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A Study on Mechanical Behaviour of Concrete Using Partial Replacement of Cement with Metakaolin

S.Aravind[1], M.Mohamed ovais akram[2], M.Mohamed abuthahir[3], M.Anandh babu[4]
[1, 2, 3] UG Scholar, [4]Assistant professor,
Department of Civil Engineering, Kalasalingam University, Tamilnadu, India.

***Abstract:* - This paper presents the results of an experimental investigation carried out to find the suitability of Metakaolin in production of concrete. The conventional concrete M20 was made using OPC 53 grade and the other mixes were prepared by replacing part of OPC with Metakaolin. The replacement Metakaolin levels were 0%, 20%, 25%, 30%. To evaluate optimize ratio and mechanical properties of metakaolin based concrete and compared with conventional mix. From the optimization 25% cement replacement by metakaolin superior than all the mixes.**

***Keywords:* - Split tensile strength, Metakaolin, Replacement, compression strength.**

I. INTRODUCTION

Concrete is one of the most common materials used in the construction industry. In the past few years, many research and modification has been done to produce concrete which has the desired characteristics. There is always a search for concrete with higher strength and durability. In this matter, blended cement concrete has been introduced to suit the current requirements. Cementitious materials known as pozzolans are used as concrete constituents, in addition to Portland cement. Originally the term pozzolan was associated with naturally formed volcanic ashes and calcined earths will react with lime at ambient temperatures in the presence of water. Recently, the term has been extended to cover all siliceous/aluminous materials which, in finely divided form and in the presence of water, will react with calcium hydroxide to form compounds that possess cementitious properties. When fine pozzolana particles are dissipated in the paste, they generate a large number of nucleation sites for the precipitation of the hydration products. Therefore, this mechanism makes paste more homogeneous. This is due to the reaction between the amorphous silica of the pozzolanic and calcium hydroxide, produced during the cement hydration reactions.

Nova John (2013) investigated the cement replacement levels were 20%, 25%, 30% by weight for metakaolin. The strength of all metakaolin admixed concrete mixes over shoot the strength

development of concrete. Mix with 25% metakaolin is superior to all other mixes. The increase in metakaolin content improves the compressive strength, split tensile strength and flexural strength up to 25% replacement. The result encourages the use of metakaolin, as pozzolanic material for partial cement replacement in producing high strength concrete. The inclusion of metakaolin results in faster early age strength development of concrete. The utilization of supplementary cementitious material like metakaolin concrete can compensate for environmental, technical and economic issues caused by cement production.

(i) Metakaolin

Metakaolin manufactured from pure raw material to strict quality standards. Metakaolin is a high quality pozzolanic material, which when blended with Portland cement improves the strength and durability of concrete and mortars. Metakaolin removes chemically reactive calcium hydroxide from the hardened cement paste. It reduces the porosity of hardened concrete. Metakaolin densities and reduces the thickness of the interfacial zone, thus improving the adhesion between the hardened cement paste and particulars of sand or aggregate.

(ii) Uses of Metakaolin

Metakaolin finds usage in many aspects of concrete:

- High performance, high strength and lightweight concrete
- Precast concrete for architectural, civil, industrial, and structural purposes
- Fibre cement and Ferro cement products
- Glass fibre reinforced concrete
- Mortars, stuccos, repair material, pool plasters

(iii) Advantages of using Metakaolin

- Increased compressive and flexural strengths
- Reduced permeability
- Increased resistance to chemical attack
- Increased durability
- Reduced effects of alkali-silica reactivity (ASR)
- Reduced shrinkage due to particle packing, making concrete denser
- Enhanced workability and finishing of concrete
- Reduced potential for efflorescence
- Improved finishability, color & appearance

Concrete can be manufactured by adopting the conventional techniques used in the manufacture of Portland Cement Concrete. The fresh concrete could be handled up to 120 minutes without any degradation in the compressive strength. The fresh Concrete was cast and compacted by the usual methods used in the case of Portland cement Concrete. The workability of the fresh Concrete was measured by means of the conventional slump test. The compressive strength of Concrete is influenced by the wet-mixing time. Test results show that the compressive strength is increased as the wet-mixing time increased.

