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An Experimental Investigation on the Properties of Concrete by Replacement of Cement with Rice Husk Ash

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ABSTRACT: Cement mortar and concrete are the most widely used construction materials. According to the present state-of-the art concrete is not merely the four-component system that is cement, water, fine aggregate and coarse aggregates. Now it is believed that it has many ingredients like fly ash, ground granulated blast furnace slag, silica fumes, rice husk ash, Metakoalin and super plasticizers. One or more of these ingredients can be used in concrete and mortar as the situation demands. The use of pozzolanic material is as old as the art of concrete construction. The use of various pozzolans mixed with OPC in optimum proportions improve many qualities of mortar and concrete in fresh and hardened state. Rice husk ash is an agro waste material. Rice husk ash (RHA) is obtained by burning of rice husk in a controlled manner.This project summarizes the research work on the properties of Rice Husk Ash (RHA) when used as partial replacement for Ordinary Portland Cement (OPC) in concrete. OPC was replaced with RHA by weight at 0%, 5%, 10%, 20%, 30% and 40%. 0% replacement served as the control. Compacting factor test and slump cone test was carried out on fresh concrete while Compressive Strength test and split tensile strength was carried out on hardened concrete cubes after 7, 14 and 28 days curing in water. The results revealed that the Compacting factor decreased as the percentage replacement of OPC with RHA increased. The compressive strength of the hardened concrete also decreased with increasing OPC replacement with RHA.

KEY WORDS: Mortar, Pozzolonic Material, Compressive Strength, Split Tensile strength, Slump Cone Rice Husk Ash, Cement, Compacting Factor, Workability and Concrete.

I. INTRODUCTION

Energy plays a crucial role in growth of developing countries like India. In the context of low availability of non-renewable energy resources coupled with the requirements of large quantities of energy for Building Materials like cement, the importance of using industrial waste cannot be underestimated.

During manufacturing of 1 tons of Ordinary Portland Cement (OPC) we need about 1…1⅓ t of earth resources like limestone, etc. Further during manufacturing of 1 t of Ordinary Portland Cement an equal amount of carbon di-oxide are released into the atmosphere. The carbon-di-oxide emissions act as a silent Killer in the environment under various forms. In this Backdrop, the search for cheaper substitute to OPC is a needful one.

Cement: -

In the most general sense of the word, cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the Romans, who used the term opus caementicium to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cimentum, cäment, and cement.

Cement used in construction is characterized as **hydraulic** or **non-hydraulic**. Hydraulic cements (e.g., Portland cement) harden because of hydration, chemical reactions that occur independently of the mixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble. Non-hydraulic cements (e.g. gypsum plaster) must be kept dry in order to retain their strength.

The problem with Portland cement: -

- **a)** Cement production is the third ranking producer of CO˙ in the world after transport and energy generation.
- **b)** Cement production is responsible for 7-10% of the world's total CO˙ emission and 2% of that produced in the UK (according to the BCA).
- **c)** For every ton of cement produced, approx. 1 ton of CO˙ is produced from chemical reaction and the burning of fossil fuel.
- **d)** The UK produces around 12,000,000 tonnes of cement per annum Cement production is increasing worldwide by approx. 5% per annum.

Rice Husk Ash Properties: -

RHA has the potential as a cheap cementing material since rice husks are essentially waste material having high silica (SiO2) content, highly porous morphology, and lightweight, angular and have a very high external surface area. Its absorbent and insulating properties are useful to many industrial applications, and the ash has been the subject of many research studies. It is estimated that the annual production of paddy rice husk globally was 600 million tons in and with a husk to paddy ratio of 20%, and ash to husk ratio of 18%, therefore the total global ash production could be as high as 21.6 million tons per year and this figure is expected to increase. Consequently, the tremendous amount of cost could be saved by partially replacing OPC with RHA. Rice Husk Ash behaves like cement because of silica and magnesium properties. This silica and magnesium improve the setting of the concrete.

Need for Rice Husk Ash Utilization: -

Rice husk is an agricultural residue which accounts for 20% of the 649.7 million tons of rice produced annually worldwide1.The produced partially burnt husk from the milling plants when used as a fuel also contributes to pollution and efforts are being made to overcome this environmental issue by utilizing this material as a supplementary cementing material. The chemical composition of rice husk is found to vary from one sample to another due to the differences in the type of paddy, crop year, climate and geographical conditions.

