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Exploring the Application of Coconut Shell as a Coarse (stone) aggregates Aggregate in Concrete

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Abstract:

As construction material costs continue to rise, there's a growing exploration of alternatives to traditional coarse (stone) aggregates aggregates in concrete. A noteworthy trend in places like Malaysia, Nigeria, and Ghana involves using coconut shells instead of conventional gravel. This innovative approach not only tackles economic challenges in construction but also contributes to managing agricultural solid waste sustainably. Every day, a significant amount of coconut shells is discarded as agricultural waste. Repurposing these shells for construction offers a substantial cost reduction, up to 48%, and aligns with environmental sustainability goals by turning waste into a valuable resource.

Implementing coconut shells as a coarse (stone) aggregates aggregate in concrete showcases resourcefulness and highlights the potential for a more eco-friendly construction industry. This novel approach not only addresses economic constraints in construction but also aligns with global efforts to promote sustainability. By transforming agricultural waste into construction material, we not only reduce the environmental impact of waste disposal but also contribute to the development of a circular economy.

As Malaysia, Nigeria, and Ghana lead the way in adopting this innovative construction practice, there's potential for broader global adoption. This promises a more sustainable and cost-effective future for the construction industry, emphasizing the dual benefits of economic savings and environmental responsibility.

Keywords: Coconut Shells, Construction Materials, Sustainable Practice, Circular Economy

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Introduction

Concrete, an artificial material mirroring the characteristics of natural limestone, is a composite of natural elements—gravel, crushed rock, sand, fine cement particles, and water. As time progresses, concrete undergoes cement paste hydration, acquiring the strength necessary for enduring various loads. Traditionally, the widespread use of coconut shells as coarse (stone) aggregates aggregates in concrete is uncommon, especially in areas necessitating lightweight concrete for non-load bearing structures like walls, non-structural floors, and strip footings. Despite coarse (stone) aggregates aggregates comprising about 50% of concrete's total self-weight, the increasing costs of construction materials pose challenges due to high demand, scarcity of raw materials, and heightened energy prices.

Globally, there is a focus on exploring alternative constituents for construction materials to conserve energy and use natural resources responsibly. Research and development have made strides in recycling solid wastes for civil engineering applications, exemplified by the successful utilization of fly ash, blast furnace slag, recycled aggregates, red mud, kraft pulp production residue, and waste tea.The coconut, cultivated in over 93 countries, traces its origin to South East Asia and plays a significant role in India, ranking as the third-largest producer. With an annual production of approximately 7562 million nuts, the coconut industry significantly contributes to global coconut oil output. However, this industry also contributes to pollution through the disposal of solid waste, primarily coconut shells, amounting to around 3.18 million tonnes annually. Coconut shell waste, constituting over 60% of domestic waste volume, presents a substantial environmental challenge.

In developing countries grappling with considerable agricultural and industrial waste, these by-products emerge as potential construction materials. Utilizing coconut shells not only addresses waste disposal but also offers a dual benefit by reducing construction material costs. As nations seek sustainable solutions, integrating agricultural and industrial waste into construction practices emerges as a promising avenue for both economic and environmental considerations.

Methodology

This study utilized volume batching with a standard 150x150x150 mm mould for casting cubes. The mould assembly, completed before mixing, ensured easy removal of hardened concrete

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cubes through proper lubrication. Various mix ratios of granite and coconut shell, ranging from 0 to 100 percent, were prepared. The mixture was diligently turned with a shovel until reaching a plastic state before being placed into the lubricated cast iron mould. Subsequently, a water curing method was applied, allowing the concrete cubes 24 hours to set before demoulding.

The demoulded cubes were then immersed in a curing tank to strengthen the concrete, aid hydration, reduce shrinkage, and absorb heat until the designated test age. Curing durations of 7, 14, 21, and 28 days were implemented. Before testing, the cubes were weighed, and their densities were measured at different testing intervals. To prepare specimens for testing, they were removed from the curing tank and left in the open air for about 3 hours before undergoing crushing tests. Compressive strength assessments adhered to BS 1881, utilizing a universal crushing machine.

Coconut Shell as Coarse (stone) aggregates Aggregate: Sourcing coconut shells involved acquiring them from a local coconut field in Kampung Kurnia, Kuantan Pahang. After a month of sun-drying, the shells underwent manual crushing. Subsequently, the crushed materials were transported to the laboratory, where they were washed and underwent an additional month of drying under ambient temperature conditions. Coconut shell particle sizes ranged from 5 to 20 mm.

Coarse (stone) aggregates Aggregate: Coarse (stone) aggregates aggregates, materials retained on a 5mm (3/16 inc) test sieve, adhered to specifications outlined by MS 29:1995, BS 410, and BS 882. Classification included uncrushed gravel, crushed stone or gravel, and partially crushed gravel—resulting from the bending of uncrushed and crushed gravel. For this study, coarse (stone) aggregates aggregates comprised sandstone with a maximum size of 15 mm.

