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Reduction of Thermal Cracking in Concrete Through the use of Coal Ash as a Partial Replacement for OPC

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Abstract:- Thermal cracking in concrete structures poses a significant challenge, jeopardizing their structural integrity and long-term performance. This study focuses on reducing thermal cracking by utilizing coal ash as a complete replacement for Ordinary Portland Cement (OPC) and reinforcing the concrete with coconut fiber. The objective is to investigate the potential of these sustainable materials in mitigating thermal cracking and improving the overall behavior of concrete.The experimental program involves producing various concrete mixtures, where coal ash replaces OPC entirely, and coconut fiber is incorporated as a reinforcement material. The mixtures are subjected to compressive strength testing to evaluate their mechanical properties. The compressive strength test results are then compared between OPC and coal ash-based concrete specimens.The findings reveal that the compressive strength of OPC-based concrete is greater than that of coal ash-based concrete. However, despite the lower compressive strength, the coal ash-based concrete exhibits improved resistance to thermal cracking. The reduced heat of hydration and thermal stresses associated with coal ash contribute to the enhanced crack resistance of the concrete.This study demonstrates the feasibility of utilizing coal ash as a full replacement for OPC and incorporating coconut fiber as reinforcement to reduce thermal cracking in concrete. The results highlight the importance of considering not only the compressive strength but also other factors such as crack resistance and overall performance when assessing the effectiveness of alternative materials in mitigating thermal cracking.

Keywords:- *Thermal Cracking, Concrete, Coal Ash, Ordinary Portland Cement (OPC), Coconut Fiber, Sustainable Materials, Compressive Strength, Crack Resistance, Heat Of Hydration, Thermal Stresses, Ductility.*

I. INTRODUCTION

Thermal cracking in concrete is a significant concern that has affected the construction industry and infrastructure development worldwide. Concrete, being one of the most widely used construction materials, offers numerous advantages such as strength, durability, and versatility. However, it is susceptible to cracking when subjected to temperature differentials during various stages of its life cycle.Basic concrete is a fragile material. Without any fibres, shrinkage from plastic, drying, and variations in concrete volume would cause fissures in the material. Fruit and shell fibres are among these materials. Since natural fibres have been used to reinforce concrete for thousands of years, the use of these materials is not new. For example, straw is used to build mud, bricks, and poles. There are two types of fibres: natural and artificial (Fordos, 1989). Numerous nations have conducted extensive investigations into the use of natural fibre as reinforcement for creating concrete (coal ash sand matrix) (Rehsi, 1991; Atnaw et al, 2011). Natural fibres are mainly used since they are readily available and reasonably priced.

Consequently, chemical treatments are applied to change the surface properties of the fibre. Globally, a great deal of research and development is still being done to better understand and use fibre concrete materials. Developing novel, stronger fibres, improved fiber-reinforced composites, and innovative alternatives are a few of these activities (Fordos, 1989). The effects of fibre length, fibre pre-treatment, and mixture ratio on the mechanical, thermal, and physical properties of coal ash composites after 28 days of hydration were also studied by Asasutjarit C. (2009). They saw an improvement in the mechanical qualities of the boiling and water-washed fibre. Furthermore, the ideal proportion of fibre length was 1 to 6 cm, and the ideal weight-ratio of the cement, fibre, and water combination was 2:1:2 for traditional reinforcement.refers to the use of steel bars, commonly known as rebar, to reinforce concrete structures. It plays a crucial role in enhancing the strength and durability of various construction elements, such as beams, columns, and foundations.

The impact of conventional reinforcement in civil engineering is significant. By adding rebar to concrete structures, engineers can increase their tensile strength, allowing them to withstand forces such as bending or stretching without fracturing. This reinforcement technique helps prevent structural failures, enhances load-bearing capacity, and improves the overall stability and safety the built environment.

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However, conventional reinforcement also has some disadvantages. Firstly, it adds complexity to the construction process, as careful planning, detailing, and installation of rebar are required. This can increase construction time and costs. Additionally, the presence of rebar can pose challenges during maintenance and repair activities, as it may obstruct access or complicate the removal and replacement of damaged concrete.Moreover, conventional reinforcement is susceptible to corrosion over time, especially in harsh environments or when exposed to moisture and chemicals. Corrosion can weaken the reinforcement, leading to structural deterioration and compromising the integrity of the concrete elements. To mitigate this issue, corrosion protection measures, such as epoxy coating or cathodic protection, may need to be implemented, adding further complexity and cost to the construction process.Overall, while conventional reinforcement is an essential technique in civil engineering, it is important for engineers to carefully consider its impact, disadvantages, and appropriate measures to ensure the long-term performance and durability of reinforced concrete structures.

II. LITERATURE REVIEW

- *Bash-a et al (2005):*

This study focuses on the use of rice husk ash (similar to coconut fiber ash) and cement for stabilizing residual soil. The researchers found that the addition of rice husk ash significantly improved the strength and durability of the stabilized soil. This outcome suggests that combining coal ash with coconut fiber ash may yield similar enhancements in the properties of composite materials.

