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EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN AND RICE HUSK ASH ON THE STRENGTH AND DURABILITY PROPERTIES OF HIGH STRENGTH CONCRETE

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ABSTRACT

In this study the influence of partial replacements of Ordinary Portland cement by Metakaolin (MK) and Rice Husk Ash (RHA) were investigated and the effects on mechanical and durability properties were determined. Namely two types of pozzolans were2 opted for this study which is Rice Husk Ash and metakaolin. The procedure of test and results of mechanical and durability properties were reviewed from engineering properties of blended concrete with Colombian rice husk ash and metakaolin. The results inferred showed enhanced performance up to 60MPa at 28 days with acceptable workability.

Keywords: - *Metakaolin, Rice husk ash, high strength concrete, pozzolanic activity.*

1. INTRODUCTION

Concrete is the most widely used construction material in the world and also the sole supplier of binder for concrete industry. Mineral admixture addition in the cement is done to save energy, money and natural resources like lime, aggregates and water. One of the major threats to environment is the emission of carbon dioxide during the manufacture of cement. In order to minimize this damage caused by the supplementary cementitious materials they are replaced by admixtures obtained from industrial and agro waste. In this investigation metakaolin is used to increase mechanical and durability properties of concrete due to its pozzolanic action. In view an experiment was done by incorporation of metakaolin and RHA in concrete as partial replacement materials in cement which gave satisfactory results. Furthermore, concrete with high compressive strength can eliminate the use of large beams and columns and hence it is mostly adopted for construction of structural building. High Strength Concrete have compressive strength greater than 41 MPa achieved after twenty eight of proper curing. In order, to achieve extra strength supplementary cementing materials such as silica fume and fly ash can also be used.

As per the Recommended Indian Standards for Methods of Mix Design boundary between NSC and HSC should be 35MPa. However, in the international forum, concrete with strength above 40 MPa is considered as HSC. Recently, the threshold rose to 55 MPa as per IS 456-

2000. Concrete is categorized into three namely: Normal Strength Concrete (NSC), High Strength Concrete (HSC) and Ultra High Strength Concrete (UHSC). HSC differs from ordinary concrete with respect to its performance in fresh and hardened states that are mainly driven by exceptional material components and mixture proportions and incorporate high-range water reducer (HRWR), supplementary cementing material (SCM), in addition to the basic materials used for ordinary concrete. The proportions of component materials in HSC are also significantly different from those of ordinary concrete. HSC includes a much higher quantity of binder, lower water content, a greater fine aggregate content, and a lesser amount and size of coarse aggregate than ordinary concrete.

Metakaolin is a thermally activated alumina silicate material obtained by calcining kaolin clay within the temperature range 650–800 °C, which is a relatively new material in the concrete industry, is effective in increasing strength, reducing sulphate attack and improving air-void network. Pozzolanic reactions change the microstructure of concrete and chemistry of hydration products by consuming the released calcium hydroxide (CH) and production of additional calcium silicate hydrate (C-S-H), resulting in an increased strength and reduced porosity and therefore improved durability. The use of Metakaolin in High Strength Concrete is discussed in this paper. This reaction leads to formation of binding phases of following types: secondary C-S-H gel, C4AH13, C3AH6, and C2ASH8 thereby increasing strength.

Rice husk ash (RHA) is a highly reactive pozzolanic material that is produced by incineration of rice husk (RH) which contains a very high percentage of either amorphous or crystalline silica. If RH is burnt under controlled temperature, time and rate of burning, amorphous silica is produced which is highly reactive in nature. When over burning occurs (above 700°C), the amorphous SiO2 will be changed to cristoballite, quartz and tridymite, and when it is burnt at low temperatures (below 500°C), much carbon will exists in the product; in either case the pozzolanic activity of RHA will be decreased greatly . Using it provides several advantages, such as improved strength and durability properties, and environmental benefits related to the disposal of waste materials and to reduced carbon dioxide emissions

This paper presents the evaluation of the performance in concrete of pozzolanic materials made from Metakaolin (MK) and rice husk ash (RHA) on mechanical and durability properties of concrete mixes.

2. EXPERIMENTAL DETAILS

2.1 MATERIALS REQUIRED:

2.1.1 CEMENT

In this investigation Ordinary Portland Cement of 53 grade with specific gravity 3.11 and specific surface of 4200 m^2/kg, easily available in local market was used. Selection of cement depends upon its modified micro porous structure, compressive strength, fineness, heat of hydration, alkali content, contents of tricalcium aluminates, tricalcium silicate,

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dicalcium silicate etc. Moreover compatibility of cement with chemical and mineral admixtures is the most important determining factor.

