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The Influence of Metakaolin on the Modulus of Elasticity of Concrete

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***Abstract*:** *This Paper presents the effect of Metakaolin on the modulus of elasticity of concrete has been presented. Concrete is a vital ingredient in infrastructure development with its versatile and extensive applications. The grade of concrete considered in the present investigation is M_{60} mix. The cement is partially replaced by Metakaolin at different percentages such as 7.5, 10, 12.5, 15 and 17.5 by weight of cement. The modulus of elasticity is determined by testing of cylinders of size 150mm diameter and 300mm height at various percentages of Metakaolin after curing for 28 days. The modulus of elasticity is computed by taking initial tangent modulus for each percentage of Metakaolin from stress-strain plot obtained by subjecting the specimens to axial compression. Variation of Young's modulus at different percentages of Metakaolin is compared with controlled concrete as 0% replacement of cement.*

Keywords: *M_{60} Grade concrete, OPC, Metakaolin, Youngs modulus.*

I. Introduction

Concrete is a vital ingradient in infrastructure development with its versatile and extensive applications. Concrete is the second largest material consumed by human beings after food and water as per WHO. High performance concrete has been used in various structures all over the world since last three decades. The major applications are in the construction of nuclear power plants, ultra high-rise buildings, tall structures, etc. Recently, a few infrastructure projects have also seen specific application of high performance concrete (HPC). The development of HPC has brought about the essential need for additives both chemical and mineral additives to improve the performance of concrete. Most of the developments across the world have been supported by continuous improvement of these admixtures. Hence, variety of admixtures, such as fly ash, silica fume, GGBS, rice husk ash, stone dust, and Metakaolin etc. have been used.

Hence an attempt has been made in the present investigation on replacement of cement with Metakaolin up to certain percentages to attain the setout objectives of the present investigations, the grade of concrete M_{60} mix case have been taken as reference concrete. Hardened concrete is tested for strength properties such as Young's Modulus of Elasticity. The variations of Metakaolin have been studied of above strengths with variation in different % of Metakaolin replaced with cement have been studied. Metakaolin is manufactured from pure raw material to strict quality standards. Metakaolin is a high quality pozzolanic material which is blended with Portland cement in under to improve 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 densifies and reduces the thickness of the interfacial zone, thus improving the adhesion between the hardened cement paste and particles of sand or aggregate. Hence, an attempt is made in this investigation to study the effect of Metakaolin on the compressive strength, split tensile strength and modulus of elasticity of concrete.

II. Experimental Investigations

2.1 Cement :

Ordinary Portland cement of 43 grade conforming to ISI standard is used in the present investigation. The following tests have been carried out according to IS:8112- 1989. Specific gravity of Cement**,** Normal Consistency of Cement**,** Initial and Final setting time of Cement**,**Compressive Strength of Cement.

2.2 Metakaolin

The Metakaolin is obtained From the 20 MICRONS LIMITED company at Vadodara in Gujarat. The specific gravity of Metakaolin is 2.5. The Metakaolin is in conformity with the general requirements of pozzolana.

2.3 Fine aggregate

The locally available Natural river sand conforming to grading zone-II of IS 383-1970 has been used as Fine Aggregate. Following tests have been carried out as per the procedure given in IS 383(1970), Specific Gravity, Bulk Density, Grading, Fineness Modulus

2.4 Coarse Aggregate

Machine crushed granite confirming to IS 383-1970 consisting 20mm maximum size of aggregates have been obtained from the local quarry. It has been tested for Physical and Mechanical properties such as Specific Gravity, Sieve Analysis, Bulk Density, Crushing and Impact values .

2.5 Water

Potable water has been used in this experimental programme for mixing and curing.

III. Casting Of Specimens:

The present experimental investigation includes casting and testing of specimens for modulus of elasticity. The specimens are prepared as per the mix design by weight. Six Metakaolin percentages (0, 7.5, 10, 12.5, 15 & 17.5) have been adopted in the preparation of the specimens. For each percentage of concrete 3 numbers of cylindrical specimen (28 days) .First the materials cement, Metakaolin, fine aggregate, coarse aggregate are weighed exactly. The materials cement and Metakaolin are blended and then fine aggregate, and coarse aggregate are added and thoroughly mixed. Water is measured exactly and added to the dry mix and entire mix is thoroughly mixed till uniformity is achieved. Immediately after thorough mixing, the fresh concrete is tested for workability using compaction factor apparatus. For casting the cylinder mould size 150mm diameter and 300 mm height. The moulds have been cleaned of dust particles and applied with mineral oil on sides, before concrete is poured in to the mould. Thoroughly mixed concrete is filled in the mould in Three layers of equal height and has been compacted each time by tampering rod. Now vibrating the concrete mould, using table vibrator and the surface of the above specimens have been finished smooth. All the precautions have been taken while moulding the specimens based on IS 10262-1962 code of practice. Tests Conducted

