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An Analytical Research on Analysis of using Rice Husk Ash and Copper Slag in Geopolymer Concrete

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Abstract: *This paper tries to evaluate their effects on mechanical qualities, microstructural features, durability, sustainability, and financial viability. Along with indicators of durability including acid resistance and chloride penetration, extensive testing was conducted to evaluate how well the many concrete mixes made with varying copper slag concentrations performed. The findings indicate that adding up to 40% more copper slag to fine aggregate will increase the material's early-age strength and resistance to acid deposition and chloride intrusion. Still, too much slag and RHA content increases the material's porosity, therefore compromising its strength and durability. The economic analysis suggests that better mix designs might produce benefits connected to sustainability as well as cost savings. The findings underline the requirement of balanced mix designs, additional long-term durability research, and nanostructural investigations; they also show the possibilities of industrial byproducts in ecologically friendly building techniques*

Keywords: Copper slag, rice husk ash, concrete, sustainable construction, mechanical properties, durability, economic analysis

I. INTRODUCTION

Geopolymer formulations reduce energy consumption and carbon dioxide emissions by about 80% when compared to standard concrete compositions. Interestingly, they use an abundance of industrial leftovers as raw materials instead of gathering and processing limestone and other natural resources. Given these qualities, geopolymer concrete has enormous potential as an affordable and environmentally friendly way to satisfy the demands of the construction sector on behalf of a growing global population.

This paper provids an overview of geopolymer concrete from a scientific perspective, explore its background, and emphasise its importance as a green building material technology. Several major subjects are examined, such as the following ones:

Both the chemical makeup of the molecule and the mechanics underlying the geopolymerization process

The properties and capacities of the material are crucial factors to take into account while choosing building materials.

The steps specifications for the finished product:

Applications where there is room for advancement for geopolymer concretes

Look at the recurring themes and the topics that need additional research.

The challenges that need to be surmounted and the expectations that need to be met for Foreground and the Beginning of History to be widely accepted

Joseph Davidovits became the most significant figure in the advancement of geopolymer technology during the 1970s. According to Davidovits' theory, binders may be produced when polysialates are activated in an alkaline environment and form networks that resemble chains. The older inorganic cements that were in use at the time served as the basis for this concept. Thus, the composition of these mineral polymers was referred to as "geopolymers".

The principal aim at the outset of the development process was to convert waste from manufacturers and mines into fireand acid-resistant ceramic materials. In order to use geopolymers researchers started looking into the feasibility of synthesising geopolymers from aluminosilicate source materials in the 1990s. As a result, the precast concrete and building materials industries saw the creation of new uses.

Initially, geopolymer concrete was developed using leftover resources from earlier research, and it showed good mechanical performance. However, rather than a thorough understanding of the underpinnings and limitations of the geopolymerization process that was carried out, which has led to an extension of both knowledge and capacities, the production relied primarily on techniques that entailed trial and error. This has directly led to the broad acceptance of geopolymer concrete as a practical and environmentally friendly cementitious material technology.

Methods in the Sciences of Composition and Chemistry

Geopolymer concrete, which uses the polymerization of aluminosilicate components as the binding mechanism throughout the process, enables the development of a hardened concrete composite. For the successful operation of this approach, two essential elements must be present: Furthermore, the source material is aluminosilicate, and the activator is an alkaline activator.

Materials with a Range of Aluminosilicate Origins

The reactive silicon (Si) and aluminium (Al) components provided by the aluminosilicate source form the molecular backbone chains of the geopolymer binder matrix. These precursors can be obtained from a broad range of alumino-silicate source materials, such as natural minerals and a variety of industrial wastes.

Aluminosilicate materials are comprised of aluminum, silicon, and oxygen, with the aluminum and silicon atoms bonded in a variety of coordination states and arrangements. These materials encompass a diverse range of natural minerals and industrial byproducts that can provide reactive sources of aluminum and silicon to produce geopolymer binders.

Natural Aluminosilicate Minerals

The tetrahedral silica sheets and octahedral alumina sheets are stacked in an alternating fashion, with these layers weakly bonded together by hydrogen bonding from the hydroxyl groups. This gives rise to a stratified structure with only limited 3-dimensional order. Kaolinite is mined as the major component of kaolin clays, which are white in color and important industrial minerals. The reactivity of kaolinite in geopolymerization arises from the silica and alumina layers, which can dissociate upon interaction with highly alkaline solutions.