From the preliminary waste named as rice husk ash, due to its low calcium is taken out for our project to replace the Cement utilization in concrete. Due to the cement production greenhouse gases are emitted in the atmosphere. For producing 4 million t of cement, 1 million greenhouse gases are emitted. Also, to reduce the environmental degradation, this ash has been avoided in mass level disposal in land. To eliminate the ozone layer depletion, production of cement becomes reduced. For this, the rice husk ash is used as partial replacement in the concrete as high-performance concrete. By utilizing this waste, the strength will be increased and also cost reduction in the concrete is achieved

Objectives: -

To investigate the utilization of Rice Husk Ash as Supplementary Cementitious Materials (SCM) and influence of this rice husk ash on the Strength on concretes made with different Cement replacement levels.

Scope: -

- **a)** To provide a most economical concrete.
- **b)** It should be easily adopted in field.
- **c)** Using the wastes in useful manner.
- **d)** To reduce the cost of the construction.
- **e)** To promote the low-cost housing to the E.W.S. group people.
- **f)** To find the optimum strength of the partial replacement of concrete.
- **g)** Minimize the maximum demand for cement.
- **h)** Minimize the maximum degradation in environment due to cement and safeguard the ozone layer from greenhouse gases & to study the crack development in hardened concrete.

Methodology: -

- **a)** Tested the material properties as per Indian standards code (IS 383 –1996) procedures.
- **b)** Mix design for concrete proportion has been developed as per IS10262 – 1982.
- **c)** Casted and cured the concrete specimens as per Indian standards procedures.
- **d)** The characteristic strength of hardened concrete specimen was tested as per IS 456 – 2000.
- **e)** Finding the optimum strength of optimum replacement of rice husk ash as cement.
- **f)** Compare the results of conventional concrete and partial replacement concrete.

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II. LITERATURE SURVEY

Kartini.K through his experiments encountered that Finding a replacement for cement to assure sustainability is crucial as the raw materials (limestone, sand, shale, clay, iron ore) used in making cements which are naturally occurring are depleting. The raw materials are directly or indirectly mined each year for cement manufacturing and it is time to look into the use of agriculture waste by-products in replacing cement. Rice husk ash (RHA) which has the pozzolanic properties is a way forward. An intensive study on RHA was conducted to determine its suitability. From the various grade of concrete (Grade 30, 40, 50) studied, it shows that up to 30% replacement of OPC with RHA has the potential to be used as partial cement replacement (PCR), having good compressive strength performance and durability, thus have the potential of using RHA as PCR material and this can contribute to sustainable construction.

Dao Van Dong- Doctor, **Pham DuyHuu-** Professor, **Nguyen Ngoc Lan-** Engineer worked on effect of rice husk ash on properties of high strength concrete.The work done by him presents several key properties of high strength concrete using rice husk ashes (RHAs). RHAs obtained from two sources: India and Vietnam were used with various contents to partially replace for cement binder in high strength concrete. Key properties of concrete, including: slump, density, compressive strength, water and chloride permeability resistances, were investigated in comparison between samples without using RHA and samples using two types of RHAs. Experimental results showed reasonable improvements in compressive strength, water and chloride permeability resistances of concrete using the RHAs. The results also presented that the improvements of samples composed the India RHA were much better than that of the Vietnam RHA. The utilization of RHA in concrete can obtain several benefits. On the one hand, it contributes to reduce of agricultural waste that is the main cause of environmental problems in agricultural countries. On the other hand, it is an approach to improve the quality of concrete without using costly additives such as silica fume.

