An Experimental Study on Strength Properties of Geopolymer Concerte with Rha & Metakaolin

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Abstract- *In every man made structure, from roads to skyscrapers and bridges to dams, concrete is used as the major constituent of all. Cement is the most important component of concrete since it ties all of the aggregates together, but it is an energy and resource consuming substance. One metric tonne of Ordinary Portland Cement (OPC) takes 4 GJ of energy to produce and releases approximately one metric tonne of carbon dioxide into the atmosphere. The cement industry accounts for about 7% of global CO2 emissions per year.*

Now-a-days extensive research work is going on Geopolymer concrete as a full replacement of cement in concrete by various pozzolanic materials such as fly-ash, Rice Husk Ash (RHA), Ground Granulated Blast Furnace Slag (GGBS), Metakaolin (MK) etc. Geopolymer concrete (GPC) is one of these, and in this study, the Portland cement is completely replaced with RHA, and Metakaolin and alkaline liquids. The sodium hydroxide (NaOH) and sodium silicate solutions are used as binding materials. Different blends are made of 10 M sodium hydroxide solution and 10 M sodium silicate solution.

The objective of this project is to review the impact of MK and RHA on the mechanical properties of Geopolymer concrete for complete replacement of OPC with different proportions of RHA0- MK100 , RHA100-MK0, RHA90-MK10, RHA80-MK20, RHA70-MK30, RHA60-MK40 while Glass (Na2SiO3) and Sodium hydroxide (NaOH) were used as base-forming activators.

The concrete cube specimens were casted and tested for the compressive strength at 7^{th} *day,* 14^{th} *day and* 28^{th} *day while Split tensile strength tests were carried out on the* 7^{th} *and* 28^{th} *day. The result shows that the Compressive strength of Geopolymer concrete is maximum at RHA70-MK30 and split tensile strength is maximum at RHA60-MK40.*

I. INTRODUCTION

Concrete is the most common material used in the construction of any building. Concrete is only second to water in terms of global use. Portland cement is the primary component of concrete. Global warming and pollution, on the other hand, are the greatest threats to humanity on the planet today. Cement processing results in emissions because CO2 is released during the manufacturing process. During the manufacturing of cement, CO2 is released from two separate sources. The burning of fossil fuels to power the rotary kiln is the most important source, but the chemical process of calcining limestone into lime in the cement kiln often emits CO2. During the year 2010, India released nearly 2,069,738 metric tonnes of CO2. The cement industry is responsible for about 5% of carbon emissions. In addition, natural resources such as lime, clay, and other minerals are used to make cement. Quarrying for these natural resources has a negative impact on the climate. Around 1.6 tonnes of raw materials are needed to manufacture 1 tonne of cement, and the time it takes to shape lime stone is much longer than the pace at which humans use it. However, because of its ease of preparation and fabrication in a variety of shapes, concrete is becoming increasingly popular. As a result, in order to solve this issue, the concrete that will be used must be environmentally friendly.

A NEED OF GEOPOLYMER CONCRETE:

To make environmentally friendly concrete, we must substitute cement with other binders that have no negative impact on the environment. The problem can be mitigated by using industrial byproducts as binders. Geo-polymer concrete, a modern technology, is a preferred technology in this regard. In terms of mitigating global warming, geo-polymer technology has the potential to minimise CO2 emissions Cement and aggregates industries contribute about 80% of the pollution to the atmosphere. In addition, proper disposal of industrial wastes will help to alleviate the issue of waste products entering the atmosphere.

II. OBJECTIVE

The main goal of using Metakaoline and RHA is to mitigate environmental pollution on agricultural lands, such as water pollution, air pollution, and disposal issues. To counteract all of the aforementioned effects, we use Metakaoline and RHA as cement substitute materials in various proportions for concrete preparation, allowing us to increase the blended mix's strength parameters.

1. To increase the strength parameters of blended mix using metakaolin and RHA
2. Alkaline binding agents like sodium hydroxide and sodium silicate are used in this mix.
3. These materials maintained with 10Molarity concentration throughout the project

III. MATERIALS USED IN THE PROJECT

The materials used in the project are as follows:

- Fine aggregate
- Coarse aggregate
- Water
- RHA
- Metakaolin
- NAOH,Na_2Sio_3

PREPARATION OF SOLUTION FOR 10M NaOH and Na2SiO3:

For 10M, the molecular weight of NaOH is 40.