Sand (Fine Aggregate): Sand was divided into two types: natural sand and crushed stone or crushing gravel sand. The study incorporated river sand and crushed sandstone, with fineness passing through a 2.36 mm BS 410 test sieve. The material used had a maximum particle size of 2.36 mm in diameter, adhering to cleanliness standards, free from clay lumps or coatings, and devoid of salt contamination. Concrete grade targeted was 30, with mixed proportions detailed in the accompanying table. A constant water-cement ratio of 0.5 was maintained for mix ratios of Cement: Fine Aggregate: Coarse (stone) aggregates Aggregate at 1:2:4.

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EXPERIMENTAL PROCEDURE:

The experimental program aimed to assess the influence of natural aggregate types on the strength characteristics of confined concrete. Key aspects included:

Identification of Optimal Mix Proportions: The investigation sought effective mix proportions for coconut shell as coarse (stone) aggregates aggregate and river sand as fine aggregate in concrete. Determination was based on the strength-to-weight ratio of sample specimens.

Evaluation of Feasibility: Assessment of the viability of utilizing coconut shell as coarse (stone) aggregates aggregate and river sand as fine aggregate in concrete was a focal point. This was carried out by examining the compressive strength behavior and durability of the combined materials.

Impact on Workability and Mechanical Properties: The study delved into how the combination of coconut shell as coarse (stone) aggregates aggregate and river sand as fine aggregate affected workability as a lightweight aggregate in concrete. Simultaneously, it examined its impact on various mechanical properties.

Optimization of Content: An essential aspect was determining the optimum content of the combination of coconut shell as coarse (stone) aggregates aggregate and river sand as fine aggregate in concrete. This aimed to enhance ductility without compromising compressive strength.

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Results

Compressive strength of concrete cubes with 25% replacement of coconut shells .

Sample ID	Age of curing (days)	Weight of cube (kg)	Average Density of cube (kg/m^3)	Crushing load (KN)	Crushing strength (N/mm^2)	Average strength
A	7	8.26	2432	465	20.22	19.90
B		8.20		450	20.00	
C		8.18		444	19.73	
A	14	8.30	2471	505	22.44	22.50
B		8.34		494	21.96	
C		8.38		520	23.11	
A	21	8.40	2501	600	26.67	26.70
B		8.45		595	26.44	
C		8.47		610	27.11	
A	28	8.52	2516	632	28.09	28.10
B		8.47		635	28.22	
C		8.49		629	27.95	

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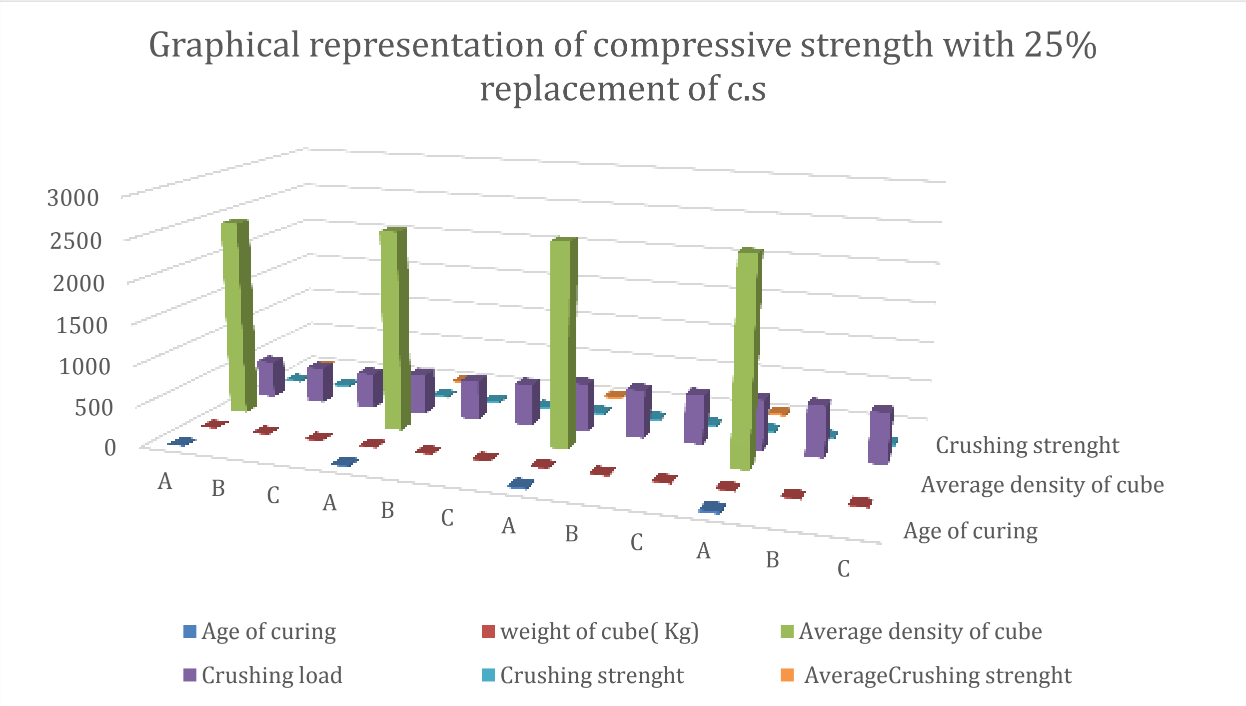

