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Analysis Of Durability And Strength Of Concrete Through Partial Replacement Of Cement With Corn Cob Ash And Rice Husk Ash

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Abstract - This study aims to decrease the cement content in concrete by partially substituting it with corn cob ash (CCA). The physical and mechanical properties of the resulting concrete were examined and compared. The research specifically focuses on evaluating the strength properties of M20 grade ordinary concrete containing CCA at different replacement levels and a combination of Corn Cob Ash and Rice Husk Ash (RHA) at a 10% replacement level of cement. Concrete cubes were tested at curing ages of 3, 7, 14, and 28 days. The results indicated that the optimum replacement level for M20 concrete was determined to be 7.5%.

In addition to strength analysis, durability tests were conducted on control mix, 7.5% Corn Cob Ash (CCA-7.5%), and a mixture of 5% Corn Cob Ash and 5% Rice Husk Ash (CR-10%) after a 28-day curing period. The compressive strength values for the control mix, CCA-7.5%, and CR-10% were found to be 27.51 N/mm², 26.73 N/mm², and 28.15 N/mm², respectively. Durability assessments were carried out using phenolphthalein and Silver Nitrate tests to determine carbonation and free chloride content in both conventional and modified concrete. The results indicated that corn cob ash and corn cob-rice husk ash can be utilized in lightweight load-bearing structures up to the specified replacement level of cement in concrete

Key Words - Corn Cob Concrete, Carbonation, Compressive strength, Free Chloride

1. INTRODUCTION

The increasing global population has led to a growing demand for concrete as a means of providing accommodation. However, the production of cement, which is a key component of concrete, releases significant amounts of carbon dioxide into the atmosphere, contributing to the greenhouse effect [10]. To address this issue, there is a need to optimize cement consumption and minimize its rate of use. Additionally, the disposal of agro waste ash generated by industries has become an environmental concern. An environmentally sustainable solution is to utilize agro waste ash, such as Rice Husk Ash, Corn Cob Ash, Bagasse Ash, Coconut Ash, Sunflower Seed Husk Ash, Groundnut Husk Ash, and others, as supplementary cementitious materials. This approach not only helps reduce the cost of concrete production, given the rising costs of cement, but also tackles the challenge of disposing of large volumes of agro waste.

The utilization of ash as a supplementary material brings both ecological and economic benefits to the world. By improving concrete technology and incorporating supplementary cementitious materials, we can alleviate the burden on natural resources and reduce environmental pollution. Maize, also known as corn, is the third most widely cultivated crop globally. In 2017, its production reached 380 million tons, accounting for 24% of total cereal production, with wheat at 27% and rice at 24% [1]. In India, Karnataka is the largest producer of corn. Corn cobs, which are the innermost cylindrical portion of the plant, can be obtained by removing the corn kernels from the upper part. These thick cylindrical cores are cut into pieces and dried for approximately one week. The resulting dried corn cobs can be used directly or crushed to serve as fuel in various industries. Burning approximately 1000 grams of dry corn generates 150 grams of corn cobs ash, 220 grams of leaves, and 500 grams of shoots. However, the composition of these by-products may vary across samples due to differences in crop type, timing, climate, and geographical conditions [1, 16].

2. LITERATURE REVIEW

According to a study by Adetogun et al. (2013), the combustion properties of briquettes made from maize cob of different particle sizes were investigated. The results showed that larger particle sizes, specifically 6.30, had higher energy values of 24.97 and a higher percentage of volatile matter (62.91), along with a moderate ash content [2]. Mitchual et al. (2013) examined briquettes made from maize cobs and Ceiba pentandra sawdust at room temperature and low compacting pressure without a binder [14]. Ikelle et al. (2014) conducted a study on the heating ability of coal and corn cob briquettes. The test revealed that a 60:40 proportion of coal and corn cob provided optimal combustibility compared to other ratios of briquettes [5].

P. Suwanmaneechot et al. (2015) investigated the improvement, characterization, and use of waste corn cob ash (CCA) in cement-based materials in Thailand. The study concluded that partial replacement of cement with CCA can enhance compressive strength, particularly with CCA and CCA600 [9]. Antonio Price et al. (2014) examined the effects of CCA on Portland cement (PC) concrete. The results showed that a 10% replacement of CCA with cement had no adverse effects on the structural properties of ordinary Portland cement (OPC), while improving compressive strength, workability, and reducing thermal conductivity of the concrete mixture.