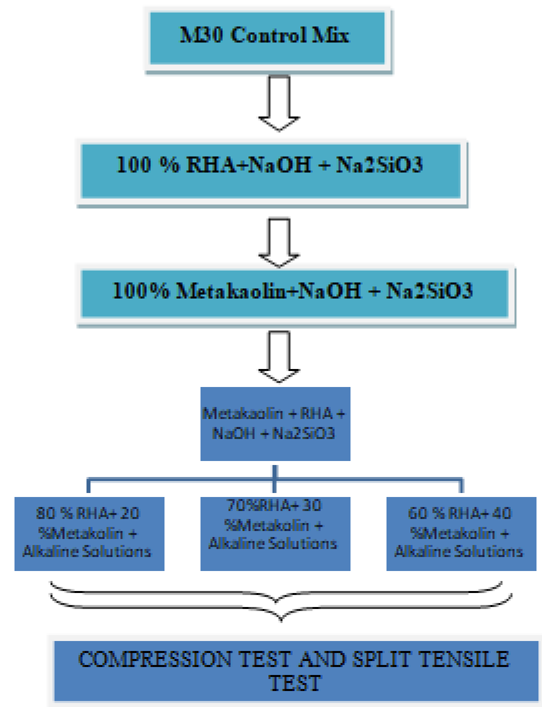
NaoH = 10 x 40
= 400 gm/lit
Total NaOH to be mixed = 400/ (specific gravity of NaOH)
= 400/2.541
= 157.43 gm/lit

Take 2.5 sodium hydroxide as the mass ratio of sodium silicate solution to sodium hydroxide solution.

Na2Sio3 = 2.5 x NaOH
= 2.5 x 400
= 1000gm/lit

Total Na2Sio3 = 1000/ (specific gravity of Na2Sio3)
= 1000/2.7
= 370.37 gm/lit

METHODOLOGY:



THE DESIGN MIX OF M 30 GRADE CONCRETE:
MIX DESIGN FOR M30:

Maximum nominal size of aggregate = 20mm
Value of slump = 50mm
Zone of aggregate = zone ll
Cement has a specific gravity of 3.15.
Coarse aggregate has a specific gravity of 2.8.
Fine aggregate has a specific gravity of 2.6.
Concrete's Target Mean Strength:

$$\overline{f_{ck}} = f_{ck} + (t \times S)$$

$$\overline{f_{ck}} = f_{ck} + 1.65 \times S$$

$$\overline{f_{ck}} = 30 + 1.65 \times 4$$

= 36.6 Mpa

$\overline{f_{ck}}$ = Average target strength of the concrete for 28days
f_{ck} = Characterstic strength of the concrete for 28days
S = sigma(Standard deviation)
t = Assumed as per IS 456-2000 =1.65

Water Cement ratio selection:

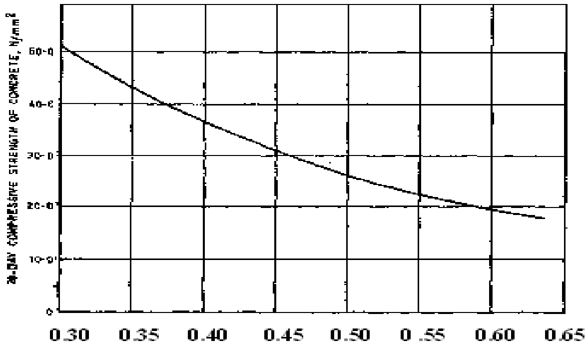


Figure 1.1: Ratio of Water-Cement

Water cement ratio = 0.45(Adopted)

Quantities for M30 design mix are as follows:

Water content = 186lit/m^3
Quantity of cement = 186/0.45
= 413.3kg/m^3
River sand (fine aggregates) = 660kgs/m^3
20mm and 12mm aggregates = 1166kgs/m^3

Table 1.5: Proportion of mix materials in mix design per m^3

Sl. No.	Grade of concrete	Cement (kg)	Sand (kg)	Coarse aggregate of 20 -12 mm	Water Liters
1	M 30	413	660	1166	186

Proportion of mix for M30 mix as per design is – 1:1.49:3.01

Testing on fresh concrete:

The following are the specific tests that can be performed in the field and in the lab depending on the condition of the concrete.