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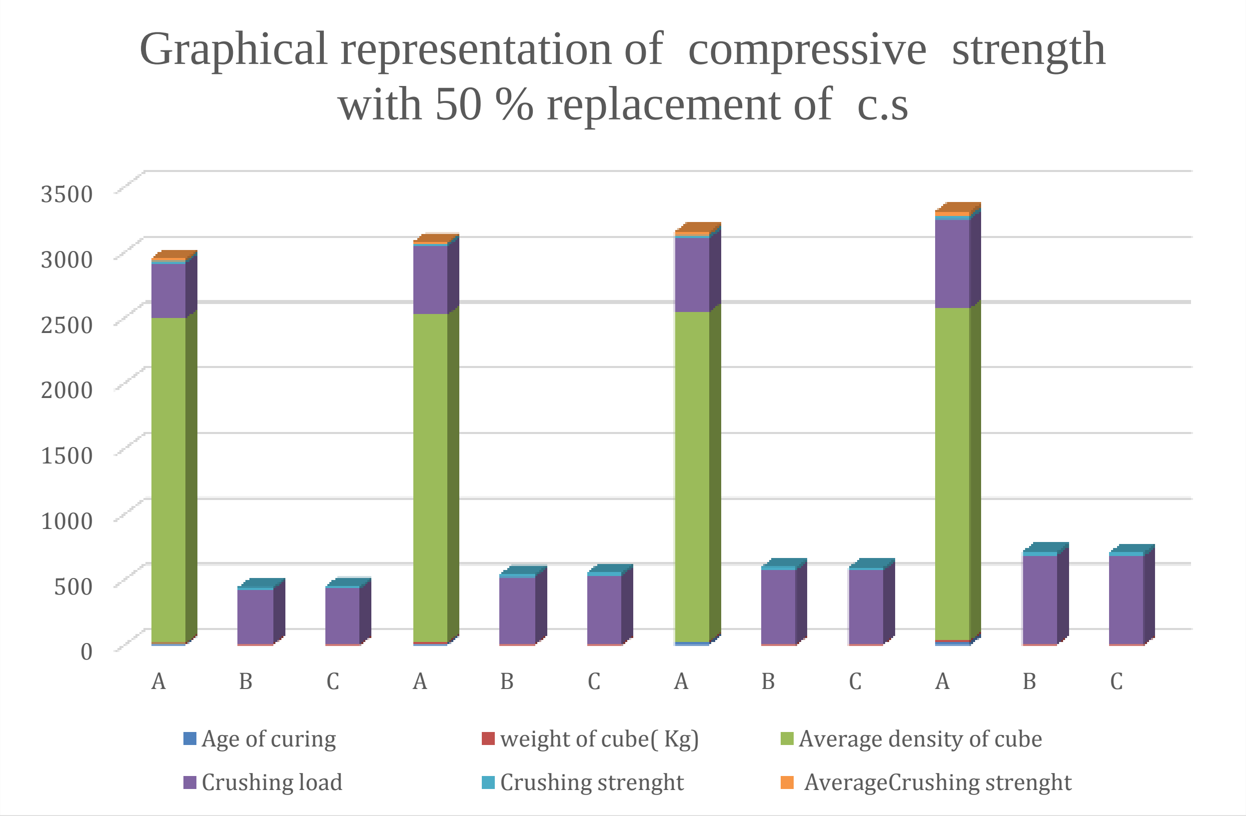
Sample ID	Age of curing (days)	Weight of cube (kg)	Average Density of cube (kg/m^3)	Crushing load (KN)	Crushing strength (N/mm^2)	Average strength
A	7	8.36	2480	420	18.17	18.50
B		8.35		416	18.49	
C		8.40		423	18.80	
A	14	8.45	2501	521	23.16	10.40
B		8.40		511	22.71	
C		8.48		525	23.33	
A	21	8.46	2516	561	24.93	24.93
B		8.52		563	25.02	
C		8.48		559	24.84	
A	28	8.56	2536	681	30.27	30.00
B		8.51		675	30.00	
C		8.60		670	29.78	



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Conclusions

Based on the findings and subsequent discussion, the incorporation of coconut shell demonstrates potential as a lightweight aggregate in concrete. Utilizing coconut shells as an aggregate in concrete has the dual advantage of reducing material costs in construction due to its economical and abundant nature. However, it's noteworthy that an increase in the percentage of coconut shell replacements resulted in a reduction in the strength and density of the concrete. The substitution of gravel with coconut shells has the potential to decrease construction material costs by up to 48%.Moving forward, additional investigations are warranted to explore the feasibility of utilizing coconut shell concrete in structural applications. Moreover, durability studies are essential to evaluate its performance in aggressive environments. In the context of developing countries such as Ghana, promoting the utilization of agricultural wastes in construction is recommended not only as an environmental protection measure but also as a means of cost reduction. Encouraging such sustainable practices can contribute to both environmental conservation and economic efficiency in construction endeavours.

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