Maurice E. Ephraim, Godwin A. Akeke and Joseph O. Ukpataexperimentally carried out to investigate the effects of partially replacing Ordinary Portland cement (OPC) with our local additive Rice Husk Ash (RHA) which is known to be super pozzolanic in concrete at optimum replacement percentage which will help to reduce the cost of housing. With this research work, the problem of waste management of this agro-waste will be solved.
The specific gravity of RHA was found to be 1.55, the density of RHA concrete was found to be 2.043, 1.912 and 1.932kg/m3 at 10%, 20% and 25% replacement percentages respectively. RHA concrete was found to be very workable with a slump value of over 100mm. The incorporation of RHA in concrete resulted in increased water demand and enhanced strength. The compressive strength values at 28days were found to be 38.4, 36.5 and 33N/mm2 at the same replacement percentages above. These compressive strength values compared favorably with the controlled concrete strength of 37N/mm2at a mix ratio of 1:1.5:3.
Adding RHA to concrete resulted in increased water demand, increase in workability and enhanced strength compared to the control sample. The compressive strength values at 28days were found to be 38.4, 36.5 and 33N/mm2 compared to the control with 37N/mm2. This result show that an addition of RHA from 5-10% will increase the strength and a further addition up to 15- 25%RHA will have a slight reduction in strength of 15% and a decreasing in strength values is pointed out.
Muhammad Harunur Rashid, Md. Keramat Ali Molla, TarifUddin Ahmed have noticed the This paper presents the effects of using Rice Husk Ash (RHA) as a partial cement replacement material in mortar mixes. This work is based on an experimental study of mortar made with Ordinary Portland Cement (OPC) and 10%, 15%, 20%, 25% and 30% of OPC replaced by RHA. The RHA used was obtained from uncontrolled auto combustion of rice husk, in a chamber, without control of temperature and burning time. Sieve no 200 was used to sieved the ash and finally collect the passing ash. The mechanical properties investigated were the compressive strength, and also the porosity of mortar was tested. The obtained results show that the strength and porosity of mortar incorporating RHA were better, up to 20% of cement replacement level.
In the analysis of the result presented in this work, the influence of addition of RHA in the behavior of mortar is quite satisfactory. The use of RHA significantly improves the mortar strength at the 20% replacement level and at the later age. At 30% replacement level of OPC by RHA the porosity of mortar is increased at 28 and 90 days as compared to OPC mortar.

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GhassanAboodHabeeb, Hilmi Bin Mahmud investigated the properties of rice husk ash (RHA) produced by using a ferro-cement furnace. The effect of grinding on the particle size and the surface area was first investigated, then the XRD analysis was conducted to verify the presence of amorphous silica in the ash. Furthermore, the effect of RHA average particle size and percentage on concrete workability, fresh density, superplasticizer (SP) content and the compressive strength were also investigated. Although grinding RHA would reduce its average particle size (APS), it was not the main factor controlling the surface area and it is thus resulted from RHA's multilayered, angular and microporous surface. Incorporation of RHA in concrete increased water demand. RHA concrete gave excellent improvement in strength for 10% replacement (30.8% increment compared to the control mix), and up to 20% of cement could be valuably replaced with RHA without adversely affecting the strength. Increasing RHA fineness enhanced the strength of blended concrete compared to coarser RHA and control OPC mixtures.

III. TESTS ON MATERIALS

The materials used in this investigation include: -

1) Cement
2) Fine Aggregate
3) Coarse Aggregate
4) Rice husk Ash

Table 1. Physical properties of cement

S.No	Type of Test	Result
1	Fineness	2.59%
2	Standard consistency	26%
3	Specific Gravity	3.09
4	initial setting time (min)	49 mins
5	Final setting time (min)	295 mins

Table 2. Physical properties of Fine Aggregates

S.No	Type of Test	Result
1	Moisture content	2.07
2	Fineness Modulus	2.68% (Z-II)
3	Specific gravity	2.71
4	% of Water Absorption	2.78%
5	Silt content	2.75%

Table 3. Physical properties of RHA

S.No	Type of Test	Result
1	Fineness Modulus	1%
2	Specific Gravity	3.07

Table 4. Physical properties of Coarse Aggregates

S.No	Type of Test	Result
1	Water Absorption	1.59
2	Specific Gravity	2.64

IV. MIX DESIGN FOR M30 GRADE

Mix Proportions for One Cum of Concrete (SSD Condition)		
1	Mass of Cement in kg/m^3	380
2	Mass of Water in kg/m^3	160
3	Mass of Fine Aggregate in kg/m^3	711
4	Mass of Coarse Aggregate in kg/m^3	1283
	Mass of 20 mm in kg/m^3	924
	Mass of 10 mm in kg/m^3	359
5	Mass of Admixture in kg/m^3	1.90
6	Water Cement Ratio	0.42

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V. EXPERIMENTAL WORK

A) TESTS ON FRESH CONCRETE:

1. Slump Cone Test

This test is used extensively in site all over the world. The slump test does not measure the workability of concrete, but the test is very useful in detecting variations in the uniformity of a mix of given nominal proportions.