1. Concrete tests on fresh materials
2. Hardened concrete tests

Fresh concrete, also known as plastic concrete, is a substance that has been freshly mixed and can be cast into any form. The strength of concrete is mainly determined by the cement paste's strength. In other terms, as the amount of cement in the paste increases, the amount of air and water in the paste decreases. If the water/cement ratio is retained, the Abrams water/cement ratio law specifies that the strength of concrete is strictly dependent on the water/cement ratio. Hence it can be clearly understood that the water/cement ratio required from the point of view of workability. Hundred percent compaction of concrete will result in air voids whose damaging effect on strength and durability is equally or more predominant than the presence of capillary cavities. To enable the concrete to be fully compacted with given efforts, normally a higher a higher water/ cement ratio than that calculated by theoretical considerations may be required.

Workable concrete is described as concrete that meets the above specifications. Workability, or workable concrete, has a much broader and deeper definition than the other terminology quality, which is often used interchangeably with workability. Consistency is a concept that refers to the degree of fluidity or mobility.

Concrete is most significant development material which is made at the site and is probably going to have changeability of solidarity from one group to another and furthermore inside the clump. The size of this variety relies upon a few primary components, for example, the variety in the nature of constituent materials, varieties in blend extents due to bunching and blending hardware accessible, the nature of generally workmanship and management at the site, and variety because of inspecting and testing of solid examples.

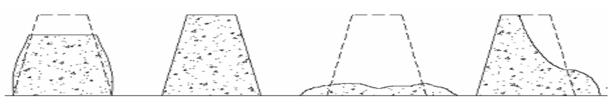
The grading and shape of aggregates even from the same source vary widely. Considerable variations occur partly due to quality of plant available and partly due to efficiency of operation. There are no unique attributes to define the quality of concrete in its entirety. Under such a situation the concrete is generally referred to as being of good, fair or poor quality. This interpretation is subjective. It is therefore necessary to define the quality in terms of desired performance characteristics, economics, aesthetics, safety and other factors. Due to large number of variables influencing the performance of concrete, the quality control is an involved task. However, it should be appreciated that the concrete has mainly to serve the dual needs of safety (under ultimate loads) and serviceability (under working loads) including durability. These needs vary from one situation and one type of construction to another. Therefore, uniform standards valid for general application to all the works may not be practical. It should be noted that the usual 28 day cube tests are not the quality control measures in the strict sense; they are in fact the acceptance tests. In situations of site production and placing, the quality of the concrete is to be controlled way ahead of the stage of testing cubes at 28days.

The aim of the quality control is to reduce the above variations and to produce uniform material which provides the characteristics desirable for the job envisaged. Thus the quality control is co-operate, dynamic program me to assure that all the aspects of materials, equipment and work man ship.

Slump test:

The slump test is the most commonly used and well-known way of determining the workability of fresh concrete. On work sites, the low-cost accuracy test is used to quickly decide if a concrete batch should be approved or refused. The test procedure is universally accepted all over the world.

A mould in the form of a frustum of a cone with a base diameter of 8 inches, a top diameter of 4 inches, and a height of 12 inches makes up the apparatus. Three equal-volume layers of concrete are poured into the mould. Each layer is compacted with 25 tamping rod strokes. The slump cone mould is raised vertically and the difference in concrete height is weighed. As seen in Figure 3, there are four different forms of slumps. The only form of slump permitted by ASTM C143 is the "real" slump, in which the concrete stays intact and maintains a symmetrical structure. Both a zero slump and a collapsed slump fall beyond the spectrum of workability that the slump test can detect. ASTM C143 specifically urges discretion when interpreting test findings that are less than 12 inch and greater than 9 inch. If a portion of the concrete shears away from the mass, the test must be replicated with a new concrete sample.



Four Types of Slump

The procedure of test in brief is as follows: -

- Using three layers of concrete, fill the frustum of a steel cone.
- Each layer of concrete should be tap 25 times by using 16mm dia of steel rod
- Slump cone dimensions were 200mm dia at base,100mm dia at top and the height of cone is 300mmdia.
- Raise the cone without using lateral or torsion motions.
- Immediately calculate the difference in height between the mould and the highest point of the specimen being tested.
- Slump checks that shear or fail must be replicated.

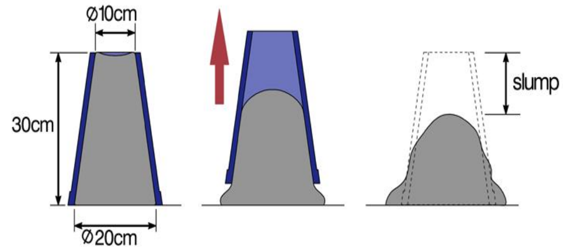


Figure 1.2: pictorial representation of slump test

Hardened concrete tests

For testing concrete in hardened state, it is required to cast the various moulds like cubes, beams and cylinders. It is cured for the required period after 24 hrs of casting.

