The Utilization of Coal Pond Ash and Rice Husk Ash as a Supplementary Cementitious Material in High-Performance Concrete: A Review

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Abstract - *Cement has become the predominant material in contemporary construction. Because of strong binding and high compressive strength capabilities, In addition, it produces the emission of the greenhouse gas (carbon dioxide), which contributes to global warming and other environmental problems. There were efforts to reduce the carbon impact and the usage of waste materials in construction. Using waste materials in concrete has become widespread during the past decade. Coal pond ash is a by-product collected from coal burning process. As pond ash is being disposed of, fly ash is recycled as an alternative to cement. Pond ash removal involves a significant amount of land, water, and energy. If improperly managed, poses a health risk and harms the environment. The demand for more coal ash disposal sites has grown urgent due to rising electricity consumption and increasing coal ash output each year. Therefore solving the aforementioned problems may be possible by reusing pond ash. An attempt has been made to utilize these cheaper materials in concrete production. The admixtures may be added in concrete in order to enhance some of the properties desired specially. Natural resource scarcity can be mitigated by the use of waste materials in concrete mixes. This review article explores the incorporation of supplementary cementitious materials (SCM) such as coal pond ash and rice husk in concrete mixtures, as well as their influence on the mix's strength and durability. The available literature shows that Portland cement may be replaced with CPA and RHA in concrete and mortar mixtures with substantial achievement.*

Key Words: Coal Pond Ash, (CPA) Rice Husk Ash (RHA), Supplementary Cementitious Material (SCM), high performance concrete

1. INTRODUCTION

The world produces about 5 billion tonnes of cement and 15 billion tonnes of concrete per year and these figures are expected to rise significantly over the next 30 years **[Scrivener, et al., 2018].** Because of the burning of process fuel and the degradation of limestone involved in making cement, 6% of all manmade greenhouse gas emissions may be traced back to this industry. Cement production facilities should be improved to minimise carbon dioxide (CO_2) emissions in line with the worldwide goal of lowering emissions overall. Reducing cement CO_2 emissions by the substitution of low-carbon supplemental cementitious materials (SCMs) for cement is one of the most promising techniques at the present moment. **[Hasanbeigi, et al., 2012].** Because of the benefits they bring to concrete durability, SCMs have been widely employed in concrete for quite some time now **[Juenger et al., 2019].** The pozzolanic and/or latent hydraulic reactions of traditional SCMs like fly ash and slag increase the durability of concrete, particularly against alkali silica reaction and sulphate assault **[Elahi et al., 2021].** The availability of fly ash and slag has decreased significantly as a result of shifting patterns in industrialization, such as the near-global shutdown of coal-fired power plants. Hence, it is crucial to discover, categorise, and implement substitute SCMs **[Juenger et al., 2019].** Concrete is the most often employed man-made building material in the world. It is made by combining the right amounts of cementitious ingredients, water, aggregate, and occasionally admixtures. If the price of cement has grown owing to higher production costs or more demand, it is necessary to replace them partially or entirely with less expensive materials. The abundance of raw materials, superior strength and durability, inexpensive production and maintenance costs, adaptability in creating different shapes, and limitless structural uses when combined with steel reinforcement account for concrete's appeal. The crucial component cement, however, poses a significant barrier for the concrete business. Cement manufacture requires a lot of energy, and the carbon dioxide released during the process raises environmental issues. Moreover, there are more and more instances when cement causes distress in concrete under harsh environmental circumstances. Because of these characteristics, researchers are now focusing more on the possibilities of using mineral admixtures to increase strength and durability while also considering ways to reduce cement usage. As a result, more cementitious materials are being used, particularly those that are by-products of industrial operations, such fly ash, ground granulated blast-furnace slag, silica fume, and rice husk ash, and coal pond ash which can partially replace Portland cement.

