Structural Analysis of Concrete containing Metakaolin and Cement as partial replacement of Cement

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***Abstract*— The use of pozzolanic materials in concrete as partial replacement of cement is gaining wide acceptance in the construction industry. Metakaolin (MK) and fly ash are the pozzolanas, which confirm the requirements of construction industry and are largely available in India. In present study, the results of X-ray diffraction (XRD) analysis of concrete containing metakaolin and fly ash were analyzed. Four samples K0, K4, K8 and K12containing 0%, 7%, 8% and 9% MK (by weight of cement) respectively were analyzed with XRD at the sample age of 1 day.**

Keywords— ***Pozzolanic materials; concrete; metakaolin; fly ash; X-ray diffraction.***

I. INTRODUCTION

Concrete is probably the most extensively used construction material in the world. However, environmental concerns both in terms of damage caused by the extraction of raw material and CO2 emission during cement manufacture have brought pressures to reduce cement consumption by the use of supplementary materials called pozzolanas (1). Typically pozzolanas are used as cement replacements rather than cement additions. Adding pozzolans to an existing concrete improve the workability and strength of concrete (2). Replacing some of the cement with pozzolans preserves the mix proportions. Of all the pozzolanas, metakaolina refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), metakaolin reacts with the calcium hydroxide (lime) by-products produced during cement hydration (3). The use of metakaolin results in considerable enhancement in strength, particularly at the early stages of curing along with the strength at later age (4).

Fly ash produces more cementitious paste as it has a lower unit weight. The greater the percentage of fly ash in the paste, the better lubricated the aggregates are and the better concrete flows. Fly ash reduces the amount of water needed to produce a given slump (5).

When X-rays interact with acrystalline substance (phase), one gets a diffraction pattern. The X-ray diffraction pattern of a pure substance is, therefore, like a fingerprint of the substance. The powder diffraction method is thus ideally suited for characterization and identification of polycrystalline phases (6).Today about 50,000 inorganic and 25,000 organic single components, crystalline phases, and diffraction patterns have been collected and stored on magnetic or optical media as standards (7). The main use of powder diffraction is to identify components in a sample by a search/match procedure. Furthermore, the areas under the peak are related to the amount of each phase present in the sample. X- ray diffraction is now a common technique for the study of crystal structures and atomic spacing.

II. MATERIALS AND METHODS

A. Cement

Cement is a fine, grey powder. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulphate (which controls the set time) and up to 5% minor constituents It is mixed with water and materials such as coarse aggregates and fine aggregates to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens. It is a material with adhesive and cohesive properties which is capable of bonding mineral fragments into a compact-solid. It is used in the making of concrete with property of setting and hardening, of which when the chemical properties reacts with water. Ordinary Portland cement (OPC) of 43 grade has been used in this study. It was fresh and free from any lumps.

B. Coarse aggregates

Materials which are large to be retained on 4.75 mm IS sieve and contain only that much of fine material as is permitted by the specifications are termed as coarse aggregates. The graded coarse aggregate is described by its nominal size i.e. 40 mm, 20 mm, 16 mm and 10 mm. Since the aggregates are formed due to natural disintegration of rocks or by the artificial crushing of rocks or gravel, they derive many of their properties from the parent rocks. These properties are chemical and mineral composition, specific gravity, hardness, strength, pore structure and colour. Some other properties of the aggregates not possessed by the parent rocks are particle shape and size, surface texture, absorption, etc. All these properties may have considerable effect on the quality of concrete. Crushed stone aggregate (locally available) of nominal size 20 mm and 10 mm in the proportion of 50:50 were used throughout the experimental study. The aggregates were washed to remove dust and dirt and are dried to surface dry condition.

C. Fine aggregate

It is the aggregate, most of which passes through a 4.75 mm IS sieve. Sand is generally considered to have a lower size limit of about 0.07 mm. Material between 0.06 mm and 0.002 mm is classified as silt, and still smaller particles are called clay. The fine aggregate may be one of the following types:-

(i) Natural sand
(ii) Crushed stone sand
(iii) Crushed gravel sand

According to size the fine aggregate may be described as coarse, medium nad fine sands. Depending upon the particle size distribution, IS: 383-1970 has divided the fine aggregate into four grading zones. The grading zones become finer from grading zone I to grading zone IV. The sand confirming to zone II was used in this study.

D. Water

Fresh potable, which is free from concentration of acid and organic substances, was used for mixing of concrete.

E. Metakaolin

Metakaolin (MK) is a pozzolanic material. It is a dehydroxylated form of the clay mineral kaolinite. It is obtained by calcination of kaolinitic clay at a temperature between 500°C and 800°C. Between 100 and 200°C, clay minerals lose most of their adsorbed water. Between 500 and 800°C, kaolinite becomes calcined by losing water through dehydroxilization. The raw material input in the manufacture of metakaolin ($Al_2Si_2O_7$) is kaolin clay. Kaolin is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain. Kaolinite is the mineralogical term that is applicable to kaolin clays. The dehydroxilization of kaolin to metakaolin is an endothermic process due to the large amount of energy required to remove the chemically bonded hydroxyl ions. Above this temperature range, kaolinite becomes metakaolin, with a two dimensional order in crystal structure.

Like other pozzolans (fly ash and silica fume are two common pozzolans), metakaolin reacts with the calcium hydroxide (lime) by-products produced during cement hydration. Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete's strength or durability. Metakaolin combines with the calcium hydroxide to produce additional cementing compounds. Less calcium hydroxide and more cementing compounds, means stronger concrete. Metakaolin, because it is very fine and highly reactive, gives fresh concrete a creamy, non-sticky texture that makes finishing easier.

