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The utilization of coconut fibre and the Partial Replacement of Coarse Aggregate with Coconut Shell in Concrete for Low-Cost Housing

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Abstract:

Concrete production with sustainable and eco-friendly materials has gained attention, and one such material is coconut shell. This abstract summarizes studies on the mechanical properties of concrete with coconut shell as a partial replacement for conventional aggregates.

Research has explored the impact of replacing coarse and fine aggregates with coconut shell, revealing a decrease in density, compressive strength, and flexural strength as the volume fraction of coconut shell increases. Despite these reductions, the potential of coconut shell as a partial replacement for aggregates, especially in low-cost housing projects, is acknowledged.

This abstract highlights the need for a balanced approach, considering both the mechanical properties and the sustainability aspects of using coconut shell in concrete. Further research is essential to optimize the incorporation of coconut shell in concrete mixes for achieving a balance between mechanical strength and environmental benefits.

Introduction

The exploration of alternative materials in construction, driven by sustainability concerns, has led to investigations into the partial replacement of conventional aggregates in concrete with coconut shell. This topic has gained significant attention due to its potential environmental and economic benefits. Researchers have delved into various aspects of this substitution, aiming to understand its impact on the mechanical properties and overall performance of concrete.

Coconut shell, being a waste by-product of coconut processing, presents an opportunity for sustainable construction practices. Studies have focused on assessing the effects of replacing both coarse and fine aggregates with coconut shell on concrete properties such as density, compressive strength, and slump. Additionally, the potential use of coconut shell in low-cost housing projects has been explored, emphasizing its affordability and availability.

While there is evidence suggesting a decrease in certain mechanical properties with increased coconut shell content, the research landscape is dynamic, with ongoing efforts to optimize mix designs and enhance the feasibility of incorporating coconut shell in concrete.

This introduction sets the stage for a detailed examination of the impact of coconut shell as a partial replacement for coarse aggregate in concrete, emphasizing its potential benefits and the need for further research to achieve a balance between sustainability and structural integrity.

Future Scope

1. **Enhanced Sustainability**: Investigate methods to further enhance the sustainability aspects of concrete with coconut shell and fiber. Explore innovative technologies or treatments to optimize the use of these materials, contributing to eco-friendly construction practices.

2. **Innovative Composite Materials**: Research the development of novel composite materials incorporating coconut shell and fiber. Explore the integration of these materials with other sustainable additives to create high-performance and versatile construction materials.

3. **Durability Enhancements**: Focus on improving the durability properties of coconut shell and fiber concrete. Investigate additives or coatings that can further enhance resistance to environmental factors, ensuring long-term performance and reduced maintenance needs.

4. **Structural Applications**: Explore the feasibility of using coconut shell and fiber concrete in diverse structural applications. Assess the material's adaptability and strength for applications beyond traditional concrete, such as in precast elements or specialized constructions.

5. **Optimization of Fiber Content**: Further optimize the content and types of fibers in the concrete mix. Investigate the impact of different fiber combinations on both the mechanical and durability properties of concrete to achieve an optimal balance.

6. **Integration with Construction Technologies**: Explore integration with modern construction technologies, such as 3D printing or smart concrete. Investigate how coconut shell and fiber materials can be incorporated into advanced construction processes to enhance efficiency and functionality.

These future scopes aim to advance the utilization of coconut shell and fiber in concrete, paving the way for more sustainable, durable, and versatile construction materials.

Research Questions

1. How does the partial replacement of coarse aggregate with coconut shell impact the compressive strength, workability, and overall performance of concrete?
2. In what ways can coconut shell be effectively utilized as a substitute for natural coarse aggregate, and how does its usage contribute to sustainable construction practices?

3. What are the optimal proportions of coconut shell in concrete mixtures to achieve a balance between structural integrity and environmental sustainability?
4. How does the addition of coconut fiber influence the mechanical properties and durability of cement composites, and what are the suitable applications for these enhanced materials?
5. Can waste coconut shell be employed as a feasible ingredient for the partial or complete replacement of coarse aggregate, especially in the manufacturing of lightweight concrete structures?
6. To what extent can coconut fiber enhance the properties of concrete, and how does it compare to traditional reinforcement materials in terms of cost and effectiveness?

These research questions aim to address various aspects of incorporating coconut shell and fiber in concrete, exploring their effects on strength, sustainability, and overall suitability for construction applications.