The most critical parameter of reinforced concrete is its compressive power, which is almost a proxy for its overall consistency. It is mostly determined by the mix's water/cement ratio, as well as curing and age after casting. Concrete's compressive strength is measured by using a compression measuring machine to analyse cylindrical or cubical specimens of concrete at different ages, such as 7 days,14days and 28days.

During mix proportioning, a compressive strength test is performed to determine the consistency of concrete cast on site.

Concrete's tensile strength and compressive strength are considered to be comparable. A flexure test on beam specimens or a split cylinder test on cylindrical specimens was used to assess it. The tensile strength of concrete is determined to demonstrate how a porous substance like concrete has very low strength due to its very strong compressive strength, despite the fact that it is of little functional significance.

Table 1.6 Compressive, Split tensile strength specimen dimensions

S.no	Type of Specimen	Specimen dimensions in mm
1	Cube	150 X 150 X 150
2	Cylnder	300mm length and 150mm diameter

After 7 and 28 days, experiments are conducted by casting cubes, beams, and cylinders from representative concrete samples.

Compressive strength of concrete test:

- Concrete's primary purpose is to withstand compressive loads.
- The three kinds of compression test specimens used to assess compressive strength are cubes, tubes, and prisms.
- In this project, regular 150 X 150 X 150 mm cubes are used..

The specimens are cast in the following order:

- Oil is added to the mould for lubrication.
- Concrete is laid in a sheet in the mould up to a certain height and compacted using a tamping rod.
- The concrete is laid in three layers in this manner, and the process is repeated.
- Vibration on a vibrating system is the next step.
- – the work The technique is the same with all blends with varying admixture substitution percentages.
- For a total of 28 days, the cubes are healed.
- The cubes are tested in a Compression Testing Machine after 28 days of curing (CTM).

Figure-1.3 After testing of cube

Testing of cubes by using Compressive strength machine:

`PARTICULARS	7 DAYS	14 DAYS		28 DAYS
100% METAKAOLIN	5.2	6.8		7.6
100% RHA	7	12		19
80%RHA+20%MK	18.6	24.3		27
70%RHA+30%MK	22	26.9		33.75
60%RHA+40%MK	20.4	24.2		31.45

The compression test is carried out in accordance with IS: 516-1959. A compression-testing unit with a size of 2000KN was used to test all of the concrete specimens. Crushing power of concrete is measured by applying a load at a rate of 140kg/sq.cm/minute to concrete cubes with dimensions of 150mm x 150mm x 150mm before the specimens collapse. The maximum load applied to the specimens was reported, and the compressive strength was determined by dividing the failure load by the region of the specimen. The effects of different factors on compressive intensity was investigated. Figure 4 shows a compression-testing unit with a size of 2000KN and a specimen.

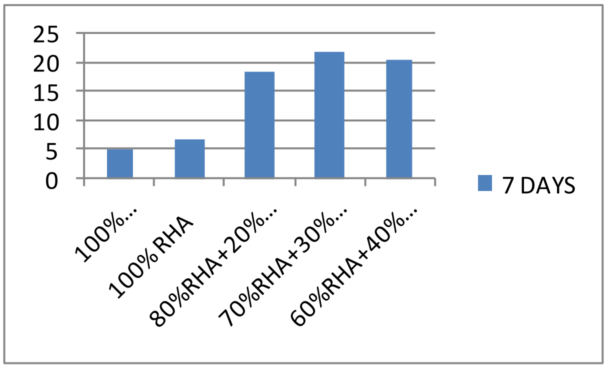
$$\text{Compreesive strength} = (\sigma_b) = \frac{Load}{Area} \text{ in N/mm}^2$$

The method for calculating the compressive strength of concrete specimens is covered in this article. The tests must be performed at known ages for the test specimens, the most common being 7 and 28 days. If checks at older ages are expected, the ages of 13 weeks and one year are preferred. When obtaining early strengths is required, tests can be performed at the ages of 24 hours 12 hours and 72 hours 2 hours. The ages must be determined from the moment the dry ingredients are added to the bath. Specimens contained in water must be checked as soon as possible after being removed from the water and when still warm. Surface water and gravel must be separated from the specimens, as well as any projecting fins. Specimens must be stored in water for 24 hours after being obtained dry before being tested. Until processing, the specimens' measurements and weight must be recorded to the nearest 0.2 mm.