- *Hwang et al (2017):*

The authors investigate the mechanical properties of lightweight aggregate concrete incorporating coconut fiber and coal ash. The study reveals that the inclusion of coconut fiber and coal ash enhances the compressive and flexural strength of the concrete while reducing its density. These findings indicate the potential use of coal ash and coconut fiber to develop lightweight, durable, and eco-friendly construction materials.

- *Islam et al (2019):*

This study examines the influence of coconut fiber and rice husk ash (similar to coal ash) on the mechanical properties of concrete. The research demonstrates that the addition of coconut fiber and rice husk ash enhances the compressive strength, flexural strength, and toughness of the concrete. These findings suggest the potential of combining coal ash with coconut fiber to improve the mechanical properties of composite materials.

- *Joseph and Mathew(2019):*

The researchers investigate the impact of coconut fiber reinforcement on the mechanical properties of concrete. The study reveals that the inclusion of coconut fiber enhances the compressive strength, flexural strength, and impact resistance of the concrete. These findings indicate that the combination of coconut fiber with coal ash may lead to improved mechanical properties in coal ash-based composites.

- *Bai et al (2019):*

This study focuses on the performance of concrete incorporating coal ash and coconut fiber. The research demonstrates that the addition of coal ash and coconut fiber improves the workability, compressive strength, tensile strength, and durability of the concrete. These findings suggest that coal ash and coconut fiber can effectively enhance the performance of concrete in construction applications.

- *Kadiranaikar et al (2020):*

This experimental study explores the properties of coconut fiber reinforced concrete incorporating coal ash. The study reveals that the addition of coconut fiber and coal ash improves the compressive strength, flexural strength, and split tensile strength of the concrete. The research highlights the potential of coal ash and coconut fiber as sustainable additives for enhancing the properties of concrete.

- *Chandramouli, et al. (2021):*

This study investigates the mechanical properties of fly ash-based geopolymer concrete incorporating coconut fiber. The research reveals that the inclusion of coconut fiber enhances the compressive strength, flexural strength, and impact resistance of the geopolymer concrete. The findings suggest that coal ash-based geopolymer composites with coconut fiber can offer improved mechanical properties and environmental sustainability.

III. MATERIAL AND METHODOLOGY

- *Coal Ash*

The main source of coal ash, also known as coal combustion residuals, or CCRs, is the burning of coal in coal-fired power plants. Several byproducts from burning coal that was received from a coal combustion site in Enugu State, a state in Nigeria, are combined to form coal ash.

- *Coconut Fiber (COIR)*

The brown fibres that were extracted from totally grown coconut husks are what were used; they came from Anambra State in eastern Nigeria. Figure 1 show the coir fibres.

Fig1 Coir Fibers

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➢ *Water*

The hydration of cement and the durability of concrete are two critical processes in the production of concrete, and water should not contain any substances that could compromise these processes. Most of the water utilized is safe to drink as well.

➢ *Aggregates*

The aggregate portion of a concrete mix typically makes up between 60 and 80 percent of the volume of the concrete, and the properties of the aggregate affect the concrete's characteristics. The texture of aggregates can be coarse or smooth. Both types of aggregates were employed in this study.

➢ *Fine Aggregate*

The concrete was mixed using river sand as fine aggregate in accordance with ASTM Standard C33 (2006). Every particle captured on sieve No. 230, aperture 63 µm, but retained on ASTM sieve No. 4, aperture 4.75 mm. This was acquired from Nigeria's Anambra state.

➢ *Coarse Aggregate*

Crushed granite was used as the coarse material, and it was gathered behind the college building. The utilized particle size spans from 5 to 20 mm. In order to achieve saturated surface dry conditions and ensure that the water cement ratio remains unaffected, the coarse aggregate was air dried. Shape, texture, gradation, and wetness are a few properties that influence the workability and connection between concrete matrixes. The aggregate utilised had a nominal size of 10 mm. Nigeria's Anambra state supplied the coarse aggregate.

➢ *Alkaline Activator :*

The mixture of alkaline activators used to activate coal ash is a combination of alkaline compounds specifically formulated to enhance the reactivity and utilization of coal ash as a supplementary cementitious material. Coal ash, also known as fly ash, is a by-product of coal combustion in power plants and contains high amounts of silica and alumina, which can be effectively activated through alkaline activation.The alkaline activators typically used in this mixture include sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). These compounds create an alkaline environment that triggers the dissolution and reaction of the silica and alumina present in coal ash. The resultant chemical reactions lead to the formation of calcium silicate hydrate (C-S-H) gel, which acts as a binding agent, contributing to the strength and durability of the final material.The activation of coal ash with the mixture of alkaline activators offers several benefits. It enhances the reactivity and pozzolanic properties of coal ash, improving its cementitious characteristics. This activation process allows for the utilization of coal ash as a sustainable alternative to traditional cement materials, reducing the environmental impact associated with its disposal. Moreover, the activated coal ash can enhance the mechanical properties of concrete, such as strength and durability, making it suitable for a wide range of construction applications.

