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# Metakaolin- Pozzolanic Material For Cement in High Strength Concrete

Sanjay N. Patil[1], Anil K. Gupta[2], Subhash S. Deshpande[3]
*1(Student, M.E.Civil (Construction & Management), Dept. of Civil Engg., Dr. JJMCOE, Jaysingpur, M.S. India*
*2( Professor in Civil Engg. Dept., Dr. JJMCOE, Jaysingpur, M.S. India.)*
*3(Student, M.E.Civil (Construction & Management), Dept. of Civil Engg., Dr. JJMCOE, Jaysingpur, M.S.India.)*

***ABSTRACT:*** *The infrastructure development is an important aspect for the overall development of country. India is developing as a major hub for service industry, automobile industry and for which the infrastructure development plays an important role. In case of infrastructure development construction of bridges, aqueducts, high rise buildings, off shore structures, nuclear power stations, dams, high strength concrete above M55 is commonly adopted. The necessity of high strength concrete is increasing because of demands in the construction industry. In all construction works, concrete is an important and costly issue, which governs the total cost of the project Concrete can generally be produced of locally available constituents, However, environmental concerns, stemming from the high energy expense and* $CO_2$ *emission associated with cement manufacture have brought about pressures to reduce cement consumption through the use of supplementary materials.. It reduces the cost, makes concrete more durable and it is ecofriendly.*

*This paper deals with the use of Metakaolin which is having good pozolanic activity and is a good material for the production high strength concrete. which is getting popularity because of its positive effect on various properties of concrete.*

***Keywords:*** *Admixture, Calcinations, High Strength Concrete (HSC), Metakaolin, Pozzolanic.*

## 1. INTRODUCTION

Concrete is generally classified as Normal Strength Concrete (NSC), High Strength Concrete (HSC) and Ultra High Strength Concrete (UHSC). There is no clear cut boundary for the above classification. Indian Standard Recommanded Methods of Mix Design denotes the boundary of 35 MPa between NSC and HSC. They did not talk about UHSC. But elsewhere in the international forum, about thirty years ago, the high strength lable was applied to concrete having strength above 40 MPa. More recently, the threshold rose to 55 Mpa as per IS 456-2000.

HSC differs from ordinary concrete with respect to its performance in fresh and hardened states that are mainly driven by exceptional material components and mixture proportions. It incorporates several special ingredients such as high-range water reducer (HRWR), supplementary cementing material (SCM), in addition to the basic materials used for ordinary concrete. The proportions of component materials in HSC are also significantly different from those of ordinary concrete. HSC includes a much higher quantity of binder, lower water content, a greater fine aggregate content, and a lesser amount and size of coarse aggregate than ordinary concrete. The W/B ratio of HPC is also much lower than that of ordinary concrete. While ordinary concrete has the W/B ratio mostly above 0.50, HSC needs a W/B ratio that typically ranges from 0.30 to 0.40.

Pozzolanic materials including silica fumes, fly ash, slag, Rice Husk Ash and Metakaolin have been used in recent yearss as cement replacement material for developing HSC with improved workability, strength and durability with reduced permeability. Metakaolin, which 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. The use of Metakaolin in High Strength Concrete is discussed in this paper.

Use of Metakaolin in construction industry as partial replacement of cement started in the 1960's and the interest in this material has considerably increased in recent years. Metakaolin has pozzolanic properties bringing positive effects on resulting properties of concrete. Pozzolanic properties cause chemical reaction of active components with calcium hydroxide (portlandite), which is formed as a product of cement hydration. This reaction leads to formation of binding phases of following types: [2]secondary C-S-H gel, C4AH13, C3AH6, and C2ASH8 thereby increasing strength.

## 2. METAKAOLIN

2.1 General The raw material in the manufacture of Metakaoline is kaolin clay. Kaolin is a fine , white, clay mineral that has been traditionally used in the manufacture of porcelain. Kaolins are classifications of clay minerals, which like all clays, are phyllosilicates, i.e. a layer silicate mineral. The Meta prefix in the term is used to denote change. In case of Metakaolin , the change that is taking place is dehydroxylization, brought on by the application of heat over a defined period of time. Dehydroxylation is a reaction of decomposition of kaolinite crystals to a partially disordered structure. The results of isothermal firing shows that the dehydroxylation begins at $420^0$C.[3] At about 100-$200^0$C clay minerals lose most of their adsorbed water. The temperature at which kaolite loses water by dehydroxilization is in the range 500-800 $^0$C. This thermal actvation of a mineral is also referred to as calcining. Beyond the temperature of dehydroxylization, kaolinite retains two dimensional order in the crystal structure and the product is termed Metakaolin.

Metakaolin is neither the by-product of an industrial process nor is it entirely natural. It is derived from naturally occurring mineral and is manufactured specially for cementing applications. Metakaolin is produced under carefully controlled conditions to refine its colour, remove inert impurities, and tailor particle size such, a much high degree of purity and pozzolanic reactivity can be obtained.

