MetaCem- Metakaolin: A High Strength Creation

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MetaCem - High Reactivity Metakaolin enhances the strength and durability of concrete to make concrete even more suitable for sustainable construction. Mineral admixtures have changed the concept of making durable and special concretes in the world. Now use of Pozzolanic material have become a traditions for high strength, high performance concrete. [10] Along with other Pozzolanic Material- Metakaolin has been researched world wide and have been found to be a product equivalent to silica fume in almost all the aspect. India has large reserves of kaolin and know-how to produce Super Quality Metakaolin for use as cement replacement in construction industry. A good amount of research work is also reported on the applications leading to beginning of use of metakaolin in cement mortar and concrete. The paper details the behavior of Metakaolin for various grades of concrete, concrete durability and comparative study with Silica Fume Concrete.

During the past few decades, the potential of Portland cement in terms of its effective utility has been realised. As a result, the use of new admixtures has increased significantly within the concrete industry. Availability of mineral admixtures marked the opening of a new era for designing concrete mix of higher and higher strengths. However it was experienced, and hence realised, over a period of time, that it was not only the strength that is important, other attributes of concrete, such as durability, workability etc. were also vital performance parameters. This has led to the work, which was initially limited to high strength concrete (HSC), then extended to high performance concrete (HPC). HPC mix is designed with mineral and chemical admixtures along with other normal ingredients of concrete, having a low water - cementitious ratio. [10] Mineral admixtures such as Metakaolin, Silica fume, GGBS & Fly Ash are added in to concrete depending on its type and requirements. Practical experience has revealed that addition of mineral admixtures to concrete reduces heat of hydration due to reduced cement content and increases durability by contributing to pore refinement.

Metakaolin

The meta prefix in the term is used to denote change. In the case of metakaolin, the change that is taking place is dehydroxylization, brought on by the application of heat over a defined period of time. This thermal activation 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. The key in producing metakaolin for use as a supplementary cementing material, or pozzolan is to achieve as near to complete dehydroxilization as possible without over heating. Successful processing results in a disordered, amorphous state, which is highly pozzolanic; Metakaolin conforms to class N pozzolana as per ASTM C 618. Class N refers to the raw or calcined natural pozzolans. Bureau of India Standards have recommended the use of Metakaolin in mortar and concrete as mineral admixture in IS: 456-2000. A separate specification for Metakaolin is under preparation. Physical & Typical Chemical Properties of Metakaolin are shown in Table 1

Physical form	White to Off-white Powder
Specific Gravity	2.5
Residue 325 Mesh (% max)	0.5
Average particle size, ƒÝ m	1.5
Bulk Density (gm/ltr.)	300
Accelerated Pozzolanic Index, %	97
$Sio_2 + Al_2O_3 + Fe_2O_3$	96 to 98%
LOI	< 1 %

Table 1. Physical & Typical Chemical Analyses of Metakaolin

Metakaolin is processed to remove non-reactive impurities, producing an almost 100 percent reactive pozzolana. Its particle size is significantly smaller than cement particles; Table 2 shows the reactivity of metakaolin with portlandite in cement as compared to other supplementary cementitious material (SCMs). The study shows that reactivity of metakaolin with portlandite of cement is highest among all supplementary cementitious materials.

Material	Pozzolanic reactivity (mg Ca(OH)2 per gm)
Bauxite (calcined)	534
Silica fume	427
Blast furnace slag	300
PFA	875
Metakaolin	1000

Table 2. Pozzolanic reactivity of various SCMs (Ref. 4)

Applications of Metakaolin

- Metakaolin has found applications in:
- High Performance, High Strength and Lightweight concrete
- Precast Concrete for Architectural, Civil, Industrial and Structural works
- Fibercement and Ferrocement products, Glass Fiber Reinforced Concrete
- Mortars, Stuccos, Repair Material, Pool Plasters
- Shotcrete applications
- Manufactured Repetitive Concrete Products

Metakaolin can be used in mortars and concrete for:

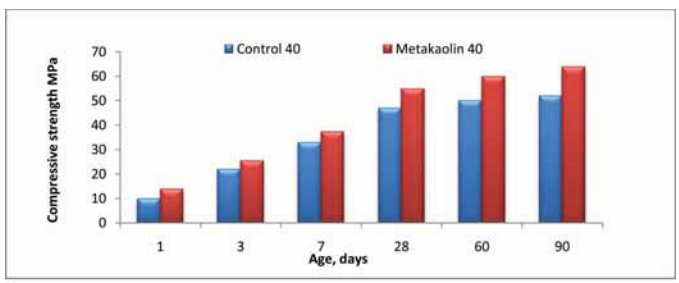
- Increased Compressive & Flexural Strengths
- Reduced Permeability & Efflorescence
- Increased Resistance to Chemical Attack & Prevention of ASR
- Reduced Shrinkage Improved Finishability, Color & Appearance

