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# A STUDY ON STRENGTH ASSESSMENT OF CONCRETE BY PARTIAL REPLACEMENT CEMENT WITH METAKOLIN

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**ABSTRACT**

*This paper deals with the utilization of waste product metakaolin in partial replacement of cement in mortar. 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 Al2O3.2SiO2.2H2O 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.*

*Partial replacement of cement with metakaolin was to be made for finding compressive strength of mortar cubes of 70x70mm The variables considered were various percentages of replacement of cement and metakaolin namely 0,10,15,20,25,30,35. water is added in terms of consistency of cement with partial replacement of cement in mortar cubes by percentages.*

*The aim of the experimental study is to find the effect of temperature on concrete cubes made by partial replacement with metakaolin. Oven drying method is used for finding durability condition of mortars at high temperatures as per ACI 318 code.*

***Keywords:*** *metakaolinite, kaolinite, ACI 318 code, amorphous, highly reactive aluminium silicate, pozzolan*

## I INTRODUCTION

Metakaolin is a highly pozzolanic material. It is obtained by calcinations of Algerian kaolin at 700˚ C for 7 hours. It is derived from the calcination of a high-purity kaolin clay. The product is then ground to between 1 - 2 µm (about 10 times finer than cement). The silica and alumina contained in the metakaolin are active and react with free lime to form C-S-H and alumina-silicates which greatly improve the strength.

### 1.1 Physical / Chemical Properties

Designations : ASTM C-618 / AASHTO M 295 Specific Gravity (range): 2.5-2.6

Color: Off-White - Grey

Blaine Fineness: ~ 19,000 m2/kg Loss on ignition: 0.7 %

**Typical Chemical Composition:**

- Silica: 53 %
- Alumina: 43 %
- Iron Oxide: 0.5 %
- Calcium Oxide: 0.1 %
- Sulfate: 0.1 %
- Sodium Oxide: 0.05 %
- Potassium Oxide: 0.4 %

## II METHODLOGY

**High Reactivity Metakaolin Features:**

- Excellent workability
- Greater advantage of pumping ability and concrete flow
- Reduced permeability
- Controls alkali-silica reactivity
- Cost beneficial as reduces usage of super plasticizer
- Can be added with Fly ash and GGBS to improve strength and economy
- Improves service life
- Enhances performance
- Less prone to plastic shrinkage cracking
- Easy consolidation into formwork
- Rapid dispersal
- Low bleed water generation
- Requires less water

**Application areas:**

- High strength concrete
- Self-compacting Concretes
- Shot crating
- Tunneling work
- Bridges and Dams
- Nuclear power stations
- Agricultural applications (esp. silage storage, milking parlors, poultry houses)
- Marine structures i.e. underground structures
- Floors where high abrasion resistance is required
- Metakaolin concrete is particularly suitable for repair work also.

## III PHYSICAL PROPERTIES OF METAKAOLIN:

| | |
|---|---|
| Density (gm/cm$^3$) | 2.17 |
| Bulk density (gm/cm$^3$) | 1.26 |
| Particle shape | Spherical |
| Color | Grey |
| Specific gravity | 2.1 |

## IV DESIGN SPECIFICATIONS OF METAKAOLIN

Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. River sand is most commonly used fine aggregate in the production of concrete poses the problem of acute shortage in many areas. Whose continued use has started posing serious problems with respect to its availability, cost and environmental impact. In such a situation the Quarry rock dust can be an economic alternative to the river sand. Quarry Rock Dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75mm. Usually, Quarry Rock

**Table-1. Physical properties of quarry rock dust**

| property | Metakaolin | Test method |
|---|---|---|
| Specific gravity | 2.54-2.60 | [5] IS 2386 (Part III) 1963 |
| Bulk relative density (kg/m3) | 1720-1810 | IS 2386 (Part III) 1963 |
| Absorption (%) | 1.20-1.50 | IS 2386 (Part III) 1963 |
| Moisture content (%) | Nil | IS 2386 (Part III) 1963 |
| Fine particles less than 0.075mm | 12-15 | [5] IS 2386 (Part I) 1963 |
| Sieve analysis | Zone II | [4]IS 383 - 1970 |

## V RESULTS &DISSCUSION

## MIX PROPORTION

Concrete mix design in this experiment was designed as per the guidelines specified in I.S. 10262-1982. Mix Proportioning by weight was used and the cement/ dried total aggregates ratio was 1:2.3:2.98. Metakaolin were used to replace OPC at dosage levels of 4%, 8%, 12%, 16% and 20% by weight of the binder. The mix proportions were calculated and presented in Table

**TABLE5 QUANTITIES OF MATERIALS PER 1$m_3$OF CONCRETE**

| Composition of the concrete mixtures (Kg/$m_3$) per $m_3$ of concrete | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Mix** | **w/c** | **OPC (kg)** | **Metaka- olin (kg)** | **Fine Agg (kg)** | **Coarse Agg (kg)** | **Super plasticiz er (kg)** | **Water (kg)** |
| NC | 0.43 | 380 | 0 | 881 | 1135 | 4.56 | 163 |
| NC + 4% MK | 0.43 | 364.8 | 15.2 | 881 | 1135 | 4.56 | 163 |
| NC + 8% MK | 0.43 | 349.6 | 30.4 | 881 | 1135 | 4.56 | 163 |
| NC + 12% MK | 0.43 | 334.4 | 45.6 | 881 | 1135 | 4.56 | 163 |
| NC + 16% MK | 0.43 | 319.2 | 60.8 | 881 | 1135 | 4.56 | 163 |
| NC + 20% MK | 0.43 | 304 | 76 | 881 | 1135 | 4.56 | 163 |

**Discussion:**

As expected the compressive strength increases with increase in content of metakaolin. As the total water/binder ratio is kept constant, the variation of strength with respect to constant water/cement ratio remains open to discussion. The compressive strength of metakaolin / metakaolin concrete increases with increase in metakaolin content upto 12% and further increment of metakaolin will result in strength reduction. The graph plotted denotes that the highest compressive strength of M-35 grade metakaolin concrete at optimum dose of 12 % is 47.016 MPa.

