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A Study on the Microstructural Characteristics of Cement Mortar Incorporating Rice Husk Ash

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ABSTRACT

This study investigates the structural properties of Rice Husk Ash (RHA) and its potential as a cement substitute. Cement was gradually replaced with RHA (from 0% to 25% in 5% increments) to assess its effects on the mechanical and physical attributes of cement mortar, including microstructure analysis. Tests were conducted on samples cured for 3, 7, and 28 days. It was observed that replacing more than 10% of cement with RHA resulted in a dry mix, hindering proper hydration and leading to decreased strength. Additionally, the consistency of cement increased as the percentage of RHA increased, with the compressive strength peaking at 15% RHA. XRD analysis revealed the presence of quartzite and coesite minerals in RHA, indicating high silica content. Thermal analysis showed weight loss of RHA, and phase transition was examined between 600 and 1000°C using DSC. Microstructure analysis using SEM and EDS was conducted on cured cement mortar with RHA at different intervals.

Keyword: Rice husk ash, cement mortor etc

INTRODUCTION: - Rice Husk Ash (RHA) is a by-product of the rice husk industry, abundantly available in India when rice husks are used as fuel in boilers. Studies have shown RHA to possess significant reactivity with cement and lime, maintaining concrete and mortar's mechanical and durability properties when used as a partial replacement for cement. This positions it as a sustainable substitute material.

Utilizing RHA as an additional cementitious material or non-reactive filler could mitigate environmental impacts, such as air and soil pollution, associated with cement production's CO2 emissions. While complete cement substitution with RHA is unfeasible due to its lack of cementing properties, replacing 10 to 15 percent of cement with RHA is viable. Physical properties of RHA, including surface area, morphology, particle size, and specific gravity, significantly influence the solid mixture's packing state. Moreover, the amount of amorphous silica in RHA affects its chemical characteristics, particularly its interaction with free lime during hydration.

LITERATURE REVIEW

Unlike industrial by-product pozzolanic materials, natural pozzolanic materials are mostly obtained by calcinations at appropriate temperatures. Pozzolans exert both filler and pozzolanic effects on the properties of concrete (Noaman et al., 2019). Rice Husk Ash shows good pozzolanic activity and proves to be a good material to produce blended mortar. (Modani &Vyawahare, 2013) states that the production of cement causeshuge environmental damage due to emission of CO_2. According to (Mosaberpanah &Umar, 2020) Cement production industry is responsible for about 7% of CO_2 emission generated with enormous effect on the environmental appearances apart from high cost. So, in order to decrease this impact partial replacement of cement is necessary.

A partial replacement of cement by reactive Rice Husk Ash reduces the cement production emitted CO_2 (Putranto & Abida, n.d.). Rice Husk is an agro-waste product which on proper burning and treatment can generate high silica rice husk ash. According to investigation conducted by (Askarulyetal., 2020) it was stated that pre-treatment of the Rice Husk with HCl can give SiO_2 with purity ~90.1 - 99.5 wt. %. The husk mainly consists of lignin, cellulose and silica (Thiedeitz&Schmidt,2020).According to (Gautam et al., 2019) The rice husk is an agricultural waste which is obtained from milling process of paddy and approximately 22% of the weight of paddy is rice husk. The waste is used as fuel in producing stream in par boiling process. The25 % the weight of husk is converted into ash which is known as rice husk ash and is again a waste which is disposed.

METHODOLOGY & EXPERIMENTAL STUDIES

Waste rubber tires were collected from landfills, waste collectors, and roadside areas. The tires were collected and sorted based on the required aggregate size criteria. A tire cutting apparatus, as illustrated in Figure, was utilized to slice the discarded tires into aggregates ranging from 22.4 mm to 6.00 mm in diameter (in accordance with IRC-SP20 guidelines).

The results of the sieve analysis clearly demonstrate that the sand meets the specifications outlined in IS 383:2016 for Zone II classification. Additionally, the sand satisfies the grading criteria for mortar according to ARE 2116:1980. The findings of the sieve analysis are presented in Table.