The slump test is done as prescribed by IS: 516.The apparatus for conducting the slump test essential consists of a metallic mould in the form of a cone having the internal dimensions as under

Bottom diameter : 200 mm

Top diameter : 100 mm

The mould for slump is a frustum of a cone, 300 mm high. It is placed on a smooth surface with the smaller opening at the top, and filled with concrete in three layers. Each layer is tamped twenty-five times with a standard 16 mm diameter steel rod, rounded at the end, and the top surface is strucked off by means of sawing and rolling motion of the tamping rod. The mould must be firmly fixed against its base during the entire operation; this is facilitated by handles or foot-rests brazed to the mould. Immediately after filling, the cone is slowly lifted vertically up, and the unsupported concrete will now slump – hence the name of the test. The difference in level between the height of the mould and that of highest point of subsided concrete is measured. This difference in height in mm is taken as slump of concrete.

2. Compaction Factor Test:

There is no generally accepted method of directly measuring the amount of work necessary to achieve full compaction, which is a definition of workability. Probably the best test yet available uses the inverse approach: the degree of compaction achieved by a standard amount of work is determined. The work applied includes perforce the work done against the surface friction but this is reduced to a minimum, although probably the actual friction varies with the workability of the mix.The degree of compaction, called compacting factor, is measured by the density ratio, i.e. the ratio of the density actually achieved in the test to the density of the same concrete fully compacted.

The test known as the compacting factor is described in IS: 516 and is appropriate for concrete with a maximum size of aggregate up to 40 mm. the apparatus consists essentially of two hoppers, each in the shape of the frustum of a cone, and one cylinder of 15cm and 30cm internal height and internal diameter respectively, the three being above one another. The hoppers have hinged doors at the bottom. All inside surfaces are polished to reduce friction.

B) TESTS ON HARDENED CONCRETE:

1. Compression Test:

Compression test was conducted on 150mm×150mm×150mm cubes. Concrete specimens were removed from curing tank and cleaned. In the testing machine, the cube is placed with the cast faces at right angles to that of compressive faces, then load is applied at a constant rate of 1.4 kg/cm^2/minute up to failure and the ultimate load is noted. The load is increased until the specimen fails and the maximum load is recorded. The compression tests were carried out at 7 days, 28 days and 90 days. For strength computation, the average load of three specimens is considered for each mix. The average of three specimens was reported as the cube compressive of strength.

Cube compressive strength = load / (area of c/s)

2. Split Tensile Strength Test:

The cylinder specimen is of the size 150 mm diameters and 300mm length. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of compression testing machine and the load is applied until failure of cylinder, along its longitudinal direction. The cylinder specimens are tested at 7 days, 28 days and 90 days. The average of three specimens was reported as the split tensile strength.

Split tensile strength = $2P / \pi DL$

Where

P = compressive load on the cylinder.

L=length of the cylinder.

D=diameter of the cylinder.

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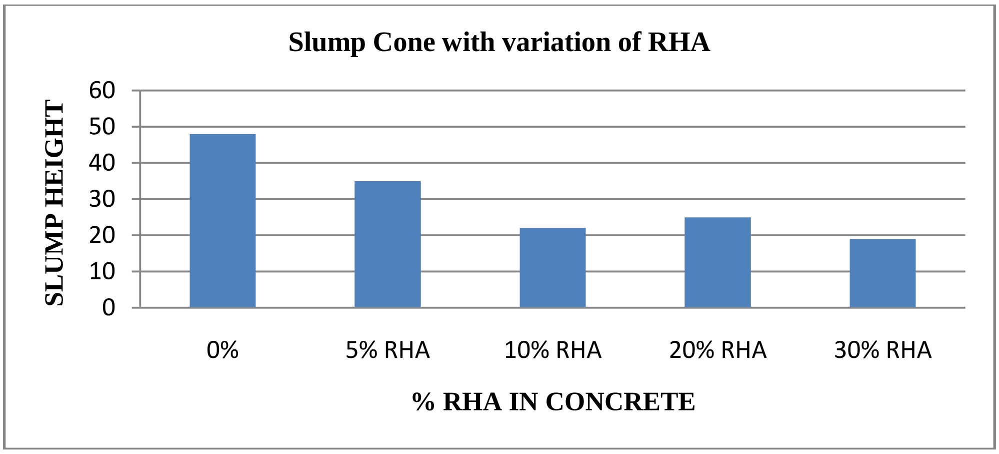
VI. RESULTS AND DISCUSSIONS