F. Fly ash

The fly ash, also known as pulverised fuel ash, is produced from burning pulverized coal in electric power generating plants. During combustion, mineral impurities in the coal (clay, feldspar, quartz, and shale) fuse in suspension and float out of the combustion chamber along with exhaust gases. As the fused material rises, it cools and solidifies into spherical glassy particles called fly ash. It is a fine grained powdery particulate material that is collected from the exhaust gases by electrostatic precipitators or bag filters. Depending upon the collection system, varying from mechanical to electrical precipitators or bag houses and fabric filters, approximately 85–99% of the ash from the flue gases is retrieved in the form of fly ash. Fly ash accounts for 75–85% of the total coal ash, and the remainder is collected as bottom ash or boiler slag.

G. Superplasticizer

Superplasticizers, also known as high range water reducers, are chemicals used as admixtures. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. Indeed the strength of concrete increase whenever the amount of water used for the mix decreases.

III. METHODS OF TESTING

A. XRD

In this study, powder method of XRD was used, which is easier to interpret and is capable of high accuracy, especially for determining the spacing of atoms in a solid. In the powder method, monochromatic X-rays are used and the sample is very finely powdered. Detail of samples used in XRD analysis is given in Table 1. The XRD analysis was conducted on the samples at the age of 1 day.

TABLE 1 XRD SAMPLE DETAIL

S. NO.	SAMPLE LABEL	MK	FLY ASH	MEAN COMPRESSIVE STRENGTH AT 1 DAY (MPa)
1	K0	0%	10%	5.27
2	K4	7%	10%	8.73
3	K8	8%	10%	12.80
4	K12	9%	10%	11.24

IV. TEST RESULTS AND DISCUSSION

The powder samples of cement, fly ash, metakaolin, K0, K4, K8 and K12 were analyzed by XRD analysis, indexing of cement was done and the peaks were marked on the basis of ICDD database. The XRD pattern of samples K0, K4, K8 and K12 are given in Figures 1, 2, 3 and 4 respectively.

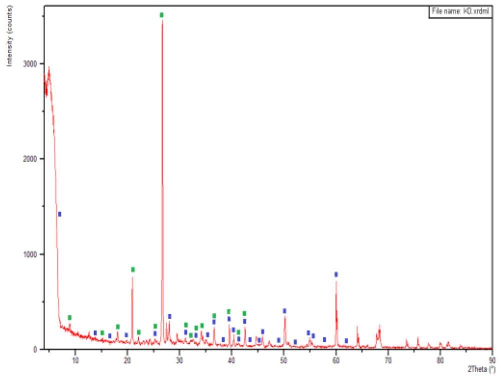

Fig. 1 XRD pattern of K0 (MK 0% and Fly ash 10%)

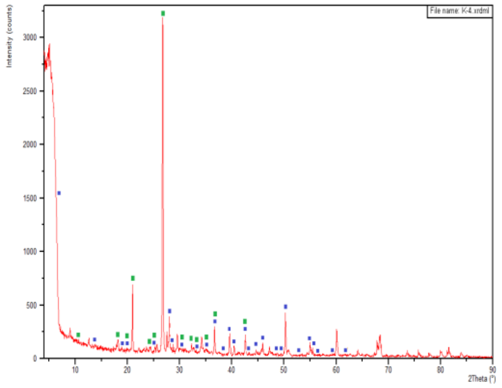

Fig. 2 XRD pattern of K4 (MK 7% and Fly ash 10%)

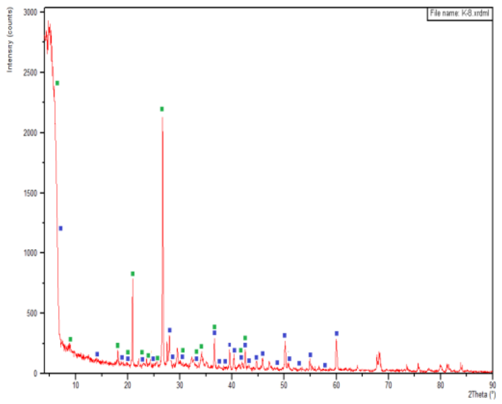

Fig. 3 XRD pattern of K8 (MK 8% and Fly ash 10%)

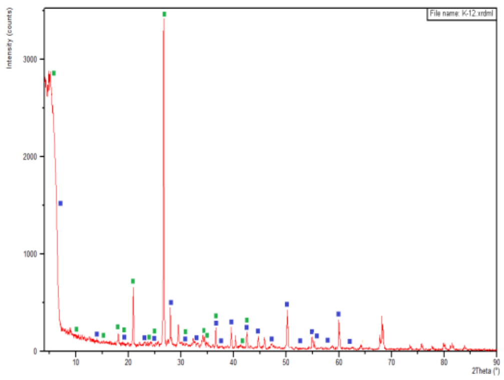

Fig. 4 XRD pattern of K12 (MK 0% and Fly ash 10%)

The XRD pattern indicates that in all samples the phase of Ca(OH)2 SiO2 H2O with a mixed phase of CaO Al2 SiO2 H2O were present. With the increase in the percentage of metakaolin, the phase CaO Al2 SiO2 H2Ois increased but in sample K12 phase CaO Al2 SiO2 H2O is decreased at 9% of metakaolin. Results of compressive strength of samples are shown in Table 1. Here we mentioned earlier the phase CaO Al2 SiO2 H2O decreased at maximum percentage of metakaolin (K12) and as compared with compressive strength of samples, the compressive strength of sample K12 is decreased. Maximum strength gain is at 8% of metakaolin.

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