2.1.2 COARSE AGGREGATE:

About 70-80% of volume of the concrete is occupied by aggregates, which constitutes the backbone of the concrete and also bring down shrinkage to a great extend. Equi dimensional coarse particles of 12.5 mm size adopted. Machine crushed granite confirming to I.S. code (6) consisting of 20 mm maximum size of aggregates has been obtained from the local quarry.

2.1.3 FINE AGGREGATE:

Mining sand with specific gravity- 2.53, fineness modulus- 4.53 and water absorption - 3.36% was used in this investigation. It has a fineness modulus ranging between 2.5-3.0. The locally available natural river sand conforming to grading zone-II has been used as fine aggregate. Tests have been carried out as per the standard procedures.

2.1.4 HIGHLY REACTIVE METAKAOLIN (HRM):

Metakaolin is obtained by the calcinations of pure or refined kaolin clay at 650-850, followed by grinding to achieve a fineness of 700-900 m^2/kg with high pozzolanicity. The partial replacement of metakaolin contributes to rapid increase in compressive and flexural strength with reduced effects of alkali-silica reactivity (ASR).

2.1.5 RICE HUSK ASH:

Rice husk is an agro based waste material generally disposed of by dumping or by burning, sometimes they are also utilized as low grade fuel. RHA is produced by burning rice husk between 600 - 700°C temperatures and has high reactivity and pozzolanic property. In finely divided form RHA chemically combine with calcium hydroxide in the presence of moisture at normal temperature to form cementitious compounds.

2.1.6 WATER: Potable water has been used in this experimental program for mixing and curing.

3. MIXTURE PROPORTIONS

Trials mixtures were prepared to obtain target strength of more than 60MPa for the control mixture at 28 days and the water/binder ratio for all the mixtures were kept constant at 0.30 to study the mechanical and durability properties. Cement content was partially replaced with

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0%,2.5%,5%,7.5%,10%,12.5% and 15% MK and same level of RHA (by mass) respectively. The binder consists of cement MK and RHA.
For the compression test, 150 × 150 × 150 mm cubes size was used as a standard specimen. In another mix design, water to cement ratio for concrete mixture was 0.29 and concrete cylinders with 150 mm diameter and 300 mm height were casted for compression test.

Table 1: Test conducted on specimens

SL NO	TYPE OF TEST	PROPERTIES STUDIED	SPECIMEN SIZES
1	Compression test(Cube)	Strength	150 X 150 X 150mm
2	Compression test(cylinder)	Strength	150 X 300mm
3	Split tensile strength(Cylinder)	Strength	150 X 300mm
4	Flexural test(prism)	Strength	500 X 100 X 100mm
5	Water absorption test(cube)	Durability	150 X 150 X 150mm
6	Porosity	Durability	150 X 150 X 150mm

3.1 Mixing and Casting Details

All the materials were mixed using a pan mixer with a maximum capacity of 80 l. The materials were fed into the mixer in the order of coarse aggregate, cement, MK and RHA.

3.2 Specimens and Curing

The following specimens were cast from each mixture:
• 150 X 150 X 150 mm cubes for the compressive strength.
• 150 X 300 mm cylinders for the splitting tensile test.
• 150 X 150 X 150 mm cubes for water absorption study.
• 150 X 150 X 150 mm cubes for porosity test.

4. STRENGTH AND DURABILITY TESTS

4.1 Compressive strength of Cubes

On the basis of the study of the data concerning the compressive strength development with water cement ratio and curing period for the concretes incorporating metakaolin (MK) and RHA was studied. The effect of MK and RHA on compressive strength of concrete can clearly be observed from the figure 1. The 28-days compressive strength of the concrete with water to cement ratios of 0.25 and 0.35 were ranged between 53.01-60.388 MPa and 70.05-63.53MPa, respectively, independent of the type of the mineral admixture and replacement