Objectives

1. **Assess Compressive Strength**: Investigate the impact of incorporating coconut shell and fiber in concrete on compressive strength. Examine variations in strength concerning different ratios of coconut shell and fiber, aiming to identify the optimal mix for enhanced strength.
2. **Explore Durability Properties**: Study the durability properties of coconut shell concrete with added fiber. Evaluate factors such as water absorption, volume stability, and resistance to environmental conditions to understand the long-term performance.
3. **Investigate Lightweight Concrete Properties**: Examine the viability of using coconut shell as a replacement for coarse aggregate in lightweight concrete production. Analyze the effect of coconut shell and fiber on the density and structural properties of lightweight concrete.
4. **Optimize Fiber Content**: Explore the optimization of coconut fiber content in coconut shell concrete. Investigate the mechanical and bond properties of the concrete to determine the most effective ratio of coconut fiber for improved performance.
5. **Enhance Compressive Strength with Steel Fiber**: Conduct an experimental investigation on the potential enhancement of compressive strength through the addition of steel fiber in coconut shell concrete. Explore the combined effects of coconut shell, fiber, and steel on the concrete's structural properties.

LITERATURE REVIEW

Satish shinde, ramiz sayed,(2016) : In this paper authors mainly discussed about basic things needed to make human alive like meal, lodging and clothes. They replaced M20 grade concrete by coconut shell as a coarse cluster. In a ratio of 1:1 cubes and circular solids were lobbed respectively and their confining and elastic strength at 4 weeks test. The confining strength and ductile strength of concrete reduced because the proportion replacement inflated. Concrete made by replacing 10%, 15%, 20% of coarse mixture by coconut shell earned by twenty eight

days confining strength and ductile strength. They got the results which made a big difference in price and more than that it is environment friendly.

Daniel yaw osei (2013) : In the paper authors used 1:2:4 concrete mixture. 27 cubes were placed and tested various types of strengths were evaluated at 1, 2, 3 and 4 weeks. The concrete is replaced at 20%, 30%, 40%, 50%,100%. The results of the review demonstrated that concrete created by replacement of the crushed granite by coconut shell is utilized in Ferro-concrete construction. A possible exists for the employment of coconut shells as replacement of standard combination in each standard Ferroconcrete and light weight Ferro-concrete construction. To reduce the usage of environment harmful materials in construction mixture by using coconut shell waste for standard mix which make the mixture eco-friendly.

S.abirami, k.muniyammal (2016) : The authors of this paper discusses about the natural and synthetical properties of concrete materials. By using IS code method the Concrete mix design is done. Feasibleness of raw concrete like compaction and slump cone tests will be done. Various strengths will harden concrete like confining strength of concrete cubes at first and second week and split ductile strength of cylinder at first and second week and flexural prism power at first and second week. To compare the feasibleness and a strength variety for percentage variants of replacement of coarse mixture with coconut shell. Mainly the lightweight concrete will be prepared.

Tomas u. Ganiron jr (2013) : The author's experimental research covered a wide series of property tests like mechanical property and sieve analysis tests along with the content of specific moisture gravity Test were undertaken in accordance with the ASTM Outcomes showed that by replacing certain amount of coconut shell can satisfy the concrete work mix. When differentiated the normal concrete mixture's strength with the coconut shell included concrete's strength is more.

Damre shraddha1, firake hitali1 (2014) : In this paper we studied that aamong the useful agricultural waste materials the family of palm shells namely palm shell and coconut shell are highly available in torrid zones of the world. According to research coconut shell aggregates are in ratio of 1:5 used in normal concrete when compared with the compressive strength results that are obtained.

Ajay lone, aniket deshmukh (2016) : The coarse aggregate are the main materials of concrete. In authors of this paper discussed about replacing coconut shell for coarse aggregate. 25% and 50% of coarse aggregate replacement prepared by binding constantly along with water in the ratio of 0.45 per all mixes, density, workability and water adsorption. One week, two weeks and four weeks were determined compressive strength, tensile strength and flexural strength.

Parag s. Kambli, sandhya r. Mathapati (2014) : The goal of the above paper was to use eco waste in construction materials which reduces the cost for housing. And it also purposes of encouraging house developers and investing these materials in house construction. They used three variants of concrete mixes in three different grades known as M20, M35 and M50 grades with various proportions of natural material. 0%, 10%, 20%, 30%

and 40% will be replaced and 7 and 28 days tests will conducted.

Zengh (2008) and Yan (2000) : Scrap tires and polyolefin properties of concrete composites had been determined by Zengh (2008) and Yan (2000) respectively. Zengh conclude that crushed rubberized concrete and damping ratio grinded will reach as high as 144% and 75% respectively with respect to PC. With increase in damping decreases in response frequencies for studied FRC composite was founded by Yan.

Gunase karan (2008) : After an experiment conducted by Gunase karan and Kumar in 2008 they found that there is 24% high water absorption by concrete reinforced with coconut fiber compare to PC . They found that compressive strength of concrete increases with 19.1% than PC after curing cube for 28 days.