Table-1 Sand Sieve Analysis Results

IS Sieve Designation (as per IS460:1978(Part I))	Cumulative Percentage Passing	Zone II grading limits (as per IS383:2016)	Sand grading Limits For use in mortar (as per IS2116:1980)
10mm	100	100	-
4.75mm	94.8	90-100	100
2.36mm	88.2	75-100	90-100
1.18mm	75.6	55-90	70-100
600um	45.2	35-59	40-100
300um	11.3	08-30	05-70
300um	2.2	0-10	0-15

- **RICE HUSK ASH**

Rice husk ash, a waste by-product from agriculture, is abundant in India and contains high silica content. Due to its pozzolanic properties, it can be utilized as a material to partially replace cement in mortar, serving as a supplementary cementitious material or inert filler. This can reduce production costs while maintaining or enhancing certain mechanical or durability characteristics of the mortar. The rice husk ash used in this study was procured from Baba Traders, a manufacturer and supplier located in Kolkata, West Bengal. According to the manufacturer, the ash was produced by burning rice husk at temperatures ranging from 700°C to 900°C and then sieved through a 90-micron sieve to remove larger un-burnt carbon particles. The specific gravity of rice husk ash was determine during Le-Chatelier flask as apparatus and kerosene oil as medium having density 0.71gm/cc according to IS1727:2004 and the specific gravity was found to be 2.1.

Figure Rice Husk and Rice Husk Ash

- **THERMAL GRAVIMETRIC ANALYSIS**

Thermal Gravimetric Analysis (TGA) is a technique that combines gravimetric analysis with oven drying. It involves observing the weight change of a material as temperature increases. TGA provides insights into physical phenomena like absorption, desorption, and phase transitions, as well as chemical phenomena such as oxidation, reduction, and solid-gas reactions. During the analysis, a finely ground sample is placed in a thermo balance, and its weight is continuously monitored as the temperature rises. The TGA apparatus heats the sample in a specific environment (e.g., N2, air, CO2) while recording data, resulting in a curve known as a thermogram, which shows the percentage weight loss of the sample relative to temperature. Researchers can adjust the heating rate as needed. However, TGA has limitations—it cannot detect chemical or physical changes that do not involve mass change during heating.

Various applications of TGA are-

1)It is employed to examine the sublimation characteristics of materials.

2) It is utilized to investigate the kinetics of reaction rate constants.

3) It is applied to analyze the composition of intricate mixtures.

4) It is utilized to assess the oxidative stability of materials.

5) It is employed in research concerning catalysts.

- **XRF ANALYSIS RESULTS OF RICE HUSK ASH**

XRF analysis was conducted to ascertain the chemical composition of Rice Husk Ash, computed at a temperature of 800°C, and the resulting chemical composition is depicted in the plot. table-

Chemical Compound	Percentage Composition
SiO_2	92.3
Al_2O_3	5.32
Fe_2O_3	3.58
CaO	3.35
MgO	0.89
TiO_2	0.54
P_2O_5	1.28
Na_2O	0.38
K_2O	1.4
MnO	0.72
LOI	2.3

Table Chemical Composition of Rice Husk Ash

- **XRD ANALYSIS RESULTS**

Samples of Ordinary Portland Cement and Rice Husk Ash underwent XRD analysis to identify their chemical composition. Raw data files were acquired from the XRD machine. Subsequently, the results from these raw data images were processed using X'Pert High Score Plus software for refinement and then plotted graphically using Origin Pro software.