A. SLUMP CONE TEST

S.No	Type of Concrete	% of Replacement	Slump Height (in mm)
1	Normal concrete	0%	48
2	RHA Concrete	5%	35
		10%	22
		20%	25
		30%	19



Graph 1: slump Cone test results

B. COMPACTION FACTOR TEST

S.No	Type of Concrete	% of Replacement	Slump Height (in mm)
1	Normal concrete	0%	0.85
2	RHA Concrete	5%	0.82
		10%	0.84
		20%	0.83
		30%	0.86

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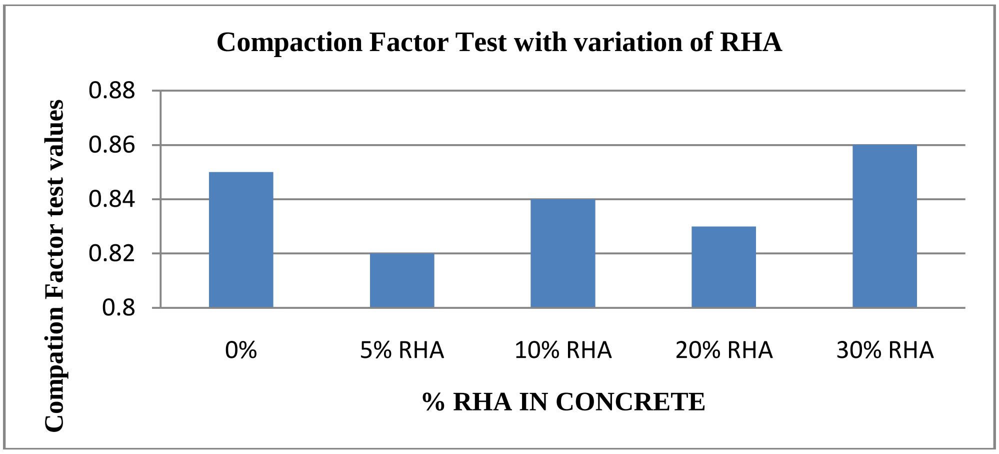

Graph 2: Compaction Factor test results

C. COMPRESSION TEST ON CUBES (150mm X 150mm X 150mm)

The measured compressive strength of the specimen should be calculated by dividing the maximum load applied to the specimen during the test by the cross - sectional area, calculated from the mean dimensions of the section and should be expressed to the nearest kg/sq.cm. An average of three values should be taken as the representative of the batch, provided the individual variation is not more than ±15% of the average. Otherwise repeat tests should be done

S.NO	Type of Concrete	Compressive Strength (MPa)		
		3 days	7 days	28 days
1	Normal concrete	23.5	27	37
2	5%	20.5	25.4	37.52
3	10%	22.5	28	37.3
4	20%	22	26.5	37.6
5	30%	20	25.85	34.3

