Optimization of Low-Carbon Concrete Developed With Rice Husk Ash Under Severe Hydrochloric Acid Environments

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Abstract- *Ordinary Portland Cement (OPC) is the most heavily consumed man-made material on Earth. However, this massive scale comes with a severe environmental penalty: The 1:1 Carbon Ratio: As a rule of thumb in material science, manufacturing 1 ton of OPC releases approximately 0.8 to 1.0 ton of Carbon dioxide directly into the atmosphere. The cement industry alone is responsible for roughly 7% to 8% of all global carbon dioxide emissions and also Cement manufacturing is a highly energy-intensive process, requiring temperatures up to 1450°C inside the rotary kiln. This works presents a comprehensive experimental investigation into the mechanical characterization and acid-resistance kinetics of sustainable binary blended concrete incorporating agro-waste Rice Husk Ash (RHA) as a partial replacement for Ordinary Portland Cement (OPC). To evaluate the structural and durability performance, cement was substituted with RHA at varying dosages ranging from 0% to 25% at increments of 5%.*

M35 grade concrete mixes were designed in accordance with IS 10262 guidelines, keeping a constant water-binder ratio. Mechanical evaluation was conducted via compressive, split-tensile, and flexural strength tests at 7 and 28 and 56 days of curing. The core focus of this study centers on the durability kinetics of the blended matrix when subjected to aggressive chemical environments. Concrete specimens were fully immersed in a 5% Hydrochloric Acid (HCl) solution for exposure durations of 7, 28 and 60 days.

Keywords: Rice husk ash, workability, compressive strength, split tensile strength test, water absorption test, Durability studies.

I. INTRODUCTION

In the last decades, environmental sustainability has become one of the most important issues. Cement is the most important ingredient of the concrete which produces carbon dioxide which is May harmful. So it is a main concern to reduce the usage of cement. The increase in price of the cement not only will increase the budget of a construction however additionally poses a significant threat to the country’s development. it's known that some industrial waste product like nano silica are having some building material and silicious properties. So the use of the commercial and agricultural wastages in concrete part as cement replacement, scale back the price of constructing concrete, additionally causes improvement within the properties of concrete

Cement is the most important ingredient of the concrete which produces carbon dioxide which is May harmful. So it is a main concern to reduce the usage of cement. The increase in price of the cement not only will increase the budget of a construction however additionally poses a significant threat to the country’s development. It’s known that some waste product like nano silica and Rice husk ashare having some building material and siliceous properties. The impact of carbon dioxide emission due to production of Portland cement can be reduced by partial replacement of cement with supplementary cementitious materials. Nano silica and Rice husk ashlike waste materials comprise pozzolanic properties but their disposal is causing acute environmental setbacks. Rapid industrial expansion produces severe difficulties all around the world, including as the depletion of natural resources and the creation of vast amounts of waste materials throughout the manufacturing, construction, and demolition stages; one option to mitigate this problem is to utilize wastes.

The impact of carbon dioxide emission due to production of Portland cement can be reduced by partial replacement of cement with supplementary cementitious materials. Rice husk ashis industrial waste materials comprise pozzolanic properties but their disposal is causing acute environmental setbacks. The utilization of industrial and agricultural waste product in concrete has been a major step on waste reduction. Rice husk ashcan be effectively used in concrete as partial replacement of cement because of their high content of silica and pozzolanic properties which plays an important role in achieving high strength and durability in concrete.

This works presents a comprehensive experimental investigation into the mechanical characterization and acid-resistance kinetics of sustainable binary blended concrete incorporating agro-waste Rice Husk Ash (RHA) as a partial replacement for Ordinary Portland Cement (OPC). To evaluate the structural and durability performance, cement was substituted with RHA at varying dosages ranging from 0% to 25% at increments of 5%.