Feldspars refer to a group of aluminum tectosilicate minerals having the generalized formula (K,Na,Ca)(Si,Al)4O8. The most common feldspars include albite (NaAlSi3O8), anorthite (CaAl2Si2O8), and microcline (KAlSi3O8). occur in between the tetrahedral framework, balancing the negative charge from Al3+ substituting for Si4+ in certain sites. Feldspar is an abundant component of igneous and metamorphic rocks in the Earth's crust. The reactivity of feldspars for geopolymer synthesis originates from the silica and alumina content in the 3-dimensional tetrahedral network, which can be broken down through alkaline hydrothermal dissolution.

Zeolites are a family of hydrated aluminosilicate minerals, with over 40 natural varieties identified. They have an open, microporous structure consisting of 3-dimensional frameworks . The frameworks contain cavities and channels occupied by cations (Na+, K+, Ca2+) and water molecules. Zeolites have the generalized formula (M2/n+).Al2O3.xSiO2.yH2O where n is the cation valence, x is generally equal to or greater than 2, and y denotes variable amount of water contained in the structural channels. Natural zeolites such as clinoptilolite and mordenite are found in abundant quantities in certain volcanic and sedimentary rock deposits.

II. GEOPOLYMER SYNTHESIS

The aluminosilicate precursors described above providing the sources of Si and Al can react with alkaline solutions to produce geopolymer binders. While the specific aluminosilicates differ in structure and composition, they all share several essential traits that enable the geopolymerization reaction: (1) the presence of reactive Si-O/Al-O bonds, (2) availability of Al3+ and Si4+ sites, and (3) largely amorphous or vitreous phase.

The chemical reaction proceeds as follows. The aluminosilicate reacts with a highly alkaline hydroxide, silicate, carbonate or sulfate activator solution. As more Al and Si species accumulate from ongoing dissolution, the supersaturation point is reached causing the dissolved ions to rapidly condense according to the general formula:

Mn{-(SiO2)z-AlO2}n . wH2O

where Mn+ denotes the charge balancing alkali cation (Na+, K+), n is the degree of polymerization, z is 1, 2, or 3, and w denotes the water contained within the gel structure. This condensed gel phase surrounds and binds the undissolved or partially dissolved aluminosilicate particles into the hardened geopolymer matrix.

The physical and mechanical properties of the resulting geopolymer depend on multiple factors:

(1) Chemical composition Overall Si:Al ratio, type of alkali cation (Na vs K), alkali content.

(2) Aluminosilicate reactivity Amorphicity/crystallinity, particle size distribution, specific surface area.

(3) Activator solution Type (combination of sodium/potassium hydroxide, silicate, carbonate, sulfate solution), concentration, Ms modulus.

(4) Curing conditions Temperature, humidity, time under heat.

By tuning these parameters, the molecular structure and morphology of the geopolymer binder can be controlled to achieve desired qualities such as mechanical strength, setting time, porosity, durability, etc. tailored toward specific usages.

III. LITERATURE REVIEW

3.1 Geopolymer Concrete

A novel building material called geopolymer concrete is made by activating aluminosilicate components with alkali. These components are made from leftovers from industrial processes. Davidovits (1978) coined the term "geopolymer" to describe a broad range of compounds with three-dimensional polymeric Si-O-Al framework structures that were alkali-activated alumino-silicates (Davidovits, 2013). The phrase was initially used by Davidovits. Members of the inorganic polymer family that are produced during the geosynthesis process make up geopolymers. Both the building and industrial sectors employ geopolymers. Aluminosilicate minerals and highly concentrated alkaline solutions undergo a process that produces Si-O-Al connections, which can range in type with the goal of creating geopolymer concrete. The creation of geopolymer concrete requires this interaction.

