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# Effect Of Chemical Compounds In High-Performance- Concrete With Metakaolin And Phosphogypsum Admixture

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***Abstract*— Water is the basis of life and hence called "Jeevan" in Sanskrit. Water sustains all biological life, eco-systems and human activities. Most of the world's water found in seas and oceans is not potable. Only about 2% of water is fresh out of which 97% is held up in the polar caps in the form of snow and in the deep depths below ground. The objective of this study is to determine effect of chemical compounds in high- performance-concrete with metakaolin and phosphogypsum admixture.**

## I. Introduction

Any concrete, which satisfies certain criteria proposed to overcome limitations of conventional concretes may be called High-Performance-Concrete (HPC). It may include concrete which provides either substantially improved resistance to environmental influences (durability in service) or substantially increased structural capacity while maintaining adequate durability. It is not possible to provide a unique definition of HPC without considering the performance requirements of the intended use of the concrete.

Neville stated that "in practical application of this type of concrete, the emphasis has in many cases gradually shifted from the compressive strength to the other properties of the material, such as a high modulus of elasticity, high density, low permeability and resistance to some forms of attack".

Traditionally, High-Performance-Concrete (HPC) may be regarded as synonyms with high strength concrete (HSC). It is because lowering of water-to-cement ratio, which is needed to attain high strength, also generally improves other properties. However, it is now recognized that with the addition of mineral admixtures HPC can be achieved by further lowering water-to-cement ratio, but without its certain adverse effects on the properties of the material. Hence, it is important to understand how concrete performance is linked to its microstructure and composition.

In fact, performance can be related to any property of concrete. It can mean excellent workability in fresh concrete, or low heat of hydration in case of mass concrete, or very quick setting and hardening of concrete in case of spray concrete which is used to repair roads and airfields, or very low imperviousness of storage vessels. However, from a structural point of view, one understands usually that high strength, high ductility, which are regarded as the most favorable factors of being a construction material, are the key attributes to HPC.

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. In practice, very often great control on properties of cement and aggregate is exercised, but the control on the quality of water is often neglected. Since quality of water affects the strength, it is necessary for us to go into the purity and quality of water.

Water from ground, lakes and rivers contains chlorides, sulphates and bicarbonates of calcium and magnesium. Higher concentrations of these affect the formation of strength causing hydrated compounds during hydration. Pure water from condensation of fog or water vapor, and soft water from rain or from melting of snow and ice, may contain little or no calcium ions. When these waters come in contact with Portland cement paste, they tend to hydrolyze or dissolve the calcium-containing products. Once the contact solution attains chemical equilibrium, further hydrolysis of the cement paste would stop. However, in the case of flowing water (natural or treated polluted water from industries) or seepage under pressure, dilution of the contact solution will take place, thus providing the condition for continuous hydrolysis. In hydrated Portland cement pastes, calcium hydroxide is the constituent, which because of its relatively high solubility in pure water (1230 mg/l), is most susceptible to hydrolysis.

Metakaolin is a high quality Pozzolanic material, which is blended with Portland cement in order to improve the durability of concrete and mortars; it removes chemically reactive calcium hydroxide from the hardened cement paste. Metakaolin reduces the porosity, densifies, thickness of interfacial zone, this improving the adhesion between the hardened cement paste and particles of sand or aggregates.

Zhang and Malhotra (1995) also noted an increased demand for air-entraining admixture comparable to a silica fume concrete. Metakaolin is beneficial in reducing drying shrinkage when compared to silica fume concrete. Optimum ranges for metakaolin addition depend upon desired properties. The optimum dosage was found out to be 15 to 25% for compressive strength.

Khatib and Wild (1996) reported that the large pores in the pates decrease with increase in metakaolin content. Wild et al. (1996) presented the mechanical properties of super plasticized metakaolin concrete. Khatib and Wild (1998) studied the improved sulphate resistance of metakaolin mortar. Curcio et

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al. (1998) presented the utility of metakaolin as micro filler in the production of high performance mortars.

Palomo et al. (1999) studied the chemical stability of metakaolin based cement composites. Frias and Cabrera (2000) investigated the relationship between the pore size distribution and degree of hydration of metakaolin based cement pastes.