1.1. High Performance Concrete (HPC)

The properties of high-performance concrete are superior to those of traditional concrete utilised in construction works. Certain materials that are blended in the right quantities for the desired performance of the buildings are needed to make high performance concrete. To manufacture high performance concrete, certain mixing, placing, and curing procedures are required. For the construction of large span bridges and high rise structures, these HPC are essential. To do this, we require:

1. High cement content

2. Lowest water-to-cement ratio, which affects the mix's workability.

3. It is important to remember that high performance concrete and high strength concrete are not interchangeable. Just the compressive strength of concrete, as measured at a specific age, is used to define high strength concrete. According to ACI, "High performance concrete" is defined as concrete that satisfies unique sets of performance and uniformity standards that are not necessarily regularly achievable with conventional components and customary mixing, placing, and curing procedures.

1.2 Supplementary Cementitious Materials (SCM)

Hydraulic or pozzolanic activity provided by supplementary cementing materials (SCM) improves the characteristics of the cured concrete. Fly ashes, slag cement (ground, granulated blast-furnace slag), and silica fume are all common examples. Any of these can be used alone or in conjunction with ordinary or mixed cement. For several reasons, including cost savings, reduced permeability, increased strength, and the capacity to alter other concrete characteristics, supplementary cementing elements are frequently added to concrete mixes.

Supplementary cementitious materials are relatively significant amounts of finely split siliceous minerals that are added to mixes. They fall under the following categories. (a) Reactive minerals that are either pozzolanic or cementitious, or both. Low-calcium fly ash is an example of a pozzolanic additive. Granulated blast-furnace slag that has been ground up is an illustration of a cementitious admixture. Fly ash with high calcium content is both cementitious and pozzolanic. (b) Inert mineral fillers without pozzolanic or cementitious characteristics. They are often included as fillers, such as silica fume. Cement is replaced by materials from the first category. They interact with calcium hydroxide in the hydrated cement paste to generate complex compounds that minimize permeability, enhance final strength and durability, and boost mix economy. These SCM's are present in several cements, including PPC and PBSC. They are employed as ready-mixed concrete as well as on-site. Fly ash, silica fume, rice husk ash, metakaolin, and crushed granulated blast-furnace slag are among the mineral admixtures that IS 456-2000 suggests using. This thesis calls for the use of fly ash, silica fume, rice husk ash, and powdered granulated blast-furnace slag as a partial replacement for cement.

As a result, a "pozzolan" is defined as "a siliceous or siliceous and aluminium material, which by itself possess little or no cementing property, but will, in a finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementite's properties." Making "high performance concrete," which has great workability and extremely high early strengths, or taking into consideration high workability and long-term durability of the concrete, are both acceptable uses for this material.

1.3 Role of supplementary cementitious materials

Using SCMs such fly ash, coal pond ash, silica fume, crushed granulated blast furnace slag, and rice husk ash can help mitigate the negative effects of calcium hydroxide (CH), which is created when cement hydrates during the curing process in concrete. When compared to regular portland cement, these SCM create a lower amount of CH (OPC). These mineral admixtures' pozzolanic reaction solely includes the consumption of CH, not its creation. Consuming CH makes cement paste thick and impermeable, which increases cement paste's durability. Thus, the SCMs improve the quality of concrete by reducing the heat of hydration and thermal shrinkage when applied in the proper proportion.

1.4 Rice husk and coal pond ash as supplementary cementitious materials

The natural outer layer of the grains, known as the husk, is widely available in many parts of the world, especially in nations that cultivate rice. Around 200 kilogrammes of rice husk, or 20%, is produced for every tonne of rice, and the burning of this husk yields roughly 18% to 20% ash. In 2011, it was predicted that the 145 million tonnes of rice husks would result from the cultivation of 723 million tonnes of rice **[Aprianti et al., 2015].** Coal is one of the world's most valuable resources because it can be burned to provide electricity and steam and because it has been utilized in this way for well over a century. Coal is used in power plants in both emerging and industrialized nations, and its popularity has increased **[Malkit and Rafat 2015].**

1.5 Advantages of Supplementary cementitious materials

Concrete mixtures can benefit from the addition of supplementary cementitious materials (SCM) for a variety of reasons, including the enhancement of durability, the reduction of permeability, the facilitation of pumpability and finishability, the mitigation of alkali reactivity, and the improvement of the overall hardened properties of concrete.