Metakaolin is white, amorphous, highly reactive aluminiumsilicate pozzolan forming stabile hydrates after mixing with lime stone in water and providing mortar with hydraulic properties. Heating up of clay with kaolinite $Al_2O_3.2SiO_2.2H_2O$ as the basic mineral component to the temperature of 500 °C - 600°C causes loss of structural water with the result of deformation of crystalline structure of kaolinite and formation of an unhydrated reactive form – so-called metakaolinite. The chemical equations describing this process is[3]

$Al_2O_3.2SiO_2.2H_2O = Al_2O_3.\ 2SiO_2 + 2H_2O$ (g).

2.2 Physical and chemical properties of Metakaolin –

A) Physical Properties –

Table No 2.2.1: Physical properties of Metakaolin

| | |
|---|---|
| Specific Gravity | 2.40 to 2.60 |
| Physical Form | Powder |
| Color | Off white, Gray to Buff |
| Brightness | 80-82 Hunter L |
| BET | 15 $m^2$/gram |
| Specific Surface | 8 – 15 $m^2$/g. |

B ) Chemical Composition –

Table No 2.2.2: Chemical properties of Metakaolin

| | | | |
|---|---|---|---|
| $SiO_2$ | 51-53 % | CaO | < 0.20% |
| $Al2O_3$ | 42-44-% | MgO | < 0.10% |
| $Fe2O_3$ | < 2.20% | $Na_2O$ | < 0.05% |
| $TiO_2$ | < 3.0% | $K_2O$ | < 0.40% |
| $SO_4$ | < 0.5% | L.O.I. | < 0.50% |

| | | | |
|---|---|---|---|
| | | | |
| $P_2O_5$ | < 0.2 % | | |

## 3. USE OF METAKAOLIN IN HIGH STRENGTH CONCRETE

The use of Metakaolin becomes ample ingradients in the production of concrete of more than 40MPa or where service environments, exposure conditions or life cycle cost considerations dictate the use of High Performance concrete. For High Strength Concrete Silica Fume/Micro Silica is used. When these are replaced by Metakaolin , concrete of equivalent strength and durability properties developed along with several additional features like reduced water permeability, workability and pumpability.

Metakaolin functions by converting an undesirable byproduct of the cement hydration process, calcium hydroxide (Free lime) to various forms of calcium aluminate. These materials can be described as cementitious, as they contribute to the strength of the concrete.In its pure form , metakaolin reacts with upto 1.6 times its mass of CH.[4]

Cement + water = Calcium Silicate( Cementatious) + Calcium Hydroxide (Non Cementatious)

Calcium Hydroxide + Metakaolin = Calcium Aluminate (Cementatious) + Calcium Alumino Silicate (Cementatious)

Metakaolin reduces the size of pores in cement paste and transforms many finer particles into discontinuous pores, therefore decreasing the permeability of concrete substantially. Metakaolin increases compressive and flexural strengths. It reduces water permeability and efflorescence. Also it reduces heat of hydration leading to better shrinkage and crack control. So use of Metakaolin has wide scope in its use in HSC.

## 4. ADVANTAGES

High Strength Concrete with Metakaolin as admixtures offers many advantages. Some of these are as follows –

a) Facilitate finishing concrete surfaces by rubbing and smoothing due to the lack of stickiness of concrete to the tool and good thixotropy.
b) It reduces the amount of cement in the formation of concrete, especially in concrete with high requirements for water resistance.
c) Can significantly increase the residual strength of refractory concrete after firing, typically lose 50% of its strength after heating to $800^0$C.
d) The strength and durability of concrete increases.
e) Use of Metakaolin accelerates the initial set time of concrete.
f) Compressive strength of concrete increases @ 20 % with metakaolin.
g) The cross sectional areas of structural members can be reduced safely, so saving in concrete and can be economically used for high rise buildings, dams, bridges etc.
h) It Imparts improved water-tightness, so safely used for water retaining structure, off shore structure etc.
i) Confers high early strength, allows a quicker reuse of formwork, and thus enhances the production rate.
j) Ecofriendly.
k) Metakaoline increases resistance to chemical attack and prevention of Alkali Silica Reaction.
l) Metakaolin reduces autogeneous shrinkage in concrete.
m) Metakaolin disperse more easily in the mixer with less dusting.
n) Being second to Diamond in hardness on Mho Scale, Metakaolin offers high abrasion resistance concrete so used for industrial flooring, Warehouses, Container Depots, Roads etc.
o) Metakaolin reduces heat of hydration leading to better shrinkage and crack control.
p) Better Sprayability
q) Lesser Rebound so used in shotcrete with reduced wastage.

## 5. APPLICATIONS

High Strength Concrete with Metakaolin as admixtures offers many advantages as mentioned above. So it can be used for –

a)Dams, b) Bridges c) Water retaining structures d) High rise buildings e) Off shore structures f) industrial flooring g) Warehouses h) Container Depots i) Roads j) Lining k) Mass concreting l)aqueducts m) Nuclear power stations n) structural members where cross section required to be small etc.

## 6. CONCLUSIONS

Literature Review shows that optimal performance is achieved by replacing 7% to 15% of the cement with metakaolin. While it is possible to use less, the benefits are not fully realized until at least 10% metakaolin is used.

Values of compressive strength of concrete with metakaolin after 28 days can be higher by 20%.

Dosage of 15% of metakaolin causes decrease of workability of suspension in time. Increasing amount of percentual proportion of metakaolin in concrete mix seems to require higher dosage of superplasticizer to ensure longer period of workability.

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