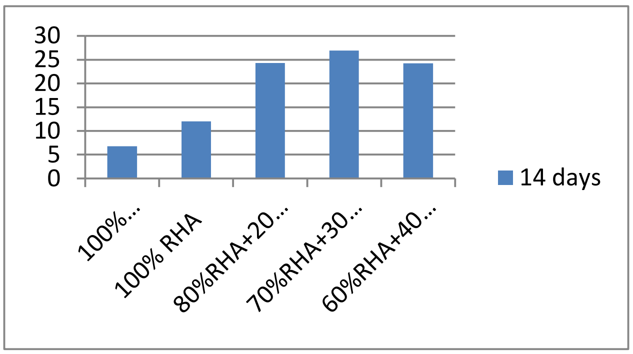
Compressive strength Results

The different results obtained for concrete are listed below, with the values tabulated.

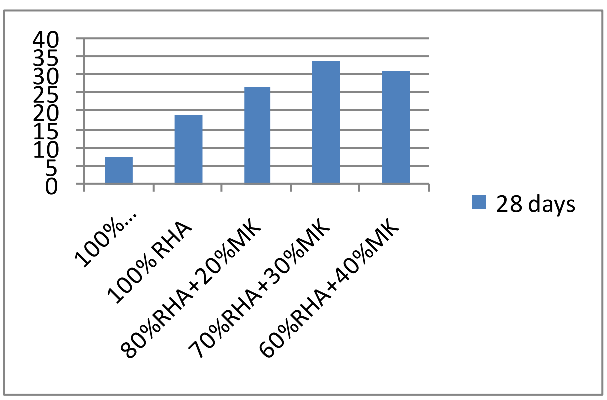
Table: 1.7: compressive strength of Metakaolin and RHA for 7 and 14 and 28 days.



Graph :1 Graph showing the Strength parameters for 7days Specimens



Graph: 2 Graph showing the Strength parameters for 14days Specimens



Graph :3 Graph showing the Strength parameters for 28days Specimens

SPLIT TENSILE STRENGTH OF CONCRETE TEST:

One of the most fundamental and essential properties of concrete is its tensile strength. Because of its porous composition, concrete is not normally able to withstand direct stress. The tensile strength of concrete, on the other hand, must be determined in order to determine the stress at which the concrete member can break. Tension collapse is a form of cracking.

Other methods for determining the tensile strength of concrete, apart from the flexure measure, can be narrowly defined as follows:

a) Direct method
b) Indirect method

The direct approach has a variety of drawbacks, including keeping the specimen correctly in the measuring machine without causing stress accumulation and applying a uniaxial tensile load to the specimen that is free of eccentricity.

Since the concrete is unstable under compression, even a slight eccentricity of load will create a combination bending and axial force condition, and the concrete will collapse at a stress greater than its tensile strength.

Due to the difficulty of conducting a direct stress evaluation. A variety of indirect methods for determining tensile strength have been developed. In these experiments, a compressive force is applied to a concrete specimen in such a manner that tensile forces form in the specimen, causing the specimen to collapse. The tensile strength of concrete is defined as the tensile stress under which the failure occurs.

`PARTICULARS	7DAYS	28DAYS
100% METAKAOLIN	4.36	6.7
100% RHA	1.25	1.4
80%RHA+20%MK	5.94	8.9
70%RHA+30%MK	6.7	9.5
60%RHA+40%MK	8.1	11.45

The Splitting Tests are well-known indirect tests for measuring concrete's tensile strength, and are also known as break tensile strength.

FIG. 1.4 Testing of cylinders for Split Tensile Strength

This test is performed in a compression-testing system with a capacity of 2000KN by positioning the cylindrical specimen horizontally, with its axis horizontal between the testing machine's plates. The load is applied uniformly and at a constant rate until the vertical diameter splits and failure occurs. The specimens' failure load is registered, and the splitting tensile stress is calculated using the IS: 5816-1970 formula. Figure 5.5 depicts the cylinder splitting. The following equation is used to calculate the concrete's split tensile power.