M35 grade concrete mixes were designed in accordance with IS 10262 guidelines, keeping a constant water-binder ratio. Mechanical evaluation was conducted via compressive, split-tensile, and flexural strength tests at 7 and 28 and 56 days of curing. The core focus of this study centers on the durability kinetics of the blended matrix when subjected to aggressive chemical environments. Concrete specimens were fully immersed in a 5% Hydrochloric Acid (HCl) solution for exposure durations of 7, 28 and 60 days.
The objective of the present study was to investigate experimentally the properties of Concrete with the following test results

1. Workability
2. Compressive strength
3. Flexure strength
4. Tensile strength
5. Acid resistance test

II. REVIEW OF LITERATURE

Considering above background, an experimental investigation was carried out to consider the both types and amount of contents of different types of cement and sand replacement materials on the properties of concrete. A lot of work has been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. Literature review of Rice husk ashand concrete exposure to severe acidic environment is presented in the following sections.

Deb, P. S., Nath, P., & Sarker, P. K. (2014): Ground granulated blast furnace slag (GGBS) with mixture of flyash content showing huge improve in the consequences of workability and high strength contrasted with Ordinary Portland Cement (OPC). By changing dissimilar (0%,10% and 20%)contents of Ground granulated blast furnace slag (GGBS) with various proportions of flayash content showing a few blemishes, One of them is with increment in GGBS content workability is diminishing simultaneously strength is expanding. By keeping up silicates to alkaline proportions of 1.5 to 2.5 and following ACI 318 and AS 3600 codes for curing we can accomplish above outcomes when contrasted with OPC.

Junaid, M. T., Kayali, O., Khennane, A., and Black, J. (2015): In this paper he decided the mix proportions geopolymer concrete (GPC) by utilizing Calcium Class F Flay Ash and Alkaline solutions of sodium silicates and sodium hydroxide. For the distinctive mix plans he discovered ideal substance of alkaline fluid to fly ash (AL/FA) proportion, water to geopolymer concrete (W/GPS) proportion and Alkaline to water (AL/W) proportion.

Patankar, S. V., Ghugal, Y. M., and Jamkar, S. S. (2015): Geopolymer concrete is made by utilizing different evaluations of fly ash and consistent sodium hydroxide with 13M focus. In view of experimentation he accomplished the ideal proportions like water to geopolymer (W/GPC) connection of 0.35, Alkaline to fly ash proportion of 0.35, sodium silicate to sodium hydroxide proportion of 1. Later he discovered workability, compressive strength for the plan mix of geopolymer concrete, the outcome came palatable for the above mix plan.

S. M. AlamgirKabir (2015) investigation concerns the use of the optimum mix proportion of two locally available pozzolanic waste materials, namely, ground granulated blast furnace slag (GGBS) and palm oil fuel ash (POFA), together with Rice husk ash(MK) as binders. In addition, another local waste material, manufactured sand (M-sand), was used as a replacement for conventional sand in the development of green geopolymer mortar. Twenty-four mortar mixtures were designed with varying binder contents and alkaline activators. The oven dry curing was also kept consistent for all the mix proportions at a temperature of 65°C for 24 hours. The highest 28-day compressive strength of about 48 MPa was obtained for the mortar containing 20% of MK, 35% of GGBS, and 45% of POFA. The increment of MK beyond 20% leads to reduction of the compressive strength. The GGBS replacement beyond 35% also reduced the compressive strength. The entire specimen achieved average 80% of the 28-day strength at the age of 3 days. The density decreased with the increase of POFA percentage. The finding of this research by using the combination of MK, GGBS, and POFA as binders to wholly replace conventional ordinary Portland cement would lead to alternate eco-friendly geopolymer matrix.

MoslihAmerSalih (2014) focused on producing high strength mortar from the alkali activation of palm oil fuel ash (POFA) blended with GGBS. Compression test was applied to evaluate the mechanical properties, TGA/DTG, and DSC tests were conducted to study the chemical composition of the geopolymeric binding phase. POFA activated with sodium silicate and sodium hydroxide at room ambient temperature. Results showed that 50% of POFA blended with 50% of GGBS was applicable to produce high strength geopolymer mortar with 70 MPa compressive strength at the age of 28 days and 85 MPa at the age of 90 days.