4.1.1 Testing of cylinders for Modulus of elasticity

The modulus of elasticity was determined using the longitudinal compression meter attached to the cylindrical specimen. The test was conducted as per the procedure given in the manual supplied by AIML India Ltd and as per IS:516-1959. The modulus of elasticity of concrete was determined by subjecting the cylindrical specimen to axial compression and measuring the deformation by means of a dial gauge fixed to the compression meter at regular intervals of loading. The load on the cylinder was applied at a constant rate (load increases in the ascending order of 200 kgs). The dial gauge reading was divided by the gauge length which is150 mm to give the strain and the load applied was divided by area of cross-section to give the stress intensity. A series of readings were taken and the stress-strain relationship was established. The modulus of elasticity is determined by taking initial tangent modulus for each percentage of Metakaolin.

4.1.2 Determination of Modulus of elasticityby means of an Extesometer.

In order to compressive strength, three test specimens for compressive strength shall be made together with each set of cylinder .The test specimens for compressive strength shall be made from the same sample of concrete as cylinders and cured and stored under identical conditions.

The static modulus of elasticity of a concrete under tension or compression is given by the slope of the stress-strain curve under uni-axial loading. Three methods for calculating the modulus of elasticity as 1)The initial tangent modulus is given by the slope of a line drawn tangent to the stress-strain curve at any point of curve .It is approximately equal to dynamic (low strain) modulus .2)The secant modulus is given by the slope of a line drawn tangent from the origin to the point on the curve corresponding to the 40% stress level of the failure load. 3)The chord modulus is given by the slope of a line drawn between two points of the stress-strain curve. Compared to the secant modulus, instead of the origin the line is drawn from a point representing a longitudinal strain of 50 micron strain to the point that corresponds of the ultimate load. The ratio of the static modulus of elasticity to the dynamic modulus is always less than one .

The dynamic modulus of elasticity is generally around 20% higher than the static modulus of elasticity for high,medium and low strength concretes respectively. Modulus of elasticity=stress/ strain .Modulus of elasticity of concrete is affected by the elastic modulus of the aggregate and by volumetric proportion of aggregate in the concrete ,the elastic modulus of the cement paste and to a certain extent, the method of measurement.

4.1.3 Influence of Metakaolin percentages on Compressive Strength of concrete

Compression test is done conforming to IS: 516-1959. All the concrete specimens that are tested in a 200 tonnes capacity of the compression-testing machine. Concrete cubes of size 150mm x 150mm x 150mm were tested for crushing strength, crushing strength of concrete was determined by applying load at the rate of 140kg/sq.cm/minute till the specimens failed. The maximum load applied to the specimen has been recorded and dividing the failure load by area of the specimen gives the compressive strength of concrete. Average value of three specimens were calculated.

% Of Metakaolin	**7 days `(N/mm^2)**	**28 days (N/mm^2)**
0	51.46	61.22
7.5	53.54	63.82
10	54.81	66.98
12.5	52.74	65.86
15	52.30	61.48
17.5	51.10	60.86

Table -1: Cube Compressive Strength of Concrete with % of Metakaolin

% Of Metakaolin	**Modulus of Elasticity 28 days in (MPa)**
0	3.9545×10^4
7.5	4.534×10^4
10	5.00×10^4
12.5	4.571×10^4
15	4.0625×10^4
17.5	3.333×10^4