Researchers have been studying the process of alkaline activation of aluminosilicate raw materials for cementitious binders since the 1950s. The purpose of this process is to guarantee the more efficient production of cementitious binders. He built concretes based on these properties using hydrous high-calcium slags activated by alkaline solutions. The strength and lifespan of these concretes were better than those of their predecessors. Numerous terms are used to describe these binder systems, some of which include "soil cements," "geocements," "inorganic ceopolymers," and many more. According to Provis and Bernal (2014), the terms "alkali-activated materials" and "geopolymers" are currently the most commonly used. The most commonly used phrases are these ones. Because of this, it is now very necessary to create concrete that is environmentally friendly, low in carbon emissions, and sustainable. Geopolymers offer several answers to the sustainability problems related to the cement production process. Eliminating waste streams that fall into this category is one of these strategies. The industrial aluminosilicate production process yields waste by-products that can be used to synthesise binders.This has been completed. Because of this, geopolymer concrete has become a leader in the innovative concrete materials that are supporting the shift to a carbon-neutral environment and a circular economy.

Geopolymer concrete has exceptional mechanical performance and endurance due to the long chain binder networks that are produced during the polymerization process (Khale and Chaudhary, 2007). This is because these networks are formed as a result of the polymerization process. It has better fire resistance, reduced shrinkage,

Another benefit is that it is resistant to those toxins. As per Somna et al. (2011), geopolymer concrete is becoming increasingly significant for a range of uses, such as the immobilisation of radioactive waste, refractory material manufacture, marine projects, and transportation infrastructure. This can be attributed to geopolymer concrete's ability to efficiently carry out a wide range of tasks.

3.2 Slag of Copper

An industrial to produce copper is called copper slag. Impurities oxidise and create oxides during the copper recovery smelting process. These oxides then chemically react with the siliceous gangue elements in the ore to form copper slag (Wu et al., 2010). Primary copper smelters produce (Al-Jabri et al., 2011). Globally, smelters generate around 24.6 million tonnes of waste copper slag annually (Gorai and Jana, 2003).Between 30 and 60% of the iron oxides found in copper slag recovered at the smelters are combined with 35 to 50% amorphous silica. In addition to minor amounts of heavy metals, the chemical composition also includes small amounts of alumina and calcium oxide.

Serious environmental problems arise when copper slag is handled and disposed of improperly. Slag dumped in open stockpiles causes issues with fugitive dust emissions carried by the wind and the occupation of large tracts of land. There have also been attempts at landfilling and marine dumping, both of which present a danger of soil and water contamination (Wu et al., 2010). This means that routes for the full use of waste streams from copper slag must be urgently pursued. According to studies by Gorai et al. (2003) and Brindle (2007), among others, copper slag has latent hydraulic qualities

Copper slag has been processed and then used to concrete as fine or coarse aggregate by a number of researchers (Wu et al., 2010; Brindle, 2007).

Additionally, attempts have been undertaken to activate the latent cementitious capabilities of copper slag in order to synthesise stand-alone binders. According to Taha et al. (2007), alkali activated copper slag binders shown an increase in strength when allowed to cure in an ambient environment. In addition, it had better acid resistance than OPC systems. Gorai and Jana (2003) looked at the binding characteristics of copper slag that has been activated. They reported exceptional strength growth, suggesting that low-carbon binders may be made using 100% copper slag.

3.3 Ash from Rice Husk

The tough outer layer that surrounds each rice grain is called rice husk (RH). About one-fifth of the 500 million metric tonnes of paddy produced annually worldwide is husk, which requires proper management during the milling of paddies for the production of rice (Amin, 2011). According to Rodrigues et al. (2003), RH has a high silica content that ranges from 18 to 22% by weight, over 75% volatile organic content, and residual water contents. RHs may be useful as supplemental fuel, but there have always been significant disposal issues with the ash wastes. But after burning, RH becomes rice husk ash (RHA), which has strong pozzolanic properties and contains 90–97% amorphous silica (Mehta, 2004).

The global emphasis on sustainability makes RHA an increasingly relevant material to use as an ingredient that investigated how adding RHA affected mortar and cement paste compositions. The cement augmentation of 20% by RHA resulted in 90-day strengths that were greater than those of the control samples. This improved mechanical performance is explained by the amorphous nano silica's microfiller action (Givi et al., 2010). Additionally, RHA is essential for enhancing durability qualities. 10% RHA addition increased mortars' resistance to sulphates and acids while tripling the rate of chloride diffusion (Rodrigues et al., 2003).