Sunny AJagtap, Mohan N Shirsath, Sambhaji L Karpe (2017) studied the Effect of Rice husk ashon the Properties of Concrete. Environmental issues are playing essential role in the sustainable development of concrete industry. Cement replacement by glass powder in the range 5% to 25% with an interval of 5% is to be studied. It was tested for compressive strength, Split tensile strength and flexural strength at the age of 7, 28 days and compared with the results of conventional concrete. The overall test results shows that Rice husk ashcould be used in concrete as a partial replacement of cement.

Saxena, S. K., Kumar, M., & Singh, N. B. (2018): In this paper he compared results of geopolymer cement with ordinary portland cement in terms of compressive strength, durability test by using sulphuric acid. The geopolymer cement was made by using fly ash, Alkaline Solution (14M NaOH) and Silicate solution (Sodium silicate solution) and also he used alccofine powder which has have similar properties of silica fume. Finally he concluded that compared to OPC this designed mix (geopolymer mix) giving better reliable results than OPC in terms of durability, Compressive strength.

Hadi, M. N., Zhang, H., & Parkinson, S. (2019): In this paper he compared the result of OPC paste vs proposed geopolymer concrete mix. In suggested mix he used ground granulated blast furnace slag (GGBFS) and Class F fly ash (FA) as silicate fount and Instead of using W/C ratio he used , sodium silicate solution to sodium hydroxide solution SS/SH, Aw/Bi ratio & alkaline solution to binder (Al/Bi) ratio in his proposed mix. Finally he concluded that at given alkaline solution to binder (Al/Bi) ratio of 0.5, sodium silicate solution to sodium hydroxide solution (SS/SH) ratio of 2, Aw/Bi of 0.15 & 40% GGBS proposed geopolymer paste given better results in respect of compressive strength, Slump test & setting time.

It has been noted that the sunshine fastness of banana fibre is inferior to cotton. this could be attributed to the impurities gift within the banana fibre within the variety of polymer and therefore the different insoluble matter. The revealed analysis works on flexural plasticity of nylon fiber ferroconcrete beam are studied by several researches few mentioned the influence of nylon fiber issue on flexural plasticity of beam and terminated that plasticity indexes increase with increasing of fiber issue.

D. Patil, Patil&Veshmawala Observed the Performance of Copper Slag as Sand Replacement in Concrete.M30 concrete was used and several tests like compressive, flexural, split tensile strength were taken for different portions of copper slag and sand from 0 to 100%. The outcome showed that workability increases with growth in percentage of copper slag. Maximum Compressive strength of concrete increased by 34 % at 20% replacement of fine aggregate with copper slag, and up to 80% replacement of copper slag, concrete gain more force than normal concrete strength. The flexural strength of concrete found to be increased by 14% with 30% substitution of copper slag.

A.N.Dancygier and Z.Savir studied the influence of nylon fiber on flexural performance of high strength concrete beam with low longitudinal reinforcement magnitude relation, that tried that nylon fiber enhance crispiness of beam compared to it of beam with minimum longitudinal reinforcement magnitude relation. Compared to nylon fiber concrete, the hybrid fiber with completely different kind and size will improve effectively strength and toughness of concrete, kind hybrid result throughout completely different fiber, play various useful influence from completely different level. However, few researches on flexural performance of hybrid fiber strengthened RC beam were studied.

Sasikumar&Tamilvanan Performed an Experimental Investigation on Properties of Silica Fumes as a Partial Replacement of Cement. The main parameters investigated in this study is M30 grade concrete with partial replacement of cement by silica fume0%, 25%, 30%, 40% and 50%. The normal consistency increases about 40% when the silica fume percentage increases from 0% to 25%. The optimum 7 and 28-day compressive strength has been obtained in the 25 % silica fume replacement level. As well the split tensile strength is high when using 25% silica fume replacement for cement.