- **XRD ANALYSIS RESULTS FOR ORDINARY PORTLAND CEMENT**

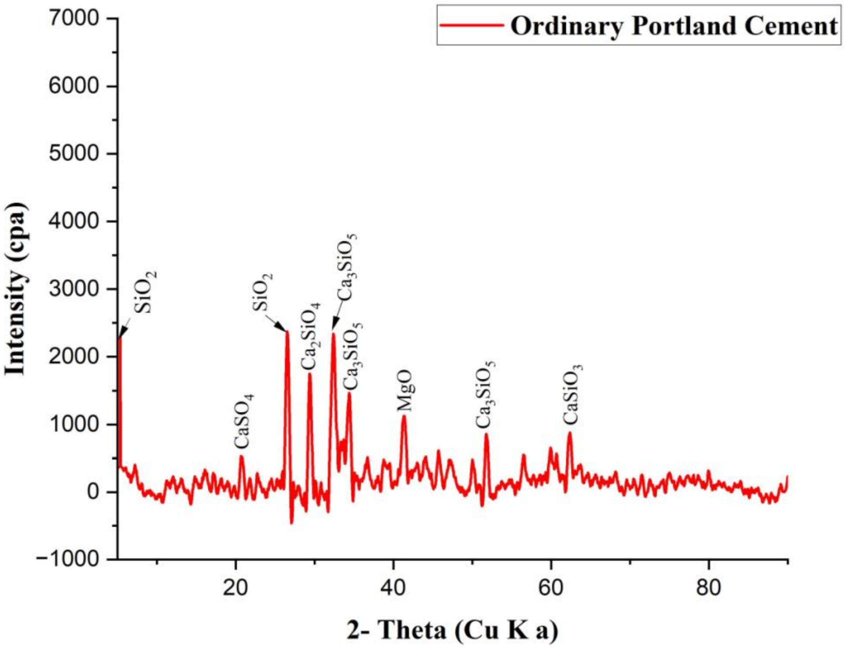

Figure Refined XRD Analysis graph of OPC

To examine the chemical composition of materials, XRD patterns of Ordinary Portland Cement (OPC) were plotted. The sharp peaks on the graph indicate the crystalline nature of OPC. The prominent peaks corresponding to Tri calcium Silicate (C3S - Ca3SiO5), Di calcium Silicate (C2S - Ca2SiO4), and Silica (SiO2) were observed, along with peaks of Gypsum (CaSO4) and Magnesia (MgO).

- **XRD ANALYSIS RESULTS FOR RICE HUSK ASH**

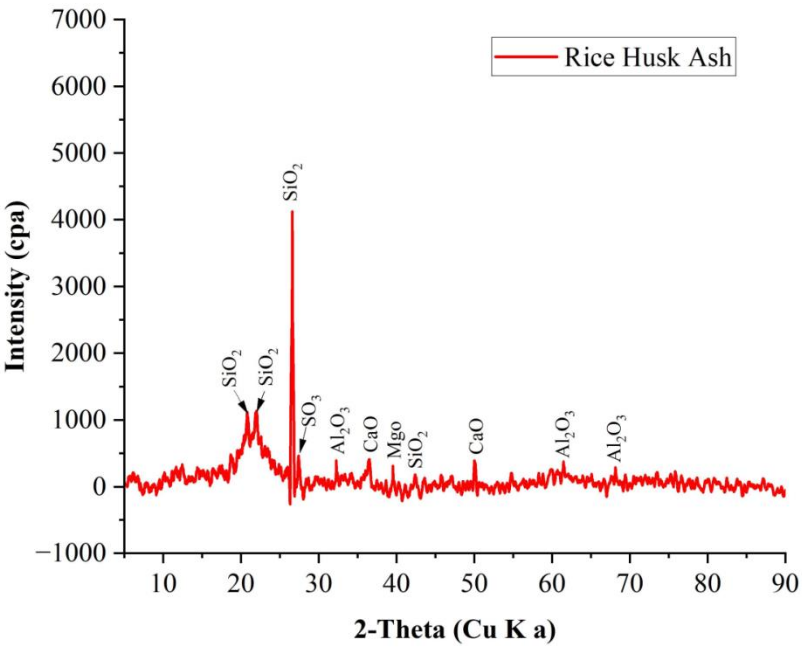

Figure Refined XRD Analysis graph of RHA

To analyze the chemical composition of materials, XRD patterns of Rice Husk Ash were plotted. The sharp peaks on the graph indicate the crystalline nature of Rice Husk Ash. The primary peak corresponding to Silica (SiO2) was prominent, indicating a high intensity of silica compared to other constituents. Additionally, peaks of Lime (CaO), Magnesia (MgO), and Alumina (Al2O3) were also observed. Silica was detected at various diffracted angles and primarily appeared in the forms of coesite, quartz, and tri dymite minerals