2. UTILISATION OF SUPPLEMENTARY CEMENTITIOUS MATERIALS IN CONCRETE MIX

A review of literature focusing on the studies related to the improvement in mechanical properties of Supplementary cementitious materials in concrete is presented. The following are some critical findings based on the research done on the effect of SCMs on concrete. It emerges from the review of the literature that several studies have been undertaken to examine the impact of SCMs on concrete characteristics, mechanical, and durability qualities of SCMs independently.

Saraswathy et al. (2007) investigated on the rice husk ash-infused concrete's mechanical characteristics and corrosion resistance. At replacement levels of 5%, 10%, 15%, 20%, 25%, and 30%, rice husk ash was used to replace OPC. The outcomes were evaluated against typical Portland cement concrete. Investigated were the mechanical and corrosion-resistant qualities. They came to the conclusion that RHA up to 30% replacement level enhances strength and corrosion resistant qualities and decreases permeability and chloride penetration.

Ghrici et al (2007) studied the mechanical characteristics and toughness of mortar and concrete incorporating naturally occurring pozzolana and blended limestone cements. Up to 20% of the mass of Portland cement was substituted with limestone filler, and 30% of it with natural pozzolana. At 2, 7, 28, and 90 days, mortar prisms underwent tests for flexure and compressive strength. The samples were evaluated for permeability to chloride ions, acid solutions, and sulphate. They came at the conclusion that ternary mixed cement enhanced both the short- and long-term compressive and flexural strengths. The qualities of durability also increased.

Chindaprasirt et al (2008) examined at the strength, porosity, and corrosion resistance of a ternary blend of OPC, RHA, and FA mortar. Pozzolans were substituted for OPC at a rate of 0–40% by weight of cementitious materials. The results demonstrated that, even at a low replacement level, the mortar strength was enhanced by the combination of OPC, RHA, and FA. The ternary mixture of OPC, RHA, and FA enhanced the mortar's resistance to corrosion.

De Sensale (2008) conducted research on the improvement of concrete's strength with the use of rice husk ash. Using both leftover RHA from a rice paddy milling company in Uruguay and RHA created by controlled incineration in the USA, this report provides the results of a study on the development of compressive strength in concretes with RHA for up to 91 days. For this experiment, we tested two different cement-to-RHA replacement percentages (10% and 20%) and three different water-to-cementitious-material ratios (0.50%, 0.40%, and 0.32%). Splitting tensile strength and air permeability of the concrete with and without RHA are compared. It is found that the presence of residual RHA has a beneficial influence on the compressive strength of concretes when tested at earlier ages, but that this effect diminishes over time.

Satish et.al (2013) performed the concrete's mechanical qualities including compressive strength, flexural strength, and split tensile strength are affected by the combination of FA and RHA in cement at varying quantities, as reported in this research. Tests showed that using a mixture of 22.5% FA and 7.5% RHA increased the compressive strength by 30.15% compared to the desired strength and decreased it by 8.73% compared to control concrete after 28 days. The flexural strength increased by 4.57% compared to control concrete after 28 days, and the split tensile strength decreased by 9.58%. Concrete made using FA and RHA that has been partially substituted for these materials were fewer negative impacts on the environment and is both more cost-effective and less harmful to the environment.

Dwidi et.al (2012) investigated flyash-containment cement's engineering characteristics. In India, coal accounted for 80% of all power production. 20% of the pond ash and 80% of the fly ash produced for total ash. The compressive strength was reduced by raising the percentage of pond ash. The results of this research showed that pond ash percentage increased in cement paste and compressive strength decreased due to pond ash's pozzolanic property.

