressive strength in relation to the reference mix (100% OPC) are reported in Table 4.5. Figure 4.1 shows that SF at the replacement level of 7.5% performed consistently better than OPC in terms of strength development at all the test ages, similar to other published results (Byung et.al.,2002; Khatri and Sirivivatnanon, 1995). The incorporation of 15% SF exhibited the best compressive strength results at both 28 days and, but at both 3 and 7 days, the compressive strength was lower than both the PC mix and the binary mix containing 7.5% SF. Table 4.5 demonstrates that the enhancement in strength (that is the rate of strength development) continued for both SF7.5 and SF15 mixes up to 28 days, beyond which the rate of strength development decreased.

III. CONCLUSIONS AND RECOMMENDATIONS

On the basis of the results obtained from this research work, the following conclusions have been drawn:

- TG data confirms that the addition of SCMs in cement resulted in the formation of decreased amount of Ca(OH)2 in the hydration products at all ages. However, this was more significant at later age (91 days) when compared to the early age (3 days). This may be attributed to the dilution effect and to the consumption of Ca(OH)2 by pozzolanic reaction.

- The incorporation of high volumes of FA and GGBS in the cement paste mixes produced a lower strength value at the early age. However, at later ages, the strength was either greater or comparable to the control specimen. Although, the compressive strength of cement paste containing 15% SF was greater than that of the FA and GGBS concrete at all ages, from cost point of view, it can be suggested that a combination of 40% FA and
- 7.5% SF or 50% GGBS and 7.5% SF can be beneficially used to improve the hydration properties and compressive strength of cement paste.

- With the w/b kept constant at 0.3, the compressive strength was detrimentally affected by the replacement of OPC with both FA and GGBS at all ages up to 91 days. However, the compressive strength increased at all ages due to the use of SF at 7.5% replacement levels. There was a decrease in compressive strength at early ages when the SF content was increased from 7.5% to 15%. It was possible to enhance the long-term compressive strength of both FA and GGBS mixes with the addition of 7.5% of SF, but there was a decrease in compressive strength at early ages.

- There was a decrease in air permeability with age for all the mixes. No advantage was observed in adding SF to both the control mix (OPC only) and binary mixes from the point of view of the air impermeability, except mixes SF15 and SF+FA20. The binary mixes with 40% FA showed a dramatic reduction in air permeability at 44 days, followed by 20% FA mix at 44 days. The control mix exhibited the lowest air permeability values at later ages, marginally above the mix with 40% FA at the same age. This means that HPCs with low air permeability could be obtained without the addition of any supplementary cementitious materials. However, these mixes may perform adequately only where air permeability is the criterion affecting its durability.

RECOMMENDATIONS

Although this research has indicated the limits in which OPC can be replaced with SCMs to beneficially produce durable HPC without detrimentally affecting the strength of concrete, the following further research is recommended in order to broaden the use of SCMs in HPC.

- In this study the SCMs considered are taken each from one source. However, as the properties of SCM vary from source to source, further research should be carried out to evaluate the effects of SCMs from different sources on the performance of HPC.
- There is a need to investigate the influence of tortuosity and interfacial transition zone on air permeability of HPC especially FA and GGBS concretes containing 7.5% silica fume at 91 days.
- In spite of the nonlinear behaviour of concrete, an estimate of modulus of elasticity is necessary for computing the design stresses under load in simple elements, and moments and deflections in complicated structures. In addition to this, the modulus of elasticity also affects the serviceability and structural performance of reinforced structures. Therefore, there is a need to investigate the elastic modulus of HPC containing high volumes of SCMs
- Due to the relatively more complicated morphology of SCMs when compared to cement particles, the drying shrinkage mechanism of concrete containing SCMs could be different from that of concrete containing only OPC. Hence, a detailed study on the drying shrinkage properties is required.
- Microscopy work should be done on the blended cement pastes. Microscopy will help showing the effect of binders on hydrated cement paste, interfacial transition zone and pore structure with direct micro- structural evidence.

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