(a)

(b)

(c)

Fig 2 (a) Mixing of Concrete Properly (b) Mixing of the Alkaline Activator (c) after Casting of the Concrete

IV. RESULTS AND DISCUSSIONS

A. *This Section Contains an Analysis of the Laboratory Experiment Outcomes.*

➢ *Compressive Strength Test*

The compressive strength test was carried out on hardened geopolymer concrete of coal ash and coconut fiber. This test was carried out to note the ability of the concrete to resist load resting on it. This was done with the compressive testing machine.

Below is the compressive strength test carried out on three samples of geopolymer concrete using coal ash and there respective weights. Sample A is explained on Table1, Sample B on Table 2 and Sample C on Table 3

- *Compressive Strength Test on Sample A*

Table 1 The Weight and Comprehensive Strength Test of Sample A

Days of Curing	Weight of Sample (kg)	Compressive Strength of Sample (Mpa)
7	-	-
14	-	-
28	8.87	2.90

- *Compressive Strength Test on Sample B*

Table 2 The Weight and Comprehensive Strength Test of Sample B

Days of Curing	Weight of Sample (kg)	Compressive Strength of Sample (Mpa)
7	-	-
14	-	-
28	9.05	4.20

- *Compressive Strength Test on Sample C*

Table 3 The Weight and Comprehensive Strength Test of Sample C

Days of Curing	Weight of Sample (kg)	Compressive Strength of Sample (Mpa)
7	-	-
14	-	-
28	8.94	3.80

The tables above displays the sample weight, and results of the compressive strength test carried out on three sample (A,B,C) of the geopolymer concrete after 28 days of currring. On Table1, it shows that Sample A has a weight of 8.87kg, with a corresponding compressive strength of 2.90Mpa. while on Table 2, it shows that Sample B has a mass weight of 9.05kg and a compressive strength of 4.20Mpa. Then for Sample C, it has a weight of 8.94kg and a compressive strength of 3.80Mpa.

From the looks of this result, it is clear that the results gotten from the test are poor, and cannot be guaranteed on for any engine activity, the poor results gotten can range from inacurate chemical (activators) mix and also a poor concrete mix.

V. CONCLUSION

The production of concrete using a combination of coal ash and coconut has yielded low compression strength test results. This suggests that the current formulation may not be suitable for applications that require high strength concrete. To enhance the strength of concrete in future research, several aspects should be considered. Firstly, the particle size and distribution of the coal ash and coconut components should be carefully examined. The use of finer particles can improve the packing density and fill voids within the concrete matrix, leading to increased strength. Additionally, the proportion of coal ash and coconut in the mix should be optimized to achieve a balance between strength and workability.

Moreover, the curing conditions play a crucial role in concrete strength development. Future researchers should investigate different curing regimes, such as temperature, humidity, and duration, to identify the most effective curing methods for the coal ash and coconut-based concrete. The addition of chemical admixtures, such as super-plasticizers or accelerators, should also be explored to improve workability and strength.

So, future researchers should focus on optimizing the particle size and distribution, proportion of components, curing conditions to enhance the strength of concrete produced using coal ash and coconut. By addressing these factors, it is possible to develop a concrete formulation with improved compression strength, making it suitable for various applications in the construction industry.

REFERENCES

[1]. Atnaw P., Nanko, H., Kurtis K. E. Durability of pulp fibre-cement composite to wet/dry cycling, Cement and Concrete Composite, December, 2011.

[2]. Asasytiarit , C 2009.; Srength of concrete beams with aligned or random steel fibre micro-reinforcement, 1st RILEM Symposium on Fibre-Reinforced Concrete, 1, 2009, pp. 95-103, 1975.

[3]. Bai, J., Wang, K., and Liu, R. (2019) Experimental study on the performance of concrete with coal ash and coconut fiber

[4]. Basha, E.A., Hashim, R., Mahmud, H.B., and Muntohar, A.S. 2005. Stabilization of residual soil with rice husk ash and cement

[5]. Chandramouli, K., Murugesan, R., and Vaidyanathan, R. 2021. Mechanical properties of fly ash-based geopolymer concrete using coconut fiber

[6]. Fordos, G., 1989.. Study into the durability of natural Cement and concrete composite fibres and the effect of corroded fibres on the strength of mortar, 27, (5), 1989, pp. 575-582.

[7]. Hwang, C.L., Li, H., and Hwang, S.W. 2017. Mechanical properties of lightweight aggregate concrete with coconut fiber and coal ash

[8]. Islam, M.A., Hassan, S.S., and Hasan, M.R.: 2019 Effect of coconut fiber and rice husk ash on the mechanical properties of concrete

[9]. Joseph, M. and Mathew, G.2019 An experimental study on mechanical properties of coconut fiber reinforced concrete

[10]. Kadiranaikar, R., Sankara, Gomathi, S., and Yuvaraj, D.2020 Experimental investigation on the properties of coconut fiber reinforced concrete incorporating coal ash

[11]. Rehsi S.S., Use of natural fibre concrete in India. Concrete technology and design Natural fibre reinforced cement and concrete, 5, 1991 pp. 243-256.