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**COMPRESSIVE STRENGTH FOR VARIOUS MIX PROPORTIONS**

| Type of concrete | Compressive Strength (N/mm2) | | |
|---|---|---|---|
| | 3d | 7days | 28 days |
| Normal Concrete | 15.34 | 28.49 | 43.17 |
| Normal Concrete + 4 % Metakaolin | 15.70 | 29.01 | 44.55 |
| Normal Concrete + 8 % Metakaolin | 16.36 | 29.34 | 45.19 |
| Normal Concrete + 12 % Metakaolin | 16.83 | 29.36 | 47.016 |
| Normal Concrete + 16 % Metakaolin | 15.05 | 24.72 | 45.47 |
| Normal Concrete + 20 % Metakaolin | 14.89 | 22.66 | 44.84 |

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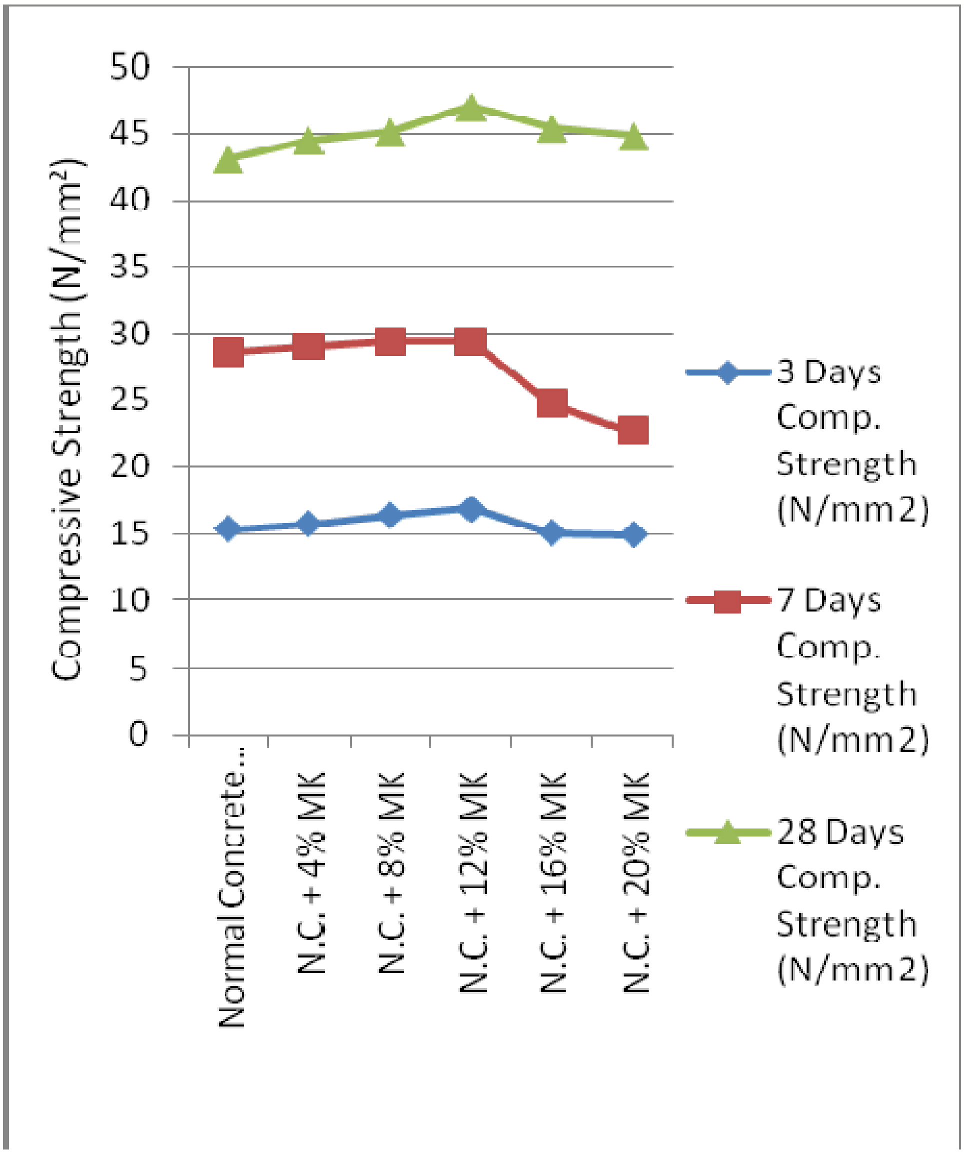


**CHART NO.1: COMPRESSIVE STRENGTH OF CONCRETE CUBES FOR DIFFERENT TRIAL MIXES FOR 3, 7 & 28 DAYS CURING PERIOD**

## VI CONCLUSION

Both the physical and chemical properties of metakaolin and cement are in compliance with the standard.

1) Cement replacement up to 12% with metakaolin leads to increase in compressive strength for M-35 grade of concrete. From 16% there is decrease in compressive strength for 3, 7 and 28 days of curing period.
2) The optimum dose of metakaolin for achieving higher compressive strength is 12%.
3) Metakaolin increases the compressive strength of concrete more than 10%.
4) In mixes blended with high percentage of metakaolin, the water demand will be more because of fineness of metakaolin. To maintain workability of concrete at construction site, use of super plasticizers becomes

necessary.

5) By effective usage of Metakaolin in optimum percentage in concrete may make concrete economic and environmental friendly.

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