Ghutke&Bhandari Examine the Influence of silica fume in concrete. Results indicated that the silica fume is a better replacement of cement. The rate of strength gain in silica fume concrete is high. Workability of concrete decreases as increase with % of silica fume. The optimum value of compressive strength can be achieved in 10% replacement of silica fume. As strength of 15% replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage is varying from 10% to 15% replacement level.

III. MATERIALS AND METHODS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

- Cement
- Coarse aggregate
- Water
- Rice husk ash
- Hydro chloric acid solution

1. Cement

Ordinary Portland cement of 43 grades manufactured by Shree Ultratech Cement was used throughout the Experimental investigation. The quality of the cement was confirming to IS 8112:1989 was used in the field.

2. Fine Aggregate

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970.

3. Coarse Aggregate

Coarse aggregate shall be of hard broken stone of granite shall be of hard stone, free from dust, dirt and other foreign matters. The stone ballast shall be of 20mm and down and should me retained in 5mm square mesh and well graded such that the voids do not exceed 42 percent. Aggregate most of which is retained on 4.75-mmIS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

4. Rice husk ash

Rice husk is a potential material, which is amenable for value addition. The usage of rice husk either in its raw form or in ash form is many. Most of the husk from the milling is either burnt or dumped as waste in open fields and a small amount is used as fuel for boilers, electricity generation, bulking agents for composting of animal Manure, etc. The exterior of rice husk are composed of dentate rectangular elements, which themselves are composed mostly of silica coated with a thick cuticle and surface hairs. The mid region and inner epidermis contain little silica Jauberthie et al., confirmed that the presence of amorphous silica Is concentrated at the surfaces of the rice husk and not within the husk itself. The chemical composition of rice husk is similar to that of many common organic fibers and it contains of cellulose 40-50 percent, lignin 25-30 percent, ash 15-20percent and moisture 8- 15 percent.

IV. MIX DESIGN

The property of workability, therefore, becomes of vital importance. The mix design is done as per IS 10262-2009. Percentage dosage of super plasticizer (high range water reducers) is an additional parameter to be considered for designing an OPC mix. Percentage dosage of super plasticizer was fixed as per the mix design method described in IS 10262-2009. Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M35.

V. RESULTS AND DISCUSSIONS

This session provides an outline of the experimental results and endeavors to draw some conclusions. The take a look at result covers the workability, mechanical properties and sturdiness properties of concrete with and while not admixtures. The results of the experimental investigation on Rice husk ash concrete wherever Rice husk ash has been used as partial replacement of cement in concrete mixes. On commutation cement with completely different percentages of Rice husk ash the workability, compressive strength, split tensile strength and flexural strength is studied then to the optimum share of Rice husk ash, keeping Rice husk ash constant acid resistance tests are conducted in HCL solution.

5.1 REPLACEMENT DETAILS

The replacement details of Rice husk ash has been given in the below table. The replacement of cement percentages by 0, 5, 10, 15, 20, and 25% with Rice husk ash varying the cement replacement percentages.

5.2 VARIATION OF SLUMP VALUES FOR PERCENTAGE REPLACEMENT OF RICE HUSK ASH

Slump test is used to determine the workability of concrete. The apparatus used for doing slump test are slump cone and tamping rod. Slump test is used to determine the workability of concrete. The apparatus used for doing slump test are slump cone and tamping rod. This is the most commonly used test of measuring the consistency of concrete. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing neither workability, not it is always a representative of the place ability of the concrete. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. It is performed with the help of a vessel, shaped in form of a frustum of a cone opened at both ends. Diameter of top end is 10cm while that of the bottom end is 20cm, height of the vessel is 30cm, a 16mm diameter and 60cm long steel rod is used for tamping purposes.

