Experimental Study of Strength & Durability of Concrete by Partial Replacement of Cement with Metakaolin

Saurabh J. Hadke[1] Dr.S.G.Makarande[2] Prof.M.M.Lohe[3]
Department of Structural Engineering
[1,2,3]Bapurao Deshmukh College of Engineering, Sewagram, India

Abstract— To achieve sustainability in construction world number of substitutions materials are used. Metakaolin is widely used green pozzolanas. Metakaolin is calcinied clay (koalite). It is obtained from raw material i.e. Kaolin Clay (very fine, white). There is very little emission of carbon dioxide whiles the production of Metakaolin as compared to cement hence it is called as green pozzolanas. Today many researches are ongoing for the replacement of Portland cement, using many waste materials like fly ash and GGBS. Like Fly ash and GGBS a Metakaolin can also use as a binder with the partial replacement of cement which take some part of reaction at the time of hydration reaction. Cement replacement by glass powder in the range 5% to 25% with an interval of 5% is to be study.Material was tested for its compressive strength and workability concrete prepared with partial replacement of Metakaolin showing significant improvement in their properties.

Keywords: Sustainability, Compressive Strength, Workability

I. Introduction

From the turn of the 20th century, rotary cement kilns gradually replaced the original vertical shaft kilns, used originally for making lime. Rotary kilns heat the clinker mainly by radiative heat transfer and this is more efficient at higher temperatures, enabling higher burning temperatures to be achieved. Also, because the clinker is constantly moving within the kiln, a fairly uniform clinkering temperature is achieved in the hottest part of the kiln, the burning zone.

The two other principal technical developments, gypsum addition to control setting and the use of ball mills to grind the clinker, were also introduced at around the start of the 20th century.

In the production of Portland cement about 1 ton of CO2 is produced for every ton of cement. Adding Metakaolin to Portland cement will reduce the final amount of CO2 developed in elation to pure cementitious binders. With the environmental concerns developed in recent years, more environmental friendly cements are produced adding ground slag, fly ash or other minerals. Metakaolin is so far the only product which will reduce the CO2 output and accelerate the setting.

Pozzolanic materials including silica fumes, fly ash, slag, Rice Husk Ash and Metakaolin have been used in recent years as cement replacement material for developing HSC with improved workability, strength and durability with reduced permeability. To maintain workability of concrete at construction site, use of super plasticizers becomes necessary. By effective usage of Metakaolin in optimum percentage in concrete may make concrete economic and environmental friendly. (Suryawanshi and Sagar Umbrae 2015)

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Metakaolin is a valuable admixture for concrete/cement applications. Rocks that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of Metakaolin is smaller than cement particles but not as fine as silica fume.

Metakaolin, is a relatively new material in the concrete industry is effective in increasing strength reducing sulphate attack and improving air-void network. Pozzolanic reactions change the microstructure of concrete and chemistry of hydration products by consuming the released Calcium Hydroxide (CH) and production of additional Calcium Silicate Hydrate (C-S-H) resulting in an increased strength and reduced porosity and therefore improved durability.

II. Literature Review

Metakaolin is manufactured from pure raw materials to strict quality standards. It is not a by-product. Other pozzolanic materials are currently available, but many are by-products, which are available in various chemical compositions. They may also contain active components (such as sulphur compound, alkalis, carbon, reactive silica) which can undergo delayed reactions within the concrete and cause problems over long time periods. Metakaolin is obtained by calcinations of pure or refined kaolintic clay at a temperature between 650°c and 850°c, followed by grinding to achieve a fineness of 700 to 900m^2/kg. The resulting materials have high pozzolanicity.

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. Metakaolinreduces the porosity, densifies, thickness of interfacial zone, this improving the adhesion between the hardened cement paste and particles of sand or aggregates.

Beulah, M &Prahallada(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 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 aluminosilicatepozzolan 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 silica fume slurry (Caldarone et al., 1994; Khatib and Wild, 1996;Khatib and Wild, 1998; Curcioet 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. In high strengthconcrete 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.

III. Materials and Methodology

A. *Materials used*

1) *Cement:*

Ordinary Portland cement of grade 43 is adopted for this work. The brand of cement used was Ultra Tech OPC with grade 53. The cement was gray and free from lumps.

2) *Aggregates:*

In this research work fine aggregates used was river sand zone II and coarse aggregates used were crushed stones. These materials were easily available from local market.

3) *Metakaolin:*

Metakaolin from Astra Chemicals, Gujarat, obtained for the experimental work.

4) *Water:*

Clean tap water was used for washing aggregates, and mixing and curing of concretes.

B. *Methods*

1) *Mix Design:*

Mix design carried out for M30 grade of concrete by IS 10262:2009, resulting to a mix proportion. The replacement of cement by Metakaolin was 5% to 25% at increment of 5% each.

2) *Compressive Strength Test:*

Concrete prepared with different percentage replacement of cement by metakaolin at increment of 5% each up to 25% was cured under normal condition and were tested at 7 days and 28 days for determining the compressive strength and compared those with the results of conventional concrete.

3) *Workability test:*

The slump is a measure representing the workability of concrete. In this experimental work, the slump value of fresh concrete was in the range of 40 mm to 63 mm.

IV. Test Result

A. *Workability*

Table 1 shows the results of workability of concrete with partial replacement of cement by metakaolinr in various percentages ranging from 5% to 25% in increments of 5%.

Mix Designation	% replacement of cement by metakaolin	Slump (mm)
A	0	68
B	5	59
C	10	59
D	15	48
E	20	42
F	25	39

Table 1: Results of workability of concrete with partial replacement of cement by metakaolin

B. *Compressive Strength*

The table gives the results of test conducted on hardened concrete with 0-25% metakaolin for 7, 28. From table 3, results shows that the compressive strength increases with increasing curing time.

Mix Designation	Mix Designation % replacement of cement by metakaolin	7 days Compressive Strength	28 days Compressive Strength
A	0	20.45	33.58
B	5	22.54	31.47
C	10	21.87	37.85
D	15	23.96	40.75
E	20	19.45	35.62
F	25	20.74	34.87

Table 2: Results of Compressive Strength of concrete with partial replacement of cement by metakaolin

V. Discussion on Test Results

As observed from table 1, the metakaolin in concrete increases workability decreases. As there is a reduction in fineness modulus of cementatious material, quantity of cement paste available for providing lubricating effect is less per unit surface area of aggregate. Percentage replacement of cement with metakaolin increases strength of concrete increases up to 15%.

VI. Conclusion

Based on experimental observations, following conclusions can be drawn:

1) Metakaolin concrete increases the compressivestrength effectively as compared with conventional concrete.
2) Workability decreases as percentage of metakaolin in concrete increases. 3) The strength of concrete increases with increase in metakaolin content upto 15% replacement of cement.
3) As the Percentage of metakaolin powder in concrete increases, workability of concrete decreases.

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