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Experimental Evaluation of Metakaolin as a Supplementary Cementitious Material

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Abstract: Concrete is the most widely used construction material. However, since the production of cement releases a significant amount of carbon dioxide (CO_2), global cement production has led to substantial environmental emissions. In recent years, supplementary cementitious materials such as silica fume, fly ash, slag, rice husk ash, and metakaolin have been increasingly used as partial replacements for cement to enhance high-strength concrete (HSC) by improving performance, durability, energy efficiency, and service life while reducing permeability. Recent studies on metakaolin, a dehydroxylated alumino-silicate material, indicate that it is a highly effective pozzolanic material that significantly enhances the strength characteristics of concrete. One of the major advancements in concrete technology is the development of high-performance concrete (HPC), which is widely used in prestigious projects such as nuclear power plants, flyovers, and high-rise buildings. This thesis investigates the partial replacement of cement with metakaolin as a mineral admixture in M80 grade high-performance concrete. Cement was replaced with metakaolin at levels of 0%, 5%, 10%, 15%, and 20% by weight. The experimental results were compared with those of conventional concrete in terms of compressive strength, split tensile strength, flexural strength, and durability characteristics.

Keywords: Rice Husk, Slag, Fly Debris, Silicon oxide, Metakaolin and Compresssive Strength.

I. INTRODUCTION

Concrete is the most commonly used construction material and is composed of cement, fine aggregate (sand), coarse aggregate, and water. It is extensively used in the construction of multi-storey buildings, dams, road pavements, storage tanks, offshore structures, and canal linings. Concrete mix design is the process of selecting suitable materials and determining their appropriate proportions to produce concrete with the required strength, durability, and workability in an economical manner. The compressive strength of hardened concrete is generally considered an indicator of its overall performance and depends on several factors such as the quality and quantity of cement, water and aggregates, batching and mixing methods, placing, compaction, and curing practices. The cost of concrete is influenced by the cost of materials, plant, and labour. Since cement is significantly more expensive than aggregates, the objective of mix design is to achieve an economical mix from a practical standpoint. Over-rich mixes may result in excessive shrinkage and cracking in structural concrete, while in mass concrete they may cause high heat of hydration, leading to thermal cracking. The actual cost of concrete is therefore related to the cost of materials required to achieve the specified characteristic strength defined by the structural designer. Although quality control measures increase the cost of concrete, they are essential for ensuring the desired performance and durability.

Composition of Concrete: There are four basic ingredients within the concrete mix:

1. Binding materials like cement or lime
2. Aggregates or Inert Materials

i) Fine aggregate (sand)

ii) Coarse aggregate (stone chips, brick chips)

3. Water
4. Admixture

The formula for producing concrete from its ingredients can be presented in the following equation:

Concrete = Cement + Fine & Coarse Aggregate +Water+ Admixture (Optional)

Truss bridge: In this type of bridge small beams are joined together to carry large amount of loads.

II.OBJECTIVE

The objective of this research is as follows:

1. Comparative study of the behavior of the concrete with & without Metakaolin.
2. To determine the compressive strength, flexural strength and split tensile strength of the Metakaloin.

3. To study the behavior of concrete using Metakaolin in strength enhancement

4. To find the optimum percentage of metakaolin for obtaining the maximum strength of concrete

III..LITERATURE REVIEW

1} Verma Ajay et.al: Investigate on the properties of materials crystalline and non crystalline. Micro silica are especially fine non crystalline material. In Present investigation we are using silica fume as a non-natural pozzolana. On adding 0%, 5%, 10%, 15% by wt of cement in concrete. Silica fume improves concrete through two mechanisms: Pozzolonic effect: Micro filler effect: Silica fume increases the strength of concrete more 25%. Silica fume is a material which can be a explanation of Air Pollution this is a by product of some Industries use of micro silica with concrete decrease the air pollution. Silica fume also reduce the voids in concrete. Addition of silica fume reduces capillary Absorption and porosity as fine particles of silica fume reacts by lime present into cement.