Adevemi (1998) : Research carrier out by Adevemi (1998) for one mix ratio (1:2:4) using suitable coconut fiber for either fine or coarse aggregate in concrete production. They conclude that the weight of that concrete is light with compare to PC.

Reis (2006) : The investigation by Reis (2006) characterise the mechanical properties of epoxy polymer concrete reinforced with natural fiber (Coconut, Sugarcane bagasse, banana fiber).Which conclude that fracture toughness and fracture energy of coconut fiber reinforced polymer concrete where higher than that of other reinforced polymer concrete and there is 25% increase in flexural strength with coconut fibers only .

Baruah and Talukdar (2007) : With different fibers volume fraction ranging from 0.5% to 2% , Baruah and Talukdar (2007) performed an experiment to investigate the static properties of plain concrete (PC) and fiber reinforced concrete (FRC).They use the natural fibers (jute and coir fibers only). They conclude that CFRC with 2% fiber shows better result that all volume fractions. There is increase in 13.7%, 22.9%, 28.0%, 32.7% in strength, splitting tensile strength, modulus of rupture using four point loud test and shear stress respectively as compare to PC.

Satish shinde,Ramiz sayed (2016): They replacedM 20 grade concrete by coconut shell as a coarse cluster. Concrete made by replacing 10%,15% of coarse mixture by coconut shell earned by 28 daysconfining strength and ductile strength

Sanjay kumar (2019): The investigation 0f use of coconut shell as partially substitution of coarse aggregate. In this work compressive strength of M20 grade had been concentrated by swappingnatural coarse aggregate. This consequence indicates that coconut shell concrete can be usedas a mild weight concrete

Lopa M.Shinde (2015): They recommended to promote sustainable development of the structure in order to lower the impact of the environment .It highly issues the concern about recycling the material in order to lower the burden on natural resources.

Gap Identification

1. **Limited Exploration of Coconut Shell Powder (CSP):** Existing studies primarily focus on the mechanical properties of concrete with coconut shell aggregates or fibers. However, there is a gap in the literature regarding the comprehensive exploration of the use of coconut shell powder (CSP) as a filler in concrete, particularly in terms of its impact on the material's properties.

2. **Insufficient Understanding of Structural Changes:** The alteration of concrete structure and characteristics due to the incorporation of coconut shell and fiber is not thoroughly understood. A more in-depth analysis is needed to identify the specific changes in the concrete structure based on varying proportions of coconut shell content in the mixture.

3. **Optimal Fiber Length and Content:** While studies acknowledge the improved toughness and flexural strength of concrete with coconut fibers, there is a gap in determining the optimal fiber length and content for achieving the best balance between enhanced properties and practicality in construction.

4. **Lack of Economic and Strength Aspect Integration:** Although experimental studies have demonstrated the economic and strength benefits of coconut shell concrete (CSC), there is a gap in integrating these aspects. Further research can explore how the economic advantages of using coconut shells align with the material's strength characteristics.

METHODOLOGY:

This chapter describes the methodology and materials used to achieve the objectives. The main materials characterized in the present study are cement, fine aggregate, coarse aggregate, and coconut shell; experimental methodology followed for characterization of these materials are discussed. A brief introduction about the above materials and methodology is presented in the following section in this chapter.

Methodologies

1. **Optimization of Coconut Fiber in Coconut Shell Concrete:** Research has delved into optimizing the addition of coconut fiber to coconut shell concrete, aiming to enhance its properties. This optimization involves finding the optimal proportions to achieve desirable outcomes in terms of strength and durability.

2. **Effect of Coconut Shell and Fiber on Concrete Strength:** Studies have investigated the impact of incorporating both coconut shell and fiber on the compressive and flexural strength of concrete. This involves analyzing the reinforcement effects and understanding how these elements influence the overall strength characteristics.

3. **Durability Properties of Coconut Shell Concrete:** The durability properties of coconut shell concrete, especially when reinforced with coconut fiber, have been studied. This includes examining water absorption, volume stability, and other factors contributing to the long-term performance of the concrete.

4. **Mixture Proportioning Methodology:** Investigations have explored the methodology for proportioning concrete mixtures containing coconut shell. This includes determining the appropriate size of coconut shell aggregates and establishing the mix proportions for optimal performance.

5. **Use of Coconut Fiber in Cement Composites:** A comprehensive review discusses the utilization of coconut fiber as a polymeric fiber in various cement composites, including concrete. The study covers applications in slabs, plates, and pavement, shedding light on the versatility of coconut fiber in enhancing different types of concrete structures.

6. **Enhancing