Dosage of Metakaolin

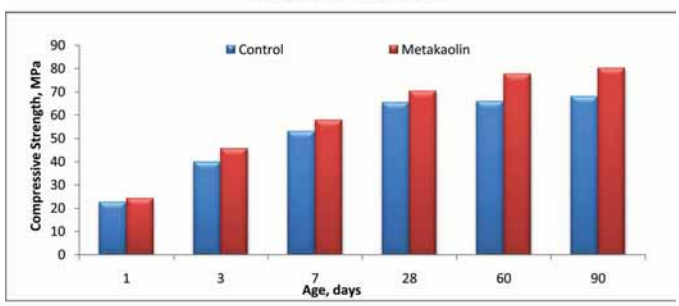
Metakaolin should be used in terms of total cement weight at 5-15% loading rate. Tests have shown that for optimum pozzolanic reactivity with Ca(OH2), an 8% replacement is efficient. Higher dosage of addition or replacement makes the mortar and concrete stickier, reduces the flowability of material and is uneconomical. [10]

Concrete with Metakaolin

Compressive strength development for M40 concrete is shown in figures below. It can be seen that metakaolin increases the early strength of concrete along with the strength at later age. Similar behavior was observed with M60 concrete also. Metakaolin improve the compressive strength between 1 to 7 days and shows consistent improvement later. Results of both the grade are shown in figure 1.



1a. Behavior in M40 concrete



1b. Behavior in M60 concrete

Figure 1 Development of Strength in concrete

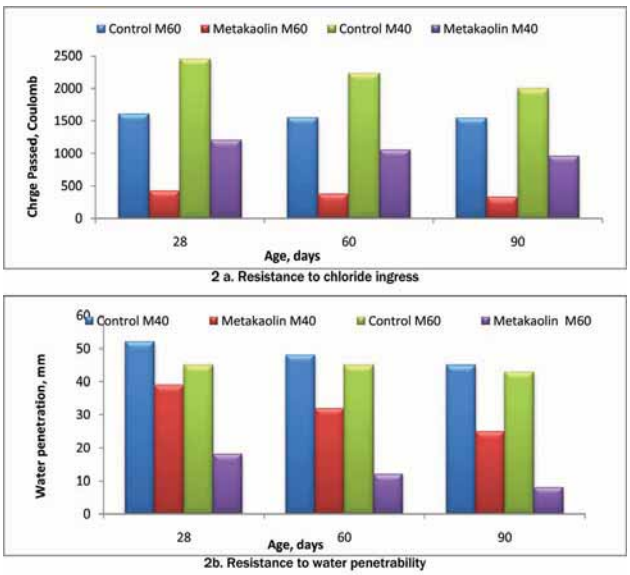


Figure 2, Effect of Metakaolin on durability of concrete

Durability of Metakaolin Concrete

Durability related properties like Water penetrability of concrete was found to improve largely the use of Metakaolin for both grade of concrete shown in figure 2b.Resistance to chloride ingress; as tested by RCPT (ASTM 1202 – 97) shown in figure 2a for both grades of concrete with respect to resistance to chloride ingress. [10]

Metakaolin for Specific Concrete

In a recent application in coastal belt, where soil has high sulphate and chloride contents,