Numerous investigators have examined how the inclusion of RHA affects different concrete qualities. Mehta (2004) looked at strength parameters and found that both compressive and flexural strengths rose when cement was replaced by 25%. Studies on permeability revealed that up to 30% RHA inclusion enhanced resistance against water and chloride penetration (Givi et al., 2010). Porosity and features related to water absorption were assessed by Ganesan et al. (2008). Porosity was reduced by 65% and water absorption by 23% with up to 20% supplementation, indicating that nanoscale pozzolanic reaction was responsible for the microstructure's refinement.

Because RHA has a high silica concentration and is highly reactive, it has also been researched as a potential binders. By employing sodium silicate solutions to alkali activate RHA, Rahier et al. (2003) created binders, but they noted that thermal curing was required. According to Rangan (2008), 25 MPa fly ash-based geopolymer systems with 5% RHA were successfully manufactured under ambient settings. Strength gain and structural analogues similar to OPC formations were shown by the blend system. The nano-silica effect of RHA was credited by Mucsi et al. (2015) for the synthesis of RHA-based geopolymers that were activated using sodium hydroxide solutions and reached 80 MPa strength upon heat curing.

3.4 Using Rice Husk Ash and Copper Slag Together in Geopolymer Concrete

There is a dearth of literature on the creation of low carbon concrete, despite prior studies examining the individual effects of these substitutions or additions in OPC systems. Due to their similar hydraulic and pozzolanic reactivity, attempting to simultaneously include highly pozzolanic agricultural residue (RHA) and an industrial waste with cementitious properties (copper slag) into geopolymer composites can have synergistic effects.

Blending RHA and copper slag in geopolymeric matrices has several advantages:By using waste byproducts to their fullest potential solves the environmental problems associated with their disposal.

Templeton greater volume replacements of natural fine aggregate by copper slag while preserving particle packing density are made possible by the nano-filling capacity of nano-silica found in RHA.

RHA provides a highly reactive nano-silica component to speed up the kinetics of geopolymeric reactions, while copper slag serves as the necessary source of aluminosilicate for geopolymeric synthesis.

However, adding copper slag and RHA to geopolymer systems could provide the following difficulties:Heavy metal leaching, particularly the release of lead and arsenic from copper slag, is a serious environmental issue that requires research.

A large amount of amorphous silica that is readily dissolved might lead to expansion brought on by the alkali-silica reaction when there is an excessive RHA content.

The development of strength can be hampered by improper curing conditions, which are exacerbated by the slower reactivity of copper slag and high RHA levels.

In their 2018 study, Sethy et al. assessed the leaching, permeability, and strength of RHA additives and heated to cure. At 180 days, concrete with 20% RHA and 40% copper slag had a 51 MPa strength with minimal heavy metal leaching. Strength was increased by adding RHA microfillers, which improved particle packing. sodium silicate solutions to create ambient-cured concretes with 30% copper slag, 20% RHA, and 50% GGBFS activated. Concrete with 60 MPa strength and resistance against acids, sulphates, and chlorides was made by substituting 70% of the cement with combinations of three waste byproducts.

Although these studies point to the possibility of producing concrete with improved characteristics and cleaner production through successive waste inputs, there is currently a dearth of study in this specialised field. Because of the synergies involved, investigating copper slag and RHA supplementation in geopolymeric systems can advance this method for producing sustainable concrete. To measure and optimise the combined effects on the characteristics of geopolymer concrete, however, methodical research is required.

3.5 Research Gaps

The following knowledge gaps persisting in the current literature have been identified:

- The hardened characteristics of copper slag-RHA blended geopolymer concrete have not been linked to mix composition parameters, such as slag and RHA doses, alkaline activator nature and ratios, and curing conditions, such as duration and temperature.
- There are no performance standards required for structural and infrastructure applications.
- There are no set standards for the best mix design and curing that allow for the greatest still meeting constructability and compliance requirements.