Verma et.al (2016) evaluated the use of pond ash in lieu of some of the cement in the concrete mix. Compressive strength, split tensile strength, flexural strength, and workability were calculated using this technique while using OPC 53 grade cement. Compressive strengths were raised for 7, 28, 56, and 90 days up to 15-20% replacement, and then they were reduced for additional replacement. Up to 15-20% of replacement level bending strength. Due to the substitution of the stronger substance with the weaker one, concrete loses strength as levels of fine aggregate replacement with coal bottom ash rise. Concrete's splitting tensile strength increased with pond use. The amount of Pond ash in concrete affects its workability because it absorbs more water because it is more permeable.

Rinki et.al (2014) studied the impact on concrete of replacing some of the cement with rice husk and fly ash. In this work, various Fly Ash and Rice Husk Ash combinations are used to partially replace cement and river sand with quarry sand. containing 60% of Fly Ash and 7.5% RHA, with a total of 22.5% Quarry sand results in maximum strength.

Siddique et.al (2015) observed the current developments in the use of supplementary cementitious elements in concrete. The literature on SCMs such fly ash, metakaolin, and rice husk ash was examined. Concrete's durability is improved over time by SCMs thanks to the pozzolanic reaction, but it's diminished in its first few years of life as a result of cement diluting. SCMs lessen the concrete's alkali silica reaction. SCMs with an appropriate quantity of limestone powder can improve the sulphate resistance of the cement pastes. It is beneficial to replace some of the clinker in cement or some of the cement in concrete with SCMs because it has a number of positive effects, including lowering the cost of the resultant concrete, reducing environmental impact, increasing long-term strength, and improving long-term durability.

Xu et al (2015) studied smaller grain particles with a porous shape and a larger specific surface are optimal for the formation of CSH gels. High acceleration and early hydration of C3S will result from cementitious materials combined with RHA with higher specific surface (tricalcium silicate). A smaller particle size in the RHA results in less hydration, and this is true even for RHA that has cementitious capabilities.

Apoorv singh et al (2014) observed mineral admixtures such as silica fume, rice husk ash, and iron slag are utilised in place of some of the cement in this case. The aforementioned components are all by products of modern industrial processes and may be found in great supply. These substances can be utilised as a cement substitute in High Performance Concrete production because of their high silica content and pozzolanic qualities. Concrete's load-bearing capacity is evaluated throughout the design process by calculating its two most essential characteristics, its compressive and flexural strengths, after it has hardened. So, comparative research is highly helpful for making an informed decision on the type of mineral admixtures to be employed.

Sofi et al (2016) conducted Effect of pond ash on engineering properties of concrete. To conduct this research, regular Portland cement of the 53 grade was used. The pond ash was measured to have a specific gravity of 2.04. Cement weight-based on-and-ash-content ranged from 0% to 30%. The aggregates used in this research were both 20mm and 12 mm in size. They concluded that the inclusion of pond ash in concrete enhanced the mechanical properties of concrete

Jamsawang et al (2018) looked at how well rice husk ash performed as a cementitious material in high-strength cement-admixed clay. Cement, RHA, and soft clay were the materials of choice for this study. We performed unconfined compression testing as specified by ASTM D2166-00. Comparisons are made between samples with 10%, 20%, and 30% cement contents without RHA and samples with 20% cement contents with various RHA levels. A material's ultimate stress or strength improves as its RHA content rises. The trials show that adding pulverised rice husk ash to cement deep mixing improves the material's strength properties. It is the ratio of cement to rice husk ash to water in the mixture and the curing time that determines how effective rice husk ash will be. Depending on the addition rate and mixing components, the RHA can increase the strength of cement-admixed clay by more than 100%. To substitute Portland cement, rice husk ash is more effective when the cement and cementitious contents of the mixture are not less than 20% and 35%, respectively, for the curing periods of 14 and 28 days and the range of water content in this investigation. In order to increase the overall strength of the combination, the RHA percentage in the cementitious components can be higher than 50%. For addition contents larger than 15%, the effectiveness of rice husk ash is greater than that of fly ash of equal grain size.