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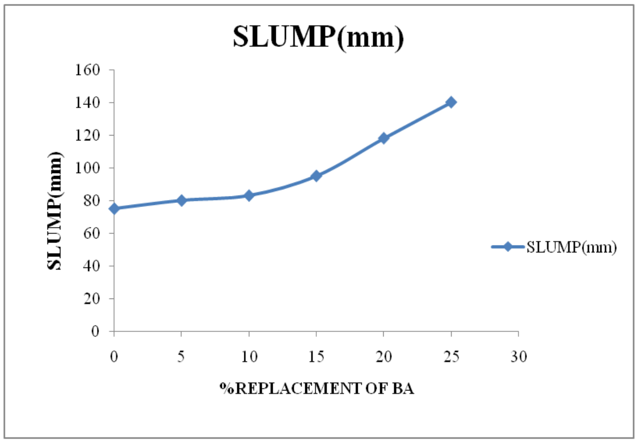
The slump of the freshly mixed concrete was measured by using a slump cone in accordance to ASTM C143. It can be observed from Figure 5.1 that all mixtures have a slump of less than 45mm and are observed that slump values increasing with increase in slag content.

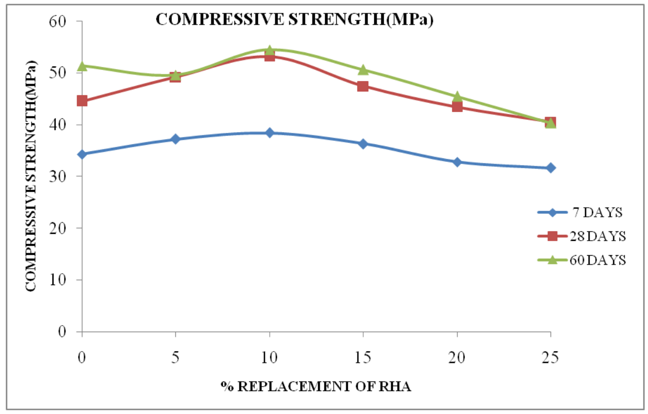


Graph 5.1 Slump vs. % Rice husk ashreplacements

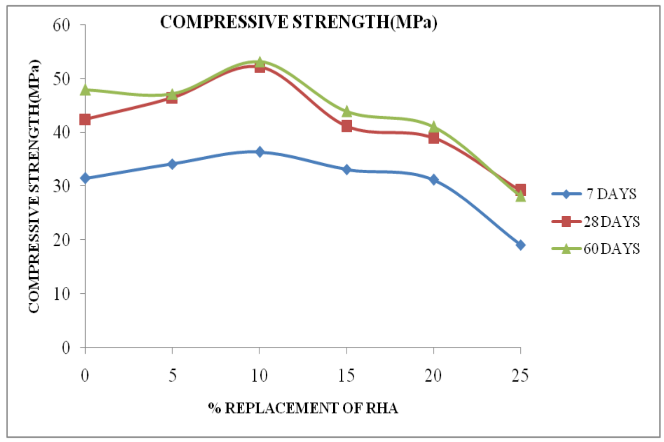
5.3 COMPRESSIVE STRENGTH

The main function of the concrete in structure is mainly to resist the compressive forces. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal.

Cubes are prepared of size 150 mm x 150 mm x 150 mm are checked for compressive strength. The specimens tested for 7, 14 and 28 days. The specimen were tested for compressive strength parallel to the plane of the board by applying increasing compressive load until failure occur. The arrangement of load is applied to the specimen by placing the specimen length vertical between the surfaces of the testing machine.



Graph 5.2 Plot shows the Variation in Compressive Strength For % Replacement of RHA in Normal Water



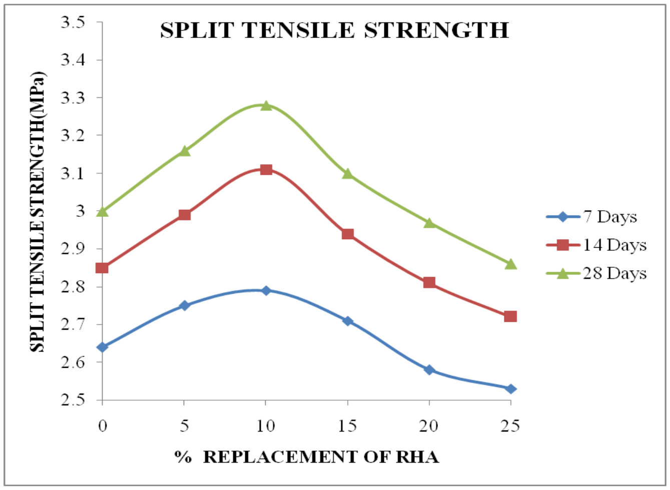
Graph 5.3 Plot shows the Variation in Compressive Strength For % Replacement of RHA in HCL