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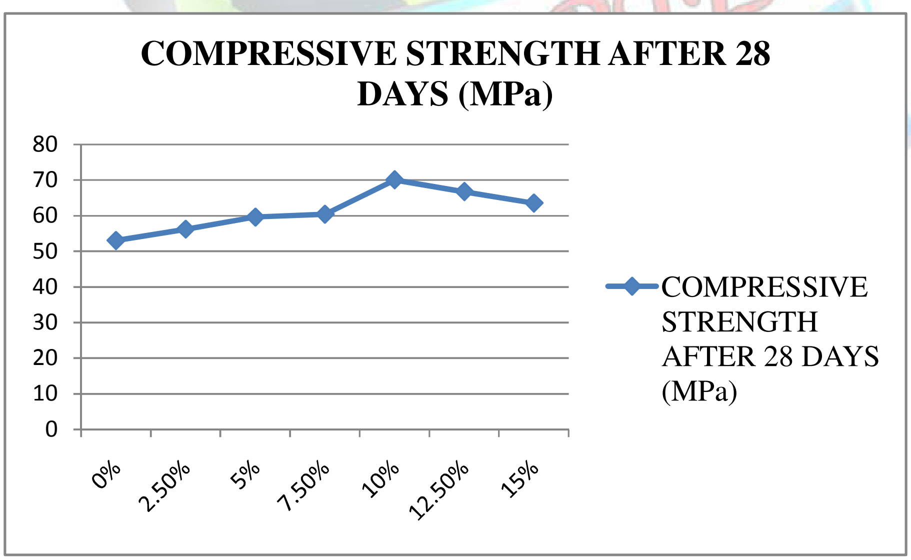
level. The figure 1 indicated that there was a systematic increase in compressive strength with the increase in MK and RHA groups.

The addition of metakaolin into the concrete matrix improved the bond between the cement paste and aggregate particles as well as increasing the density of the cement paste which in turn significantly enhanced the compressive strength of the concrete. The main factors that affect the contribution of metakaolin in the compressive strength are the filling effect, the dilution effect, and the pozzolanic reaction of metakaolin with CH. However concretes achieved over 80% of control concrete's strength at 28 curing days. They reached 92% and 96% of control concrete compressive strength at 56 curing days, for 7.5% and 10% of MK and RHA content respectively.

TABLE 2: Test results of compressive strength on concrete cubes for different replacement levels at 28 days.

NAME	COMPRESSIVE STRENGTH AFTER 28 DAYS (MPa)
0%	53.01
2.5%	56.18
5%	59.59
7.5%	65.63
10%	69.87
12.5%	66.77
15%	63.53



4.2 Compressive strength of Cylinder

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The cylinder compressive strength of concrete prepared using the optimized mix is found to be greater than that of the control mix. It was also noticed that the 28th day compressive strength of the optimized mix showed an increase of about 13 percent t han that of the control mix. The increase in compressive strength is attributed to the pozzolanic property and filling ability of RHA which have finer particle size when compared with cement.

4.3 Splitting Tensile Strength

The tensile strength results of MK and RHA concretes with varying amounts of MK and RHA are shown in Table 3. The average value of the 28-day tensile strength for the concretes made was about 5.23 . Table 3 shows that the average ratio between the tensile strength (fsp) to cylinder compressive strength (fck) of concrete at 28 days was lower than the range (of about 9–10 %) for medium strength concrete.

From the results it can be seen that similar to compressive strength the splitting tensile strength also exhibited the highest strength at replacement of 10% of MK and RHA. Figure 2 presents the relation between compressive strength and splitting tensile strength of all the mixtures at 28 days. It can be observed that as the compressive strength increases, the tensile strength also increases. The relationship between compressive strength (fck) and split tensile strength (fsp) can be expressed as below

fsp ¼ 0:0357ðfckÞ1:08014 R2 ¼ 0:94: e

In this study, it was observed that 0 % replacement level exhibited the lowest coefficient of permeability. This could be due to the fact that the pores were filled by hydration products, which would result in pore refinement leading to improved performance of the concrete

TABLE 3: Test results of compressive strength on concrete cylinder for different replacement levels at 28 days.

REPLACEMENT LEVEL (%)	COMPRESSIVE STRENGTH AFTER 28 DAYS (MPa)	SPLIT TENSILE STRENGTH (MPa)
0%	41.952	4.51
2.5%	44.42	5
5%	49.81	5.24
7.5%	49.81	5.57
10%	56.98	5.92
12.5%	52.81	5.77
15%	51.08	5.62