Owolabi T.A. et al. (2015) investigated the effect of CCA as a partial replacement for cement in concrete in Nigeria. The results indicated that the workability of CCA concrete decreased with an increase in CCA content [12]. Ndububa et al. (2015) described the effect of Guinea Corn Husk Ash (GCHA) as a partial replacement for cement in concrete in Nigeria. The compressive strength and density were found to decrease with an increase in GCHA percentage, except for the 5% replacement level, which exhibited values of 25.5 N/mm^2 and 2432 Kg/cm^2, respectively, at 28 days. The study indicated that GCHA exhibited favorable pozzolanic qualities [11]. Adesanya et al. (2010) investigated the permeability and acid attack resistance of corn cob ash blended cement at replacement levels ranging from 0% to 25%. The results indicated that at a 15% replacement level, there was a reduction in permeability and weight loss, indicating increased resistance against HCl and H_2SO_4 [1]

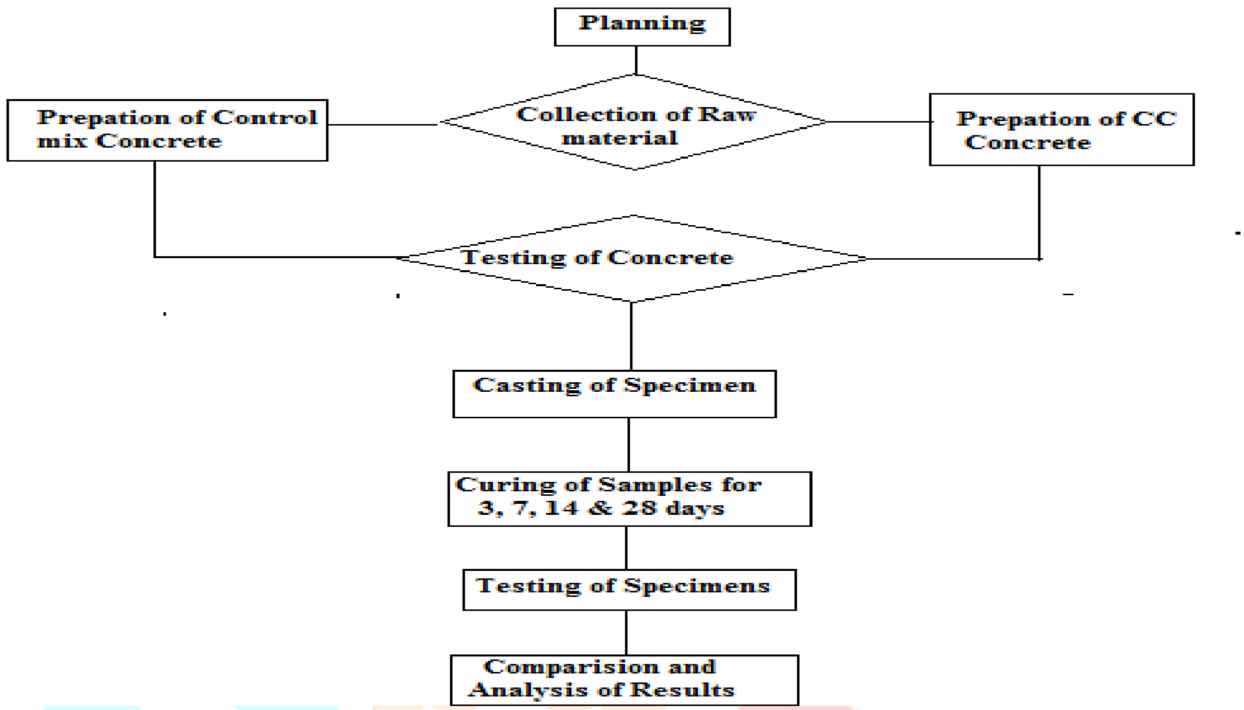
3. OBJECTIVES

The objective of the present study is –

To investigate the suitability of Corn Cob Ash (CCA) as pozzolanic material for partial replacement of Cement.

To study the durability of modified concrete at optimum level of corn cob ash and rice husk ash (CR).

4. Methodology



5. EXPERIMENTAL WORK

5.1 Material

5.1.1 Cement

For the experimental work, Ordinary Portland cement (OPC) of 43 grade from the Wonder brand was used. Various tests were conducted to determine its properties, including specific gravity, consistency, initial setting time, and final setting time. These test values were compared with the permissible limits specified in IS code 10262:2009. The cement exhibited an initial setting time of 190 minutes and a final setting time of 345 minutes. The specific gravity of the cement was measured to be 3.18.

5.1.2 Aggregates

Fine aggregates were obtained from locally available sand of zone-II. Coarse aggregates were crushed angular stones. Physical property tests such as specific gravity, fineness modulus, sieve analysis, and moisture content were conducted on both types of aggregates.

Material Specific Gravity Fineness Modulus Moisture Content

Fine aggregates 2.69 2.64 1.647

Coarse aggregates 2.703 2.89 1.377

5.1.3 Corn Cob Ash & Rice Husk Ash

Corn cobs were collected from nearby villages in Sonepat. After removing the corn kernels, the cobs were broken into small pieces and dried in the sun for one week. The dried corn cobs were then burned in an open-air furnace at a controlled temperature of 900°C. The resulting ash was cooled down for two days and then ground to a fine powder using a miller. The ash was sieved through a 90-micron sieve. The specific gravity of the corn cob ash was determined to be 1.937.