$$F_t = \frac{2p}{\pi DL} \text{ in N/MM}^2$$

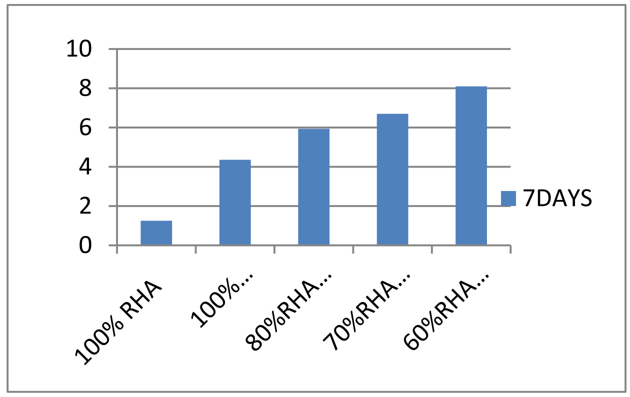
Where p = Compressive load on the cylinder
L is the cylinder's length.
D is the cylinder's diameter.

The data was tabulated, and graphical variations were investigated. The specimen fails by breaking vertically into two pieces due to tensile stress; this measure is also known as the split test.

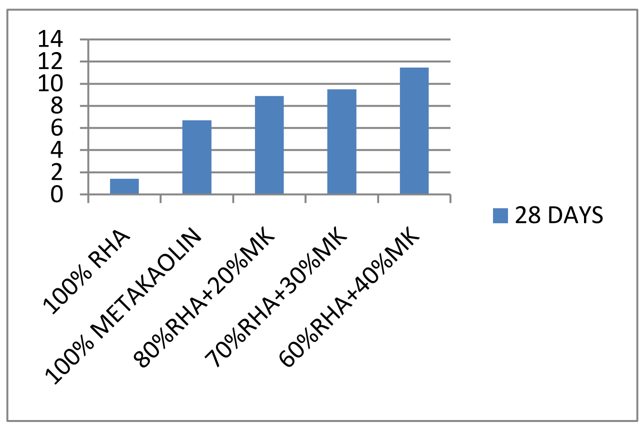
For concrete specimens with a diameter greater than four times the maximum size of coarse aggregate or 150 mm, whichever is greater, the test has been standardised. The specimens' length must not be less than the diameter and must not be greater than twice the diameter. For regular testing, the specimens must be cylinders with a width of 150 mm and a length of 300 mm; for concrete with a gross nominal aggregate size greater than 38 mm, the aggregate sample must be filtered to exclude aggregate with a size greater than 38 mm. Until using, gently grease the mould and the base plate.

The specimen must be prepared and cured in accordance with IS: 516-1959. The specimens should be examined as soon as possible after being removed from the bath. When the specimen is obtained dry, it should be placed in water for 24 hours before being tested. Surface water and grit should be cleaned from the specimens, and any projecting fins from the surface that may be in contact with the packing strips should be withdrawn. The test machine's bearing surface as well as the packing strips must be swept clean. The cylinder should be centred in the measuring unit. The load should be implemented in a non-shocking manner.

Table1.8: Split tensile strength for 7& 28days.



Graph 4: Split tensile strength with % compositions for 7days



Graph 5: Split tensile strength with % compositions for 28days

IV. CONCLUSIONS

Based on limited experimental investigations conducted on concrete the following conclusions are drawn

1. The compressive strength of concrete is found to be very low at 100 percent Metakolin
2. The compressive strength of concrete is found to be very low at 100 percent RHA
3. As varying proportions of RHA and Metakaolin are substituted, the compressive strength of concrete is

found to be optimal at 70% RHA and 30% Metakaolin.

4. At 60 percent RHA and 40 percent Metakaolin material, the split tensile strength of concrete is considered to be optimal.
5. Based on the above findings, geopolymer concrete based on RHA and metakaolin seems to have higher compressive strength than standard concrete.
6. As RHA, Metakaolin, and Alkaline solutions were used instead of OPC, the concrete's strength improved.

V. OBSERVATIONS AND SUGGESTIONS:

1. Based on the results of the above analyses, it can be inferred that RHA and Metakaolin can be used as a cement substitute and provide excellent results in terms of strength and consistency, outperforming the control concrete.
2. It has been used as a complete substitute for cement based on limited research into RHA and Metakaolin.
3. Environmental pollution can be reduced by using RHA and Metakaolin as a filler or substitute in cement.
4. Using RHA and Metakaolin as concrete raises the expense of alkaline solutions thus lowering cement manufacturing costs.
5. The findings revealed that replacing 70 percent RHA with 30 percent Metakaolin resulted in higher compressive strength, higher splitting tensile strength, and improved resilience(durability) properties.

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