Table -2 Modulus of Elasticity of Concrete (E) with % of Metakaolin

Fig.4.1 Slump VS % of Metakaolin

Fig.4.1.1 Compressive Strength ;7days &28 days

View of the materials used in the present Investigation

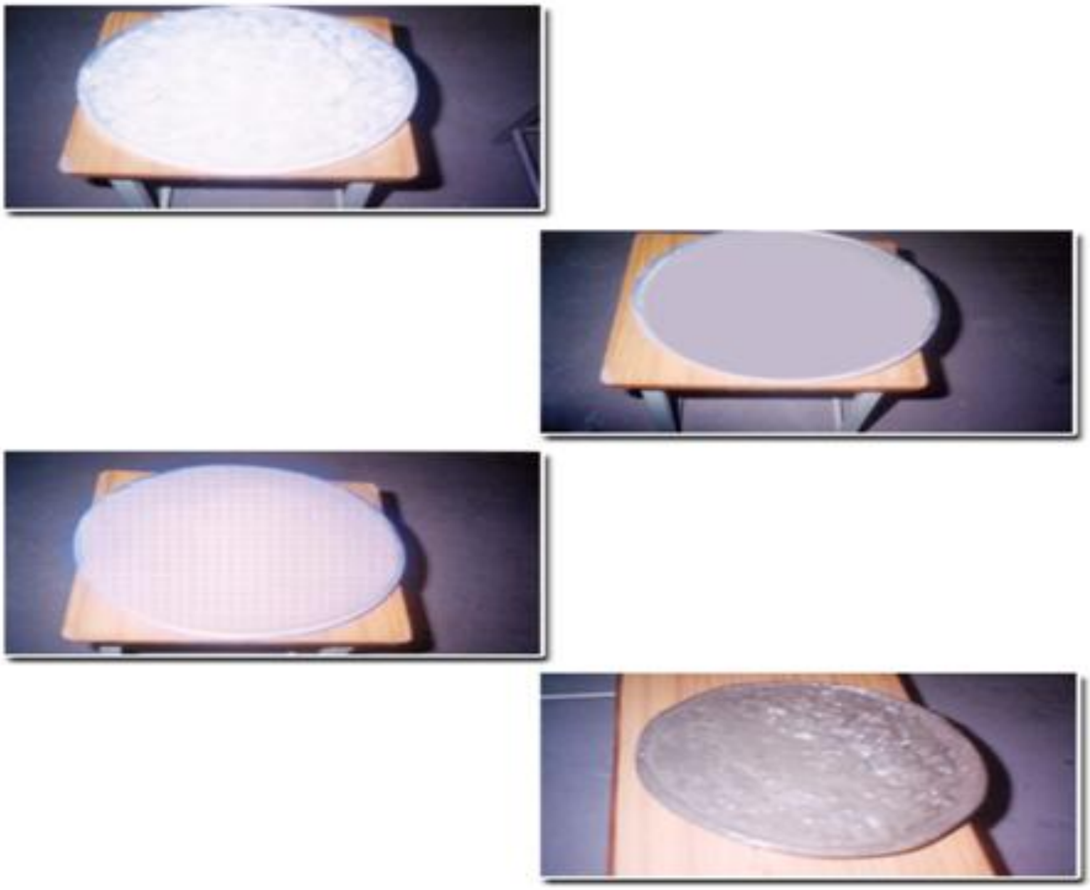

Fig: 4.2-4.5: Metakaolin, Cement ,sand and Concrete

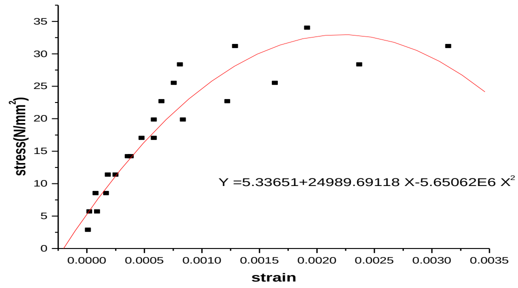

Fig. 4.6 STRESS Vs STRAIN CURVE FOR 0% METAKAOLIN @ 28 DAYS

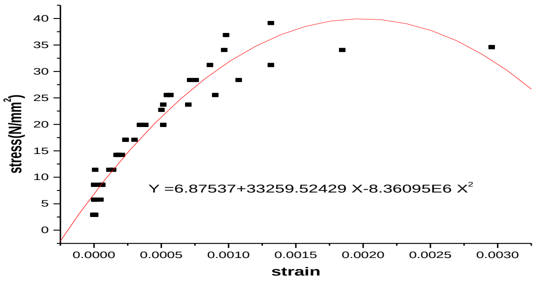

Fig. 4.7 STRESS Vs STRAIN CURVE FOR 7.5% METAKAOLIN @ 28 DAYS

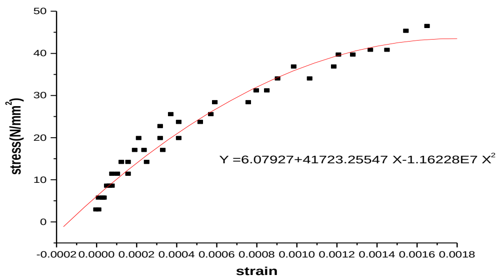

Fig. 4.8 STRESS Vs STRAIN CURVE FOR 10% METAKAOLIN @ 28 DAYS

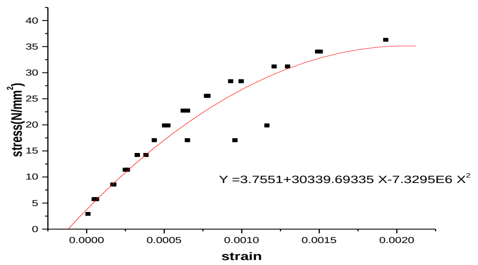

Fig. 4.9 STRESS Vs STRAIN CURVE FOR 12.5% METAKAOLIN @ 28 DAYS

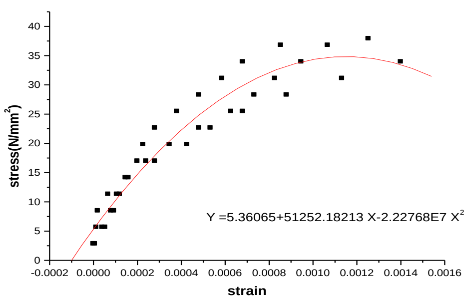

Fig. 4.10 STRESS Vs STRAIN CURVE FOR 15% METAKAOLIN @ 28 DAYS

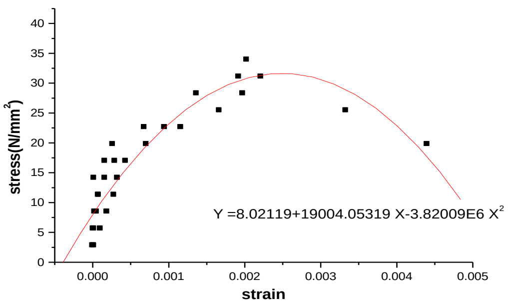

Fig. 4.11 STRESS Vs STRAIN CURVE FOR 17.5% METAKAOLIN @ 28 DAYS

Fig 4.12. Modulus of Elasticity curves : Stress Vs Strain with different replacements o Metakaolin (0%,7.5%,10%,12.5%,15% &17.5%)

Fig. 4.13 Load vs Delections

IV. Results And Discussions

5.1 *Influence of Metakaolin percentages on Compressive Strength of concrete*

The cube compressive strength of concrete with different percentages of Metakaolin is shown in Table-1. The variation is also represented in the form of a bar-chart in Fig.4.1.1

The compressive strengths of the mix M_{60} i.e without mixing of Metakaolin are 51.46 N/mm^2 for 7 days and 61.22 N/mm^2 for 28 days respectively. In the present investigation the Metakaolin has been used as replacement to cement up to a maximum of 17.5%. When Metakaolin is used as admixture in different percentages the strength is increased. For example, with 7.5% replacement of cement by Metakaolin the compressive strength at 28 days is 63.82 N/mm^2 and there is an increase in compressive strength by 