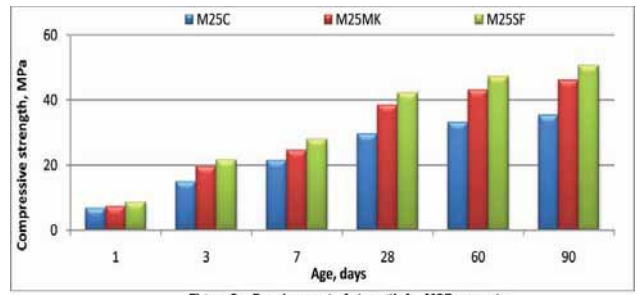


Figure 3a. Development of strength for M25 concrete

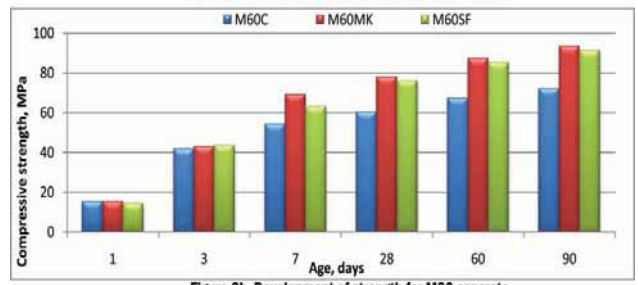


Figure 3b. Development of strength for M60 concrete

concrete of ternary blend has been proposed. The combination of Normal Portland cement, GGBS and Metakaolin has been used to impart both chloride and sulphate resistance to concrete. The use of Metakaolin in this combination allowed GGBS concrete to achieve enough initial strength. The ternary blend not only results the GGBS use costing less but also gives better durability to structures in the coastal area.[10] Table 3 details the concrete mixtures of two grades used for the structure. Results of both the grade M25 & M60 of ternary blend concrete are shown in figure 3a & 3b respectively.

Details	M25C	M25M	M25SF	M60C	M60M	M60F
Water/Binder	0.48	0.48	0.48	0.33	0.33	0.33
Cement, kg	255	221	221	280	250	250
GGBS, kg	196	196	196	150	140	140
MetaCem, kg	0	35	0	0	35	0
SF, kg	0	0	35.28	0	0	35
Water, kg	215.6	215.6	215.6	140	140	140
Sand, kg	254	254	254	325	325	325
Crusher dust, kg	375	375	375	320	320	320
MSA 10 mm, kg	625	625	625	640	640	640
MSA 20 mm, kg	575	575	575	590	590	590
SP- SWC, kg	2.95	2.95	2.95	3.95	3.95	4.25
Initial Slump, mm	140	175	168	110	120	115

Table 3. Concrete Mixtures for 1 cum

MetaCem - Metakaolin for Superstructure Concrete

In view of today's scenario; analyse compatibility of Metakaolin for M90 grade of Concrete compared with Micro Silica.

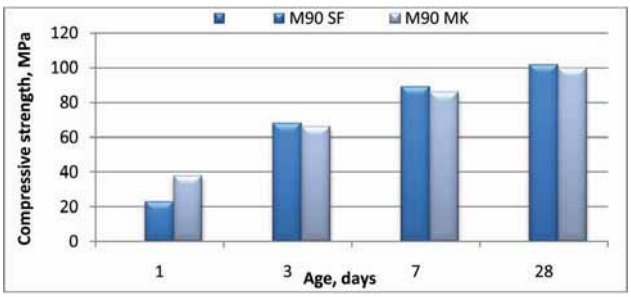


Figure 4a. Development of strength for M90 concrete

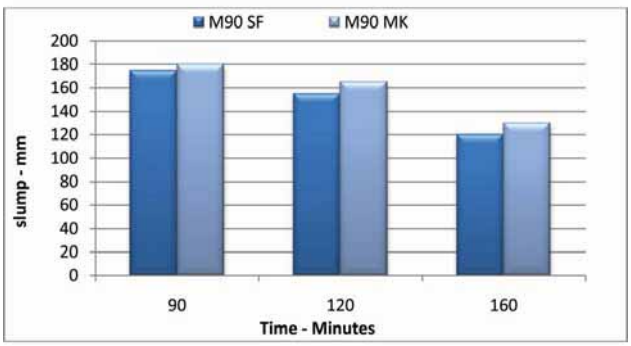


Figure 4b. Slump Retention for M90 Concrete

It was found that Metakaolin produced concrete with similar strength of Micro silica Concrete & more workability is an additional advantage, also analyse the retention time for both the concrete using super quality PC based Admixture and found that Metakaolin concrete is similar of Micro Silica Concrete, especially for the ready mix concrete where transit time is essential . The MetaCem Metakaolin required less super plastizer than silica fume to achieve equal workability as measured by the slump cone. The results of compressive strength & slump retention are shown in figure 4a & 4b respectively:

Conclusions

Metakaolin has a great potential in concrete as cement replacement at lower cost as compared to traditionally used super pozzolans. Concrete produced with metakaolin shows similar behaviour to that with one produced with silica fume.

Metakaolin with designed PSD (particle size distribution) does not increase the water demand of concrete and improves durability of concrete.[10] During the last decade, Metakaolin has found a number of applications in mortar, shotcrete and high strength- high performance concrete since Super Quality MetaCem -Metakaolin is available in India at a reasonable cost.

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