{2}. **Debabrata Pradhan, et.al** They carried out of silica fume into the normal concrete is a routine one in the present days to produce the high strength and high performance concrete. The design parameters are increasing by the integration of silica fume in usual concrete and the mix proportioning is becoming complex. The main objective of this paper have been prepared to investigate the unusual mechanical properties like compressive strength, compacting factor, slump of concrete incorporate micro silica. In this five mix of concrete incorporating silica fume are cast to perform experiments. These experiments be carried out by replacing cement with different percentages of silica fume at only constant water-binder materials ratio keep other mix design variables constant. Silica fume is replaced by 0%, 5%, 10%, 15% and 20% for water-binder materials (w/cm) ratio for 0.40. For all mixes compressive strengths be determined next to 24 hours, 7 and 28 days for 100 mm and 150 mm cubes.

{3} N. K. Amudhavalli, et.al:- Reviewed on the study of M35 grade concrete with partial substitute of cement by micro silica by 0, 5, 10, 15 and by 20%. It gives a detailed experimental study on Compressive strength, split tensile strength, flexural strength on age of 7 and 28 days. Durability study on acid assault was also study and percentage of weight loss is compared by normal concrete. Test results shows that use of micro silica in concrete have enhanced the performance of concrete in strength as well as in durability feature The optimum micro silica replacement percentage for obtaining highest 28- days strength of concrete range from 10 to 20 %.

{4} Dr. B. Krishna Rao {2016}: The objective of the present study is to evaluate the effect of replacing cement with metakaolin and fine aggregate with waste foundry sand. For this study M25 grade concrete is prepared and is evaluated for fresh concrete properties and hardened concrete properties like compressive, split tensile, flexural strength and modulus of elasticity. Ordinary Portland cement is replaced with metakaolin keeping10% constant, while the fine aggregate is replaced with waste foundry sand at 0, 10, 20, 30 and 40% by weight. The compressive, split tensile and flexural strength properties are compared among all the mixes at periods of 7, 28 and 56 days.

METHODOLOGY

As Cement is halfway supplanted by metakaolin, so in first phase of work 5 batches of various proportions of binders are arranged and cubes, beams 7 cylinders are casted. Results acquired were examined and extent that gave ideal qualities is taken for the following stage.

3.2 Tests on Cement:

3.2.1 Fineness

3.2.2 Consistency

3.2.3 Initial & Final Setting Time of Cement

3.2.1.Fineness test for cement (IS 4031 (Part 1) : 1996)

To determine the fineness of cement by dry sieving 90-micron IS sieve as per IS: 4031 (Part 1)– 1996. Principle of this work is that we find out the percentage of cement whose grain Size is better than specified mesh size.9

Tests on Hardened Concrete for M-20 Concrete

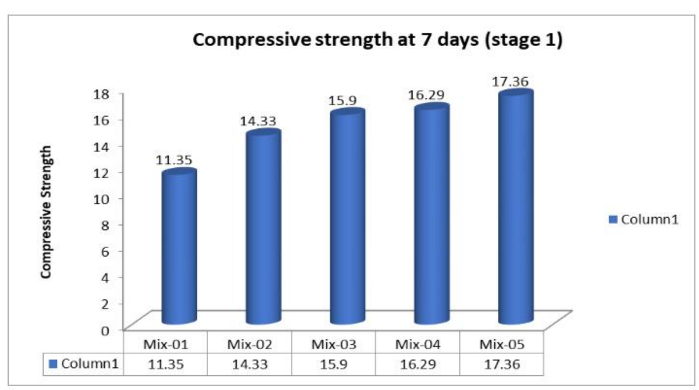
5.2.1 COMPRESSIVE STRENGTH TEST RESULT

A minimum of three cubes are casted in each batch mix for determining compressive strength. Tests are performed at the age of 7 days, 14 days & 28 days of the specimens. Specimens are placed in the test machine as per IS: 516-1959 clause no 5.5.1 page no 11, also loading is applied on the specimen as per the same IS code

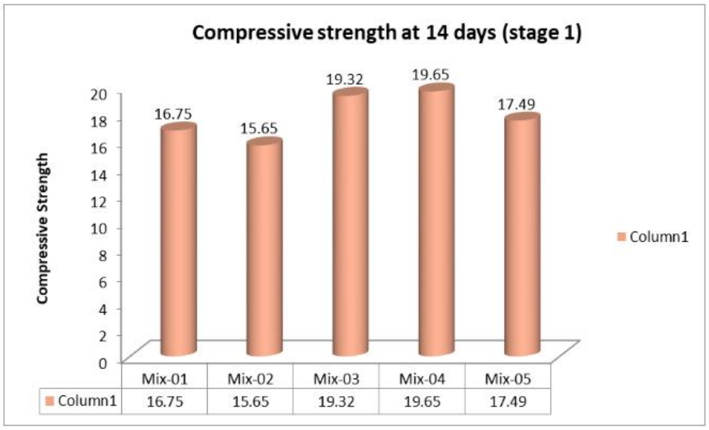
Table: Variation of compressive strength with age (M-20 Concrete)