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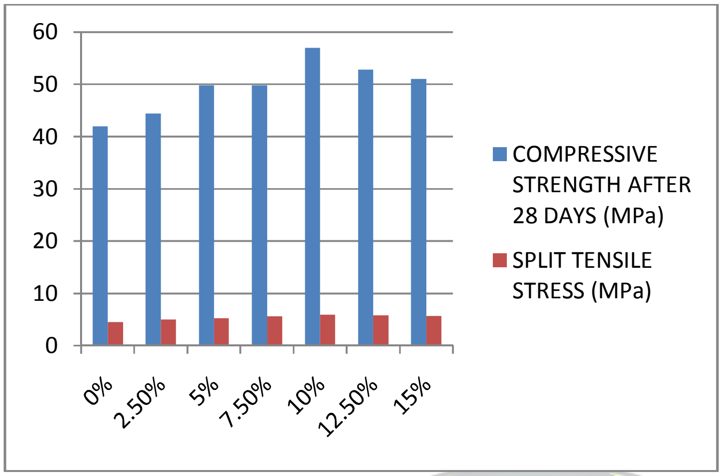

4.4 Flexural Strength

In figure 4 the graph is plotted between flexural strength and % replacement of MK and RHA. Graph shows that Flexural strength firstly increases and after a limit the flexural strength decreases. This is because proper binding is not taking place between cement replaced by RHA & aggregate. The maximum increase in Flexural strength was for 10% replacement .The minimum Flexural strength is observed at 0% replacement of RHA and MK at 28 days of testing.

TABLE 4: Test results of flexural strength on concrete prism for different replacement levels at 28 days.

REPLACEMENT LEVEL (%)	FLEXURAL STRENGTH AFTER 28 DAYS (MPa)
0%	6.59
2.5%	6.88
5%	7.08
7.5%	7.37
10%	5.87
12.5%	7.85
15%	7.663

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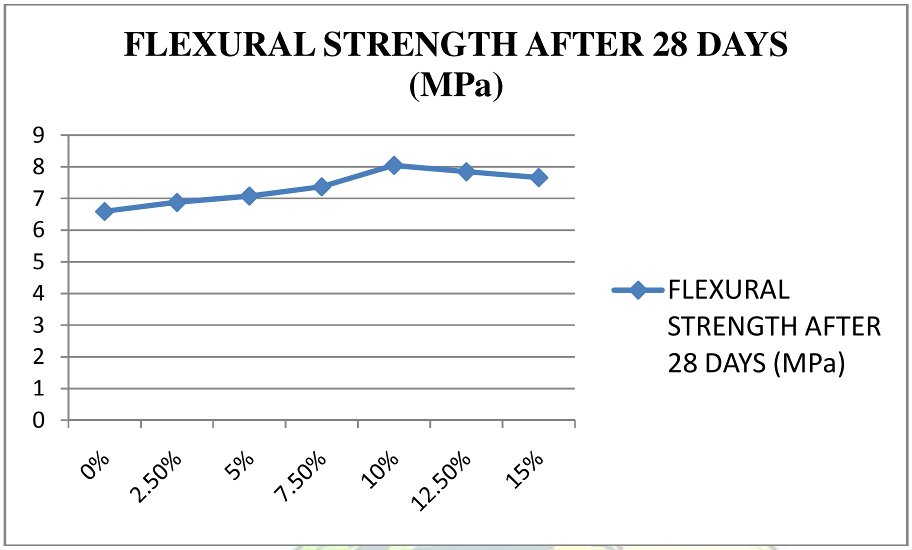

4.5 Saturated Water Absorption

Saturated Water absorption (SWA) tests were carried out on 100 mm cube specimen at the age of 28 days curing as per ASTM C 64212. The results of the saturated water absorptions (SWA) tests of various concrete mixes at the age of 28 days are given in Table 5 , and its pictorial representation is shown in Figure 5. Saturated Water Absorption (SWA) is a measure of the pore volume or porosity in hardened concrete, which is occupied by water in saturated condition. The test results of saturated water absorption of concrete for various percentages of rice husk ash and MK are shown in Table 5.

TABLE 5: Test results of saturated water absorption on concrete cubes for different replacement levels at 28 days.