In their investigation, **Kartini et al (2012)** found that the compressive strength decreases as the fraction of RHA increases. Nevertheless, 10% substitution of cement with RHA achieved the desired compressive strength. Furthermore, the inclusion of RHA in lieu of cement not only increases compressive strength, but also improves the durability of typical concrete

According to the findings of **Seyed et al (2017),** there is a favourable correlation between the addition of 15% RHA and an increase in compressive strengths of around 20%. After that point, there is a correlation with a little loss in strength parameters of around 4.5%. The optimal level of strength and durability attributes normally gain with addition up to 20%, but beyond that point, there is generally a gain. The identical findings were found for water absorption ratios, which suggest that they are undesirable. The amount of chloride ions that penetrated the cement rose by around 25 percent with every cement replacement.

Concrete made with 5, 15, and 25% RHA was subjected to water absorption tests by **Abdul et al (2014)** The resistance of the concrete to water absorption was improved by the addition of 5% when compared to the control mix. There appears to be a positive correlation between the rate of RHA replenishment and the rate of water absorption. it leads to the lower the compressive strength, the greater the proportion of water absorption.

Thomas krankal et al (2020) studied Performance of Rice Husk Ash as Supplementary Cementitious Material after Production in the Field and in the Lab. The use of supplemental cementitious materials (SCM) in concrete production has the potential to reduce the amount of Portland cement clinker required. Rice husk ashes (RHA) can be converted from an agricultural by-product to a high-performance concrete constituent to the high levels of reactive silica with pozzolanic characteristics. The silica form and, by extension, the RHA's chemical and physical performance, are influenced by the combustion technique, burn time, cooling rate, and temperature. In order to compare the findings, RH was burned in both a makeshift furnace and a muffle oven in the lab. Finally, there is encouraging research on the effectiveness of field-produced RHA and its possible application as SCM when the rice husks have been properly treated.

Mohamed Sutan et al (2022) evaluated integration of rice husk ash (RHA) as Supplementary Cementitious Material in the Production of Sustainable High-Strength Concrete. As a percentage replacement for cement, RHA was used at 5%, 10%, 15%, and 20% by weight. Slump, compacting factor, density, and surface absorption were among the newly measured parameters. Compressive strength, splitting tensile strength, and flexural strength were measured to evaluate its mechanical properties at 7, 28, and 60 days. Also assessed were the microstructural quality, the environmental impact, and the cost-benefit analysis of conducting an initial surface absorption test. Compressive, splitting, and flexural strengths are all improved by as much as 7.16%, 7.03%, and 3.82%, respectively, when RHA is added to fresh mixes, although their workability is decreased. In addition, using 10% RHA results in the maximum compressive strength, splitting tensile strength, and flexural strength; it also enhances initial surface absorption and microstructural evaluation, and it has stronger eco-strength efficiency.

2.1 Summary of literature

The research reviewed above indicates that the use of SCMs in concrete and their characteristics. Coal bottom ash and rice husk ash added in concrete increasing the workability and reduce the environmental impact. Finally, the test results are conducted improve strength of the concrete long term and increasing the durability.

3. CONCLUSION

From above the discussions, understood the coal bottom ash and rice husk ash are good mineral admixtures in concrete. The mineral admixtures benefit increasing impermeability, workability, strength, and reduce corrosion of steel reinforcement. In high performance concrete mix design as water cement ratio adopted is low, it is necessary to maintain super plasticizers for required workability. When the percentage of mineral admixtures in the mix increases super plasticizer percentage also increases for obtaining of required strength. Because of this, RHA and CPA might be added to concrete blends to improve their performance.

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