High-reactivity metakaolin (HRM) is a more recently developed supplementary cementitious material. It is a reactive aluminosilicate pozzolan formed by calcining purified kaolinite at a specific temperature change. Chemically, HRM combines with calcium hydroxide to form calcium silicate and calcium aluminate hydrates. It has been shown that HRM in powder form is a quality-enhancing mineral admixture that exhibits enhanced engineering properties comparable to a silica fume slurry (Caldarone et al., 1994; Khatib and Wild, 1996; Khatib and Wild, 1998; Curcio et al., 1998; Frias and Cabrera, 2000).

Brooks et al. (2000) studied about the effect of silica fume, Metakaolin, fly ash and ground granulated blast furnace slag on the setting times of high strength concrete. They observed that the general effect of silicon, metakaolin, fine aggregate and GGBS is to retard the setting time of high strength concrete. High strength concrete containing metakaolin there was increase in the retarding effect up to 10% replacement level and at higher replacement level of 15%, the retarding effect appears to reduce.

Concrete property improvements include the following: increased compressive strength and improved sulfate resistance. (Ramlochan et al., 2000) and reduced permeability. Through research, Frias and Cabrera (2000) noted increased heat of hydration when incorporating metakaolin. The researchers noted that heat of hydration curves for metakaolin concrete can be obtained to closely match heat of hydration curves for PCC when the metakaolin is incorporated at amounts less than 10% by weight.

## II. MATERIALS AND EXPERIMENTATION

Ordinary Portland cement of 43 grade of Ultra-tech Cement confirming to IS: 8112-1989 standards was used.

The locally available sand confirming to Zone-II grade of Table 4 of IS 383-1970 has been used as Fine Aggregate.

The locally available crushed granite has been used as coarse aggregate in this investigation.

Superplasticizer used was Polycarboxylicether (PCE) based free flowing liquid having specific gravity of 1.15 conforming to ASTM C 494-92 (2006).

Potable tap water conforming to BS 3148 (1981) was used for mixing and curing.

## III. EFFECT OF STRONG ALKALINE SALTS

### Effect of Sodium Carbonate ($Na_2CO_3$)

The effect of presence of sodium carbonate in mixing water on the setting times of cement, compaction factor, vee-bee time, compressive strength and split tensile strength of HPC with OPC, HPC with phosphogypsum and HPC with metakaolin is presented in the following sections.

### Effect on Setting times of Cement

The effect of sodium carbonate on initial and final setting times is shown in Figures 1and 2. From the table and figures it is observed that both the initial and final setting times of cement got accelerated with the increase of the sodium carbonate concentration in de-ionised water. For the samples with only OPC, the initial setting time at 4 g/L concentrations is 70 minutes the difference being 35 minutes. The final setting time at 4 g/L concentrations is 315 minutes, the difference being 35 minutes. The significant decrease in both the setting times is observed from 4 g/L concentrations of Na2CO3. For the samples with OPC and phosphogypsum the initial setting time at 4 g/L concentrations is 95 minutes, the difference being 40 minutes and the final setting time is 360 minutes the difference being 50 minutes. And in the case of samples with OPC and metakaolin, the initial setting time at 4 g/L concentrations is 140 minutes, the difference being 45 minutes and the final setting time is 400 minutes the difference being 50 minutes. So the significant decrease in both the setting times is observed from 4g/L concentration of Na2CO3 in the case of samples with only OPC and cement blended with phosphogypsum and metakaolin. However, even at 20 g/L concentrations the initial setting time is more than 30 minutes, which are prescribed by IS 456:2000. So it is safe from this point of view up to 20 g/L.

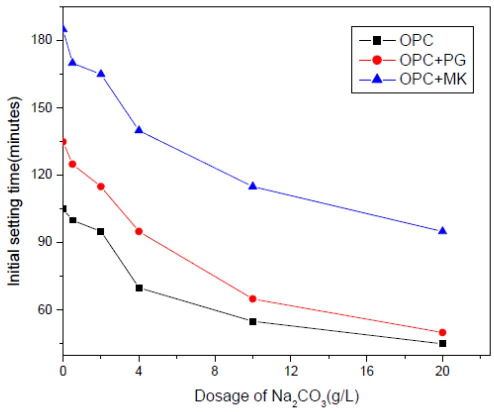


Fig. 1: Variation of initial setting times of cement with dosage of $Na_2CO_3$ in Water