5.5 SPLIT TENSILE STRENGTH TEST

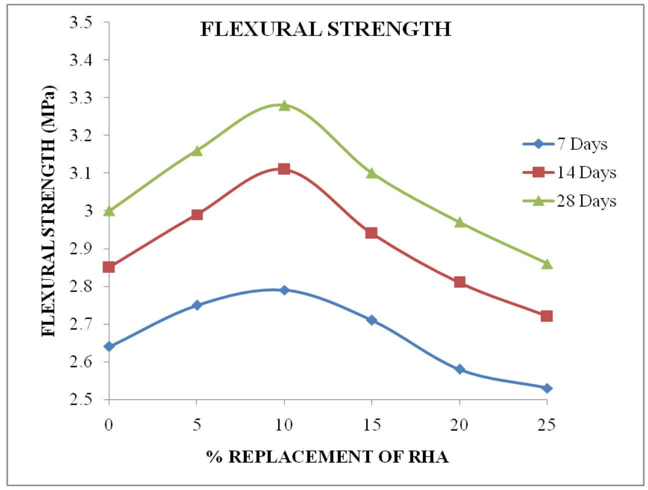
The size of specimens 150 mm dia and 300 mm length was used and the specimens were cured in normal water. Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per as per IS 516 (1959) and IS 5816 (1999).

The Split Tensile strength of the concrete mix for with partial replacement of cement by Rice husk ashshowed higher Strength against splitting after 7 and 28 days for M30 grade.

Compressive stress = $2P/\pi LD \{D^2 / (D-r)-1\}$
Tensile stress $=2P / \pi LD$
Where, P = Compressive load on cylinder
L = Length of cylinder =300 mm
D = Diameter of cylinder = 150mm
r& (D-r) are distance of the element from the two loads respectively.



Graph 5.4 shows the effect of RHA on split tensile strength of concrete



Graph 5.6 shows the effect of RHA on flexural strength of concrete

5.6 FLEXURAL STRENGTH TEST

In the flexural strength test theoretical maximum tensile stress reached at the bottom fibers of the test beam is known as the modulus of rupture. When concrete is subjected to bending stress, compressive as well as tensile stresses are developed at top and bottom fibers respectively. If the largest nominal size of aggregate does not exceed 20mm, the dimension of specimen may be 150mm×150mm×700mm.

$$f = \frac{M}{Z} = \frac{(PL/6)}{(bd^2/6)}$$

$$f_b = \frac{PL}{Bd^2}$$

When ‘a’ greater than 20 cm for a 15cm specimen,

$$f_b = \frac{3Pa}{bd^2}$$

The Flexural strength of the concrete mix for with partial replacement of cement by Silica fume and Cenosphere respectively showed higher Strength against splitting after 7 , and 28 days for M30 grade.

5.7 DURABILITY STUDIES

The durability properties of the concrete mainly depend on its curing age among the other factors. When concrete is exposed to aggressive environment, its durability may get affected. Earlier, people were more concerned about the strength of concrete without thinking about its durability. But at present the durability of concrete and concrete structures has become a major concern. In this experimental study, the effect of hydrochloric Acid on concrete made using Rice husk ashwas investigated. The optimum replacement level of Ordinary Portland Cement (OPC) with Rice husk ashin respect of compressive strength was found.

As the percentage of sugarcane Rice husk ash increases the compressive strength of concrete tends to increase up to certain percentage and then start’s decreasing with the increase of ash content.