4.07%. Considering 10% replacement, the compressive strength is 66.98 N/mm^2 and there is an increase in compressive strength by 8.6%. With 17.5% replacement, the compressive strength is 60.86 N/mm^2, and there is a decrease in compressive strength by 0.58%. From this strength, it is clear that there is no advantage in using Metakaolin beyond 10%. Hence, 10% Metakaolin can be taken as the optimum dosage which can be mixed as a partial replacement to cement for giving maximum possible compressive strength at any age.

5.2 Influence of Metakaolin percentage on Modulus of Elasticity (E) of concrete

The typical stress Vs strain curve for 10% metakaolin at 28 days is shown in Fig.4.12.Similar curves are obtained for other percentages of metakaolin.The modulus of elasticity of concrete with different percentages of Metakaolin given in table.2 In the case of Modulus of Elasticity for 28 days value without Metakaolin is 39545N/mm^2. When 7.5% replacement is used the Modulus of Elasticity is 45340 N/mm^2. There is an increase in strength by 12.78%. The Modulus of Elasticity at 28 days with 10% replacement is 50000N/mm^2 showing an increase of strength by 20.91%. With 17.5% replacement the strength for 28 days is 33333 N/mm^2. There is a decrease in strength by about 15.71%. Therefore, it is advisable to use 10% as replacement. Hence the optimum percentage of Metakaolin is again 10% only, even in the case of Modulus of Elasticity.

V. Conclusions

- The value of compressive strength, increase from 0% upto 10% of Metakaloin and then decrease.
- The value of Young's modules increase from 0% upto 10% of Metakaloin and then decrease.
- The optimum dosage of Metakaolin is considered to be 10% based on the experimental investigations carried out in this investigation.
- The slump decreases with increasing % replacement of metakaolin.

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