% of MK	0%	5%	10%	15%	20%
7 Days	11.35 N/mm2	14.33 N/mm2	15.90 N/mm2	16.29 N/mm2	17.36 N/mm2
14 Days	16.75N/mm	15.65 N/mm2	19.32 N/mm2	19.65 N/mm2	17.49 N/mm2
28 Days	24.46 N/mm2	28.26 N/mm2	29.22 N/mm2	28.56 N/mm2	27.75 N/mm2

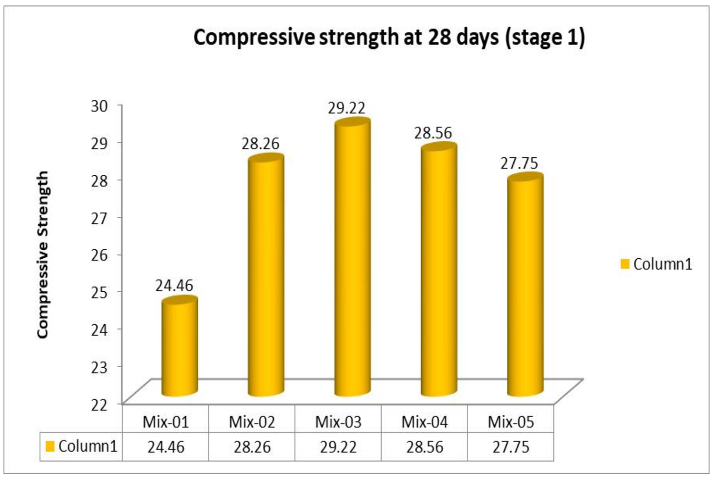
Following Graphs have been prepared for compressive strength



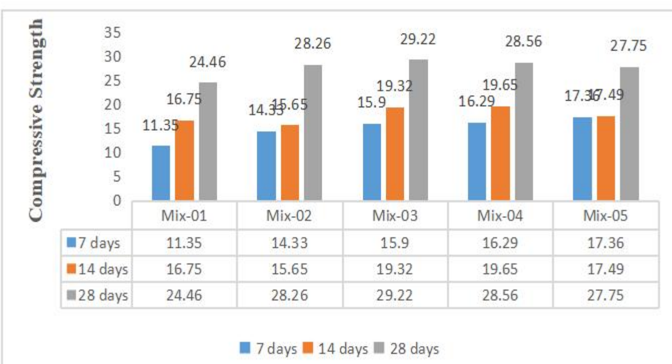
Graph:1. Compressive Strength at 7 days (Stage-1)



Graph:2 Compressive Strength at 14 days



Graph:3 Compressive Strength at 28 days



Graph:4 Compressive Strength in N/mm2 at Various age (days) (Stage-1)

IV.CONCLUSIONS

Compressive strength, Flexural strength, Split tensile strength of concrete Mixes made with and without metakaolin has been determined at 7, 14 & 28 days of curing. The strength gained has been determined of metakaolin added concrete with addition of 5%, 10%, 10%,15%, 20% for M20 & M25 grade as a partial replacement of cement in conventional concrete. From the results it is conclude that the metakaolin is a superior replacement of cement. The rate of strength increase in metakaolin concrete is high. After performing all the tests and analyzing their result, the following conclusions have been derived:

1. The results achieved from the existing study shows that metakaolin is great potential for the utilization in concrete as replacement of cement.

2. Workability of concrete decreases as proportion of metakaolin increases.

3. Maximum compressive strength for M20 concrete was observed when metakaolin replacement is about 5%.

4. Maximum split tensile strength for M20 was observed when metakaolin replacement is about 10%.

5. Maximum flexural strength for M20 was observed when metakaolin replacement is about 10%.

6. Maximum compressive strength for M25 concrete was observed when metakaolin replacement is about 5%.

7. Maximum split tensile strength for M25 was observed when metakaolin replacement is about 10%.

8. Maximum flexural strength for M25 was observed when metakaolin replacement is about 15%.

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