➢ **TGA-DSC ANALYSIS RESULTS**

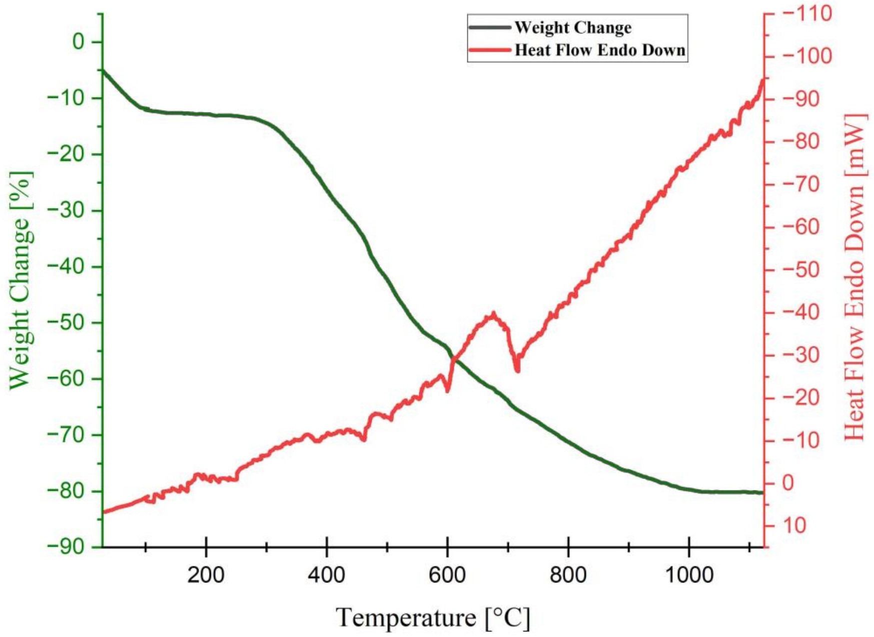

Figure TGA-DSC Curve of Rice Husk

In Figure , thermograms of rice husk are presented, showing three distinct peaks corresponding to stages in decomposition. Initially, there is an endothermic curve followed by an exothermic shift at 200°C. At 500°C, the second peak transitions from exothermic to endothermic. The third peak occurs at 650°C, followed by another exothermic shift. The first weight loss of 10% below 110°C is attributed to absorbed water loss, while the subsequent rapid weight loss of 56% begins above 400°C. At 900°C, the weight loss exceeds 83%. The first peak is followed by a 5% weight loss, representing absorbed water loss. The degradation of cellulose is indicated by the second exothermic peak, followed by rapid weight loss, while the breakdown of cellulose and lignin occurs simultaneously. The third peak shows a continuous decrease in the weight of rice husk due to the ongoing degradation of lignin and other organic components.

CONCLUSION

After thorough investigation, several conclusions have been drawn from this study. During the calcination process of Rice Husk to produce Rice Husk Ash, the silica content increased significantly from 28.12% to 92.30% as determined by X-Ray Fluorescence Technique. Morphological analysis of Rice Husk Ash revealed its porous and soft nature. The primary peaks identified in X-Ray Diffraction analysis were SiO2, Al2O3, and CaO. In Ordinary Portland Cement (OPC), Ca, Si, and O were identified as the main components, whereas in Rice Husk Ash, Si and O were predominant components according to EDS analysis. Thermo Gravimetric analysis of Rice Husk showed a sudden decrease in weight change percentage between 200 and 350°C, followed by a linear trend between 350 and 400°C. Differential Scanning Calorimetry indicated exothermic to endothermic transitions between 600 and 800°C. The highest compressive strength was observed at a 10% substitution level with mortar made from Rice Husk Ash mix with consistent consistency, compared to a 15% replacement level with mortar made from Rice Husk Ash mix in various consistency blends. All blended mixes with different consistencies exhibited higher compressive strength than corresponding blends made with constant water content. As the level of Rice Husk Ash increased in blended mixtures, EDS analysis showed decreasing Ca peaks and increasing silica content peaks.

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