REPLACEMENT LEVEL (%)	WATER ABSORPTION
0%	-
2.5%	25.47
5%	27.35
7.5%	29.84
10%	20.24
12.5%	34.27
15%	39.25

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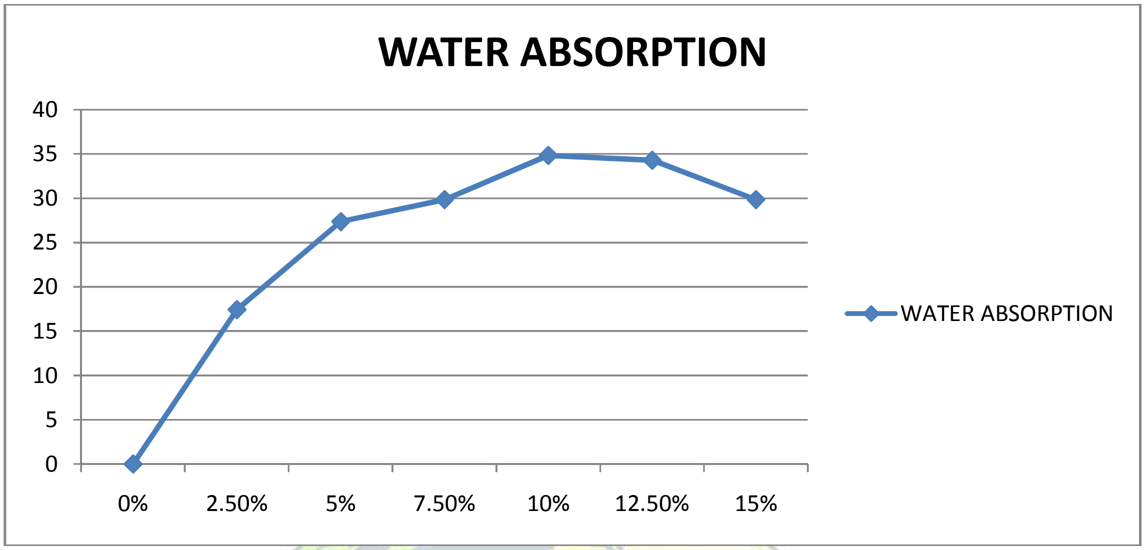
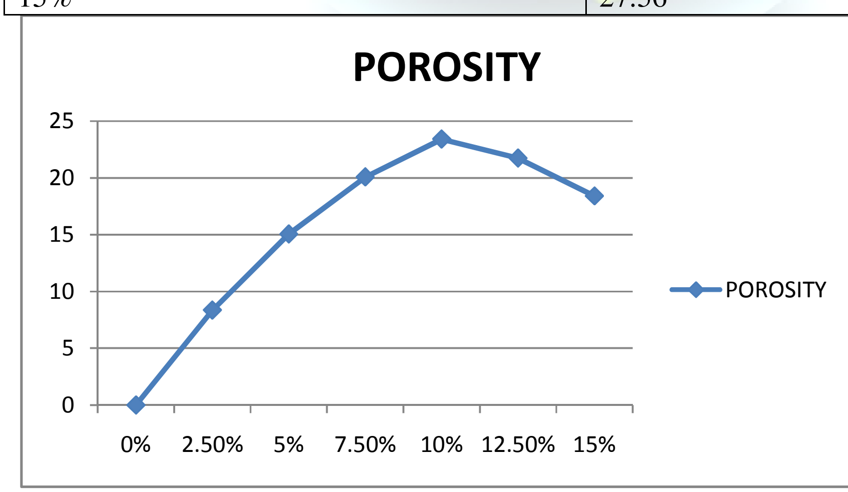


4.6 Porosity

The results of the porosity tests of various concrete mixes at the age of 28 days are given in Table 6. The influence of different levels of RHA and MK on the porosity of concrete mixes is shown in Figure 6.

TABLE 6: Test results of porosity on concrete cubes for different replacement levels at 28 days.

REPLACEMENT LEVEL (%)	POROSITY
0%	-
2.5%	21.58
5%	26.58
7.5%	29.36
10%	20.84
12.5%	24.54
15%	27.56



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5. CONCLUSION

Using Metakaolin and Rice Husk Ash as partial replacement for cement decrement in the plastic density of the mixture was found. The results emphasis that by incorporation of MK and RHA with low water bind ratio of 0.31 lead to development of high strength concrete with compressive strength greater than 100 MPa. The optimum replacement level of Ordinary Portland cement was 10% which gave the highest compressive strength in comparison to that of other replacement levels. This concrete also exhibited the 28 days split tensile strength in the range of 8.5% of the compressive strength.

As far as the durability properties are concerned MK and RHA was found to reduce saturated water absorption and porosity as the replacement percentage increases. This may be due to filler effects of MK and RHA particles.

6. FUTURE SCOPE

1) Other levels of replacement with Rice husk ash and MK can be researched.
2) The study may further be extended to know the behavior of concrete whether it is suitable for pumping purpose or not as present day technology is involved in RMC where pumping of concrete is being done to large heights.
3) For use of Rice husk ash and MK concrete as a structural material, it is necessary to investigate the behavior of reinforced Rice husk ash and MK concrete

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