- Have high early strength and low shrinkage properties
- Increased compressive and flexural strengths
- Increased resistance to chemical attack
- Increased durability
- Reduced effects of alkali-silica reactivity (ASR)
- Reduced permeability

II. EXPERIMENTAL PROGRAM

MATERIALS

a) Metakaolin:

Metakaolin (MK) is a pozzolanic material. It is obtained by the calcination of kaolinitic clay at a temperature ranging between 500 °C and 800 °C. The raw material input in the manufacture of metakaolin (Al2Si2O7) is kaolin. Metakaolin on reaction with Ca (OH) 2, produces CSH gel at ambient temperature and reacts with CH to produce alumina containing phases, including C4AH13, C2ASH8, and C3AH6 (Changling et al., 1995; Zhang and Malhotra, 1995).Metakaolin had 99.9% particles b16 μm with a mean particle size of about 3 μm (Table 1). The typical chemical composition.

b) Aggregate:

River sand with Specific gravity 2. 44 is used as Fine aggregate and granite stone jelly with Specific gravity 2.74 is used as coarse aggregate

TABLE I - MIX PROPORTION

MATERIAL	MASS(Kg/m$^{3)}$
Coarse Aggregate	1500
Fine Aggregate	1721

The ordinary Portland cement Concrete mix proportion is 1: 1.84: 3.13

c) Specimen Preparation:

The Coarse aggregate comprise of 20mm. First the dry mix of Metakaolin with cement, Coarse and Fine aggregate is mixed. The Water was added for suitable workability. Then compact in three layers.

d) Curing:

Specimens were cured in water after casting are proposed.

e) Test Specimens:

The thirty six 75mm * 75mm * 75mm size mortar cube, thirty six cylinder and thirty six concrete cube specimens. The concrete cube size is 150mm * 150mm * 150mm.

III. STRENGTH TEST

The following are the test conducted for evaluating the strength properties of METAKAOLIN Concrete.

- Compressive strength test
- Spilt tensile strength test

a) Compressive Strength Test

The cement is partially replaced with Metakaolin in 20%, 25%, and 30% during casting of concrete, cubes were mechanically vibrated. After 1 or 2 days the specimen were removed from the mould and subjected to water curing for 7, 14 and 24 days. After specified period of curing, the specimens were tested using compressive testing machine.

TABLE II – 7 DAYS COMPRESSIVE STRENGTH

Source Material	**Compressive Strength N/mm^2**
Conventional concrete cube	24
Concrete with Metakaolin 20%	25.19
Concrete with Metakaolin 25%	27.76
Concrete with Metakaolin 30%	26.67

TABLE III – 14 DAYS COMPRESSIVE STRENGTH

Source material	Compressive strength N/mm²
Conventional concrete cube	25.55
Concrete with Metakaolin 20%	28
Concrete with Metakaolin 25%	30
Concrete with Metakaolin 30%	27.78

TABLE IV – 28 DAYS COMPRESSIVE STRENGTH

Source Material	Compressive Strength N/mm²
Conventional concrete cube	28.22
Concrete with Metakaolin 20%	29.92
Concrete with Metakaolin 25%	34.37
Concrete with Metakaolin 30%	29.13

Fig. 1 Cube Specimens

Test Setup

The concrete cube specimen set up is shown in fig 2. The cube were subjected to uniform loading at each end. The load was measured by means of a load cell.

TABLE V – 7 DAYS SPLIT TENSILE STRENGTH

Source Material	Split tensile Strength N/mm^2
Conventional concrete cube	9
Concrete with Metakaolin 20%	9.72
Concrete with Metakaolin 25%	11.03
Concrete with Metakaolin 30%	8.23

TABLE VI – 14 DAYS SPLIT TENSILE STRENGTH

Source Material	Split tensile Strength N/mm^2
Conventional concrete cube	9.55
Concrete with Metakaolin 20%	10.19
Concrete with Metakaolin 25%	11.20
Concrete with Metakaolin 30%	9.68

TABLE VII – 28 DAYS SPLIT TENSILE STRENGTH

Source Material	Split tensile Strength N/mm^2
Conventional concrete cube	11.55
Concrete with Metakaolin 20%	11.76
Concrete with Metakaolin 25%	12.28
Concrete with Metakaolin 30%	10.44

Fig. 2 cube Testing Arrangement

b) Split tensile strength

The 36 no's of concrete cylinder size 100mm diameter and 200 mm height specimen was tested.

Fig. 3 Reinforced Geopoymer Concrete Beams

Test Setup

The concrete cylinder specimen set up is shown in fig 4. The concrete cylinder were subjected to uniform loading at each end. The load was measured by means of a load cell.

Fig. 4 Concrete cylinder Testing Arrangement

IV. RESULTS AND DISCUSSION

Compressive strength value for 20% estimation 29.92, 25% estimation 34.37,30% estimation 29.13 in 28 days which will show the compressive strength increase when compare with nominal specimen. In split tension value for 20% estimation 11.76, 25% estimation12.28,30% estimation10.44 in 28 days which will show the split tensile strength increase when compare with nominal specimen.

V. CONCLUSION

The percentage of Metakaolin increase from 20% to 30%.In which 25% of the replacement will show the maximum values of compression & split tensile strength compare to nominal values.

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Fig. 15. Relationship between threshold radius and (a) WA and (b) WAC of concrete.

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