Rice husk ash was obtained from a chemical industry. It was collected and transported to the laboratory, where it was oven dried for 2 hours to remove moisture and then cooled before use. The specific gravity of the rice husk ash was found to be 1.781.

5.1.4 Control Mix Concrete

The control concrete mix ratio, based on IS 10262:2000, was used. The ratio consisted of 1 part cement, 1.99 parts fine aggregates, and 3.42 parts coarse aggregates, with a water-to-cement ratio of 0.55. The quantities for one cubic meter of the mix were as follows: 348.36 kg of cement, 695.71 kg of fine aggregates, 1190.32 kg of coarse aggregates, and 191.6 kg of water.

5.1.5 Corn Cob Concrete

Corn cob concrete was prepared by partially replacing cement with corn cob ash at various levels: 2.5%, 5%, 7.5%, 10%, 12.5%, and 10% (combination of corn cob ash and rice husk ash). Nine cubes, each measuring 150mm x 150mm x 150mm, were cast for each mix: CCA-0%, CCA-2.5%, CCA-5%, CCA-7.5%, CCA-10%, and CCA-12.5%. The cubes were then cured for 3, 7, 14, and 28 days. After the curing period, the cubes were crushed using a compressive strength testing machine to determine their compressive strength. Crushed samples were also collected for further analysis.

6 RESULT AND DISCUSSION

This section presents a comprehensive analysis of the chemical composition, SEM characteristics, mechanical properties, and durability of concrete incorporating Corn Cob Ash (CCA) and Rice Husk Ash (RHA). The key findings are summarized as follows:

6.1 Chemical Analysis:

6.1.1 CCA Analysis: The chemical analysis of CCA revealed the presence of various components in the following percentages: 25.77% SiO_2, 1.64% Al_2O_3, 2.69% CaO, 0.32% Fe_2O_3, 1.06% MgO, 0.29% Na_2O, 1.56% K_2O, and 0.45% SO_3.

5.2 RHA Analysis: The chemical analysis of RHA showed that it consisted of 82.10% SiO_2, 0.95% Al_2O_3, 0.89% CaO, 0.93% Fe_2O_3, 0.53% MgO, 0.80% Na_2O, 0.89% K_2O, and 0.61% SO_3.

6.2SEM Analysis:

The SEM analysis of both CCA and RHA indicated the presence of irregular particles with micro pores. These particles are formed during the combustion of organic constituents. It is recommended to sieve the ash samples before incorporating them into cement to address the issue of irregular particle size.

6.3 Mechanical Properties:

6.3.1 Slump: The slump test, which measures concrete workability, demonstrated that the slump values decreased as the percentage of CCA replacement increased. This decline in workability suggests a decrease in the ease of concrete placement and compaction.

6.3.2 Compressive Strength: The addition of CCA resulted in a reduction in the compressive strength of the concrete. Higher replacement levels of CCA led to lower compressive strength values, indicating a potential compromise in the structural integrity of the concrete.

6.3.3 Density: The density of the concrete containing CCA replacements was lower compared to the control mix. This decrease in density implies a lower mass per unit volume of the concrete, which may have implications for certain applications.

6.4Durability Test:

6.4.1 Water Absorption: The water absorption test demonstrated that the concrete incorporating CCA replacements exhibited higher water absorption compared to the control mix. This can be attributed to the presence of pores in CCA, which have the ability to absorb water.

6.4.2 Acid Attack: When exposed to acids such as sulfuric acid and nitric acid, the concrete samples experienced a decrease in compressive strength. Acid attack can cause deterioration and weaken the structural integrity of concrete.

6.4.3 Carbonation Test: The visual assessment of concrete samples using phenolphthalein solution revealed that all samples were non-carbonated. This indicates that carbonation did not occur within the tested timeframe.

By considering the chemical analysis, SEM analysis, mechanical properties, and durability tests, a comprehensive understanding of the behavior and characteristics of concrete incorporating CCA and RHA can be obtained. These findings provide valuable insights for optimizing the utilization of these ash materials in concrete applications.

7 CONCLUSION

The research findings demonstrate that corn cob ash is a suitable material for partially replacing cement in concrete. It can be effectively used as a replacement up to 7.5% in load-bearing structures and up to 12.5% in non-load-bearing structures. Furthermore, by incorporating rice husk ash, the replacement level can be increased to 10%, resulting in improved compressive strength and the utilization of larger quantities of waste ash from corn cobs and rice husks. The quality of corn cob ash can be enhanced through controlled incineration, leading to favorable results in terms of compressive strength, sulfate resistance, and acid attack resistance.

In conclusion, the use of corn cob ash concrete or corn cob-rice husk ash concrete as alternative cementitious materials is recommended. These ashes offer significant benefits, including reducing carbon dioxide emissions into the atmosphere, minimizing environmental impacts, and lowering the cost of cement production.

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