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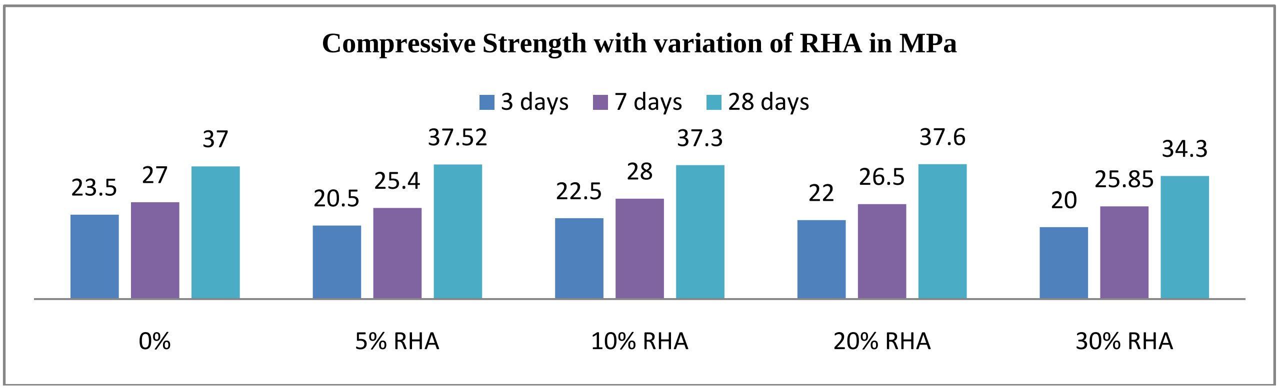

Graph 3 :Compressive Strength with variation of RHA

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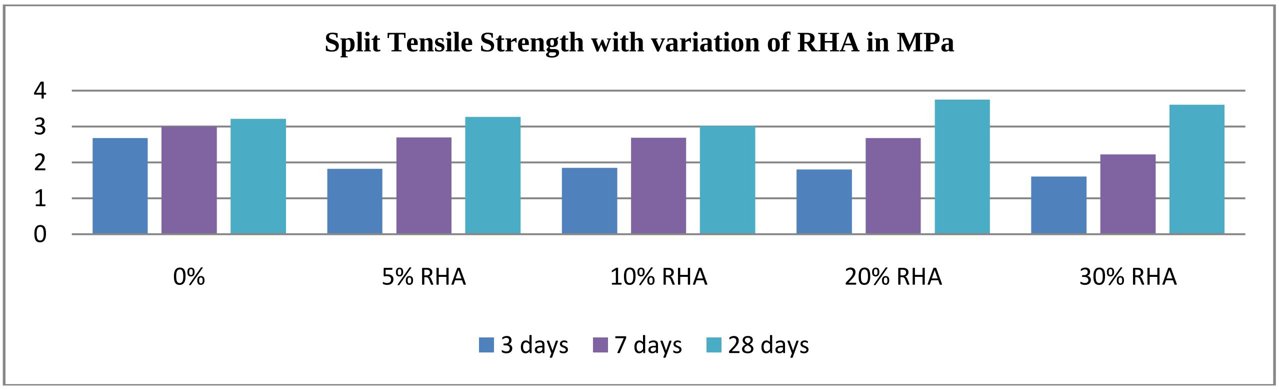
D. SPLIT TENSILE STRENGTH

The measured split tensile strength of the specimen should be calculated by dividing the maximum load applied to the specimen during the test by the cross - sectional area, calculated from the mean dimensions of the section and should be expressed to the nearest kg/sq.cm. An average of three values should be taken as the representative of the batch, provided the individual variation is not more than ±15% of the average. Otherwise repeat tests should be done.

S.NO	Type of Concrete	Split Tensile Strength (MPa)		
		3 days	7 days	28 days
1	Normal concrete	2.68	3.0	3.21
2	5%	1.82	2.7	3.27
3	10%	1.85	2.69	3.02
4	20%	1.8	2.68	3.75
5	30%	1.61	2.22	3.61



Graph 4: Split Tensile Strength with variation of RHA

VII. CONCLUSION

- For compressive strength 10%, 20% and 30% of RHA is suitable
- The acceptable content is 20% to replace for cement with an acceptance of reduction in compressive strength. The optimum replacement of OPC with RHA taken at 28 days strength for Grade 30 and Grade 40 was 30%, while for Grade 50 was 20%
- %. Replacement of OPC with RHA reduced the water permeability of the concrete. Thus, suggested that the presence of RHA in the mix and with concrete of higher grade, the coefficient of permeability reduces, thus improves the durability of concrete.
- The RHA used in this study is efficient as a pozzolanic material; it is rich in amorphous silica (88.32%). The loss on ignition was relatively high (5.81%). Increasing RHA fineness increases its reactivity
- The water absorption values of RHA concrete are lower than the OPC control concrete

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