The strength of 10% sugarcane Rice husk ash concrete is more than 5% Rice husk ash concrete and strength of 5% Rice husk ash concrete is more than normal concrete. This shows that till 10% sugarcane Rice husk ash concrete the strength increases while percentage of sugarcane Rice husk ash increases.

The strength of cubes having 10% Rice husk ash is almost equal to 15% Rice husk ash concrete.

This increase in strength in Rice husk ash concrete is due to presence of Silica in Rice husk ash. Silica in Rice husk ash reacts with residual CH after the formation of C-S-H gel, and increase the amount of C-S-H gel and results in increase the strength.

VI. CONCLUSIONS

The The Conclusions and Recommendations that could be drawn from the results of this project and experiments are summarized and the use of Rice husk ash as a cement replacing material in concrete production was studied and after the research work is done, the following conclusions were made:

1. Fresh Properties and Workability

- Increase in Slump Value: The workability of fresh M35 concrete, as measured by the slump cone test, increases continuously with higher replacement levels of Rice Husk Ash (RHA).
- Reduced Water Demand: The upward trend in slump values indicates that the incorporation of RHA progressively reduces the net water demand required to achieve identical or enhanced consistency and flow characteristics in fresh concrete.
- Mix Integrity: Within the tested replacement range (up to 25%), the fresh concrete demonstrates good cohesive behavior without exhibiting any adverse signs of segregation or bleeding.

2. Hardened Properties

- Optimum Replacement Level: The optimum replacement level of cement with RHA for maximizing compressive strength is determined to be 10%.
- Strength Enhancement Trend: Under normal water curing, the compressive strength increases steadily up to 10% replacement, outperforming the control mix (0% RHA) across all curing periods (7, 28, and 60 days). For instance, at 28 days, the strength peaks at 10% RHA compared to the control mix.
- Declining Trend Beyond Optimum: Replacement levels beyond 10% (i.e., 15% to 25%) lead to a progressive decline in compressive strength. At a 25% replacement level, the 28-day compressive strength drops below the control line to 40.55 MPa.
- Microstructural Mechanism: The strength enhancement up to the optimum limit is attributed to the high silica content in RHA. The silica chemically reacts with the residual Calcium Hydroxide produced during cement hydration, generating secondary Calcium-Silicate-Hydrate gel, which densifies the concrete matrix.
- The optimal replacement level of Ordinary Portland Cement (OPC-43) with Rice Husk Ash (RHA) for maximizing tensile capacity is precisely 10%. For normal water curing, the 28-day split tensile strength peaks at an expected 3.28 MPa, yielding a 9.3% increase over the 0% RHA control mix (3.00 MPa).
- The rate of flexural strength development between 7 and 14 days accelerates more sharply for the 5% and 10% RHA mixes than the control concrete. The optimum replacement level of cement with RHA for maximizing flexural strength is determined to be 10%.

3. Durability Performance under Severe Acid Attack

- Acid Resistance Peak: Concrete incorporating 10% RHA exhibits the highest resistance to aggressive chemical environments when exposed to severe Hydrochloric Acid solutions.
- Minimal Strength Loss: At the 10% optimum threshold, the percentage reduction in compressive strength due to acid immersion is minimized across all exposure durations:

7 Days: Only a 2.0% decrease in strength (38.4 MPa down to 36.4 MPa).

28 Days: The lowest overall degradation, 0.98% decrease in strength.

60 Days: A minor 1.3% decrease in strength.

- Vulnerability at High Replacements: Lower replacement levels (5%) or higher replacement levels (15% to 25%) undergo more severe degradation under acid exposure. The maximum vulnerability is noted at 25% RHA replacement, where the strength plummets by 12.51% at 7 days , 11.29% at 28 days , and 12.1% at 60 days when subjected to HCl.

4. Final Core Recommendation

- For the development of sustainable, low-carbon M35 grade concrete, an optimal cement replacement level of 10% Rice Husk Ash is recommended. This specific configuration successfully balances enhanced structural load-bearing performance with superior durability and asset life extension in severe acidic environments. noble.

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