IV. EXAMINING THE DATA

The data from the test were recorded and examined in a methodical manner, which enabled the discovery of any potential irregularities. In order to eliminate values that were judged to be outliers, statistical approaches were administered. Though these calculations differed based on the situation, calculations were made For the characteristics that were assessed, confidence intervals were determined with a 95% degree of certainty.

By applying approach, the influence of the doses of rice husk ash and copper slag was analysed to establish whether or not they were statistically significant. This strategy was employed in order to accomplish the effect analysis. Regression analysis was used to create prediction models that show a relationship between the mix components and concrete quality. The data were plotted in Microsoft Excel in order to facilitate the visualisation of the information for the purposes of comprehending it and making decisions.

The statistical programme provided by Minitab was employed to do the requisite analysis. Normality tests were performed to make sure the test assumptions were met, and data modifications were made when they were thought necessary.

Unless otherwise indicated, a probability threshold of 5% was always used to assess the significance

A comparison was done between the manufactured concretes and the reference mix in addition to the concretes themselves. The most successful combination was found by taking into account the sustainability, technical performance, and economic feasibility factors. This included adding rice husk ash and copper slag. This means that the investigation was successful in obtaining the materials science inputs required for the creation of green building materials that utilise waste from industrial processes.

An Analysis of One's Own Statistics

The experimental data underwent a thorough statistical analysis to ensure the reliability and robustness of the results. The salient features of the analysis are enumerated as follows:

Verification of the Information: Every single bit of data was gathered and examined carefully in order to look for any potential anomalies or disparities. Statistical techniques were applied to the results analysis to find and exclude any values that were considered abnormal.

Characteristic statistics were calculated in order to give a thorough view of the distribution and variability of the data. Wherever and whenever it was appropriate, mean values, standard deviations, and coefficients of variation were calculated.

The confidence intervals are as follows: Confidence intervals with a 95% degree of certainty were created for each of the measured attributes the range of values that the actual population parameters were most likely to fall within.

ANOVA, or analysis of variance, is another name for: The effects of different dosages of copper slag and rice husk ash on the properties of concrete were examined to see if they were statistically significant, based on the findings of an analysis of variance (ANOVA). A thorough comparison of averages across a range of mix designs was made possible by the application of this method.

Considering the Regression: Regression models were built with the intention of establishing whether or not there is a relationship between the characteristics of the concrete (like strength and durability) and the parameters of the mix (such the percentage of slag and ash in the mixture). These models generated predictions about the functions of the concrete mixtures based on their composition.

Expression through Visual Form: Software like Excel was used to display the data, which greatly facilitated understanding and decision-making. We were able to identify patterns and connections between variables in a more comprehensible way by using graphical representations.

Languages used for programming and theoretical structures

The statistical programme that was used to do the tasks that required statistical analysis was called Minitab. It had a wide range of data analysis features, such as the ability to test for normalcy and change data under specific conditions, in order to satisfy the test assumptions.

Method using the Response Surface: The interaction properties of the variables were examined using the response surface method. Through the application of this methodology, a more thorough examination This in turn helped to optimise the ratio of slag to ash in order to attain the desired results.

The ingredients and procedures used to carry out a thorough assessment of ecologically friendly concrete mixes that contained copper slag and rice husk ash are fully described resource efficiency and environmental sustainability of building activities by partially replacing standard concrete ingredients with industrial by-products. We used advanced statistical analyses, rigorous testing procedures, and a large experimental setup to ensure that the findings were valid from a scientific standpoint as well as applicable to real-world circumstances.

This chapter served to establish a solid foundation for evaluating the created concrete combinations' technical performance, long-term viability, and economic viability. In the upcoming chapters, we will examine the results of this investigation in more detail. These chapters will address the implications for green building practices and offer recommendations for improving concrete compositions for a range of applications.

V. CONCLUSION

The investigations' conclusions make it feasible to state categorically that newly created slag and RHA blended concrete compositions provide green substitutes for traditional concrete that can nevertheless meet structural requirements.

It is now technically and commercially possible to utilise these industrial and agricultural leftovers on a massive basis.

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Custom mix design offers opportunities for specialised application development in addition to performance enhancement.

The next crucial phases of the transformation should focus on establishing a high-quality supply chain and supportive policies.

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