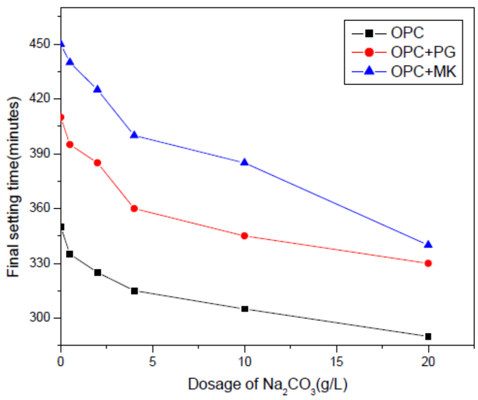


Fig.2: Variation of final setting times of cement with dosage of $Na_2CO_3$ in Water

### 3.2.2 Effect on Compaction factor and Vee-bee time

The effect of compaction factor and vee-bee time is presented in the Figures 3 and 4. The compaction factor decreased as the concentration of chemical in deionised water increased in all the three cases. The compaction factors for HPC with metakaolin are more when compared with HPC with OPC and HPC with phosphogypsum. It is observed that vee-bee time increased with the increase in concentration of sodium carbonate in deionised water. It is also observed that the veebee

times for HPC with metakaolin are less when compared to HPC with OPC and HPC with phosphogypsum. The presence of Na2CO3 in mixing water decreased the workability as the concentration increased. Workability for HPC with metakaolin is high when compared to other two HPCs. And also workability for HPC with phosphogypsum is high when compared to HPC with OPC

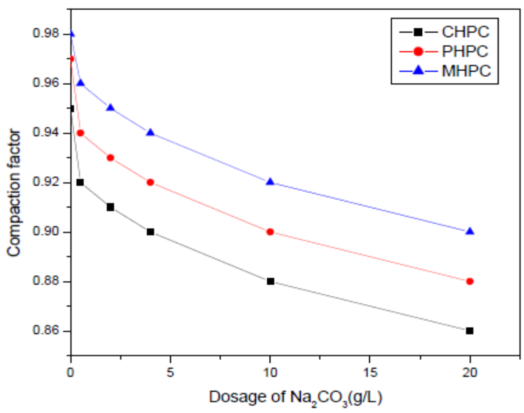


Fig.3: Variation of compaction factor with dosage of $Na_2CO_3$ in water

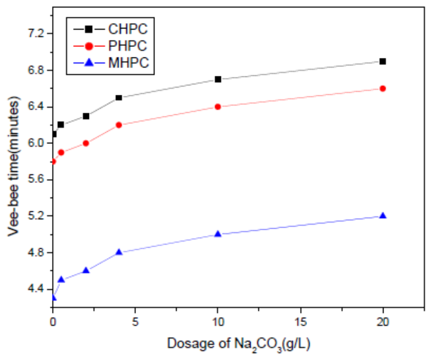


Fig.4: Variation of vee-bee time with dosage of $Na_2CO_3$ in water

## CONCLUSIONS

The strong alkaline substances that are generally present in water are sodium carbonate and sodium bi-carbonate. The effect of these compounds in various concentrations in deionised water on the setting times of cement, workability in terms of compaction factor and vee-bee time , Compressive and split tensile strengths of all the three HPCs have been already discussed in the above sections. The behavior of strong alkaline substances is elucidated in a comprehensive manner as follows:

$Na_2CO_3$ in deionised water accelerates both the setting times whereas $NaHCO_3$ retards them at all concentrations.

Workability has decreased with the increase of concentration of both $Na_2CO_3$ and $NaHCO_3$. But it is more for HPC with metakaolin when compared to other two HPCs. Workability is more for HPC with phosphogypsum when compared to HPC with only OPC.

$Na_2CO_3$ and $NaHCO_3$ in deionised water decrease the compressive strength and split tensile strength significantly at 7,28 and 90 days respectively. The significant decrease in both the strengths is observed at 10 g/L and 20 g/L concentration of both the salts. Comparison of the results of strong alkaline compounds with those of control mixes reveals that both $Na_2CO_3$ and $NaHCO_3$ affect the strengths negatively. The negative effect goes on increasing with the increase in concentration. However, it is safe to use both the salts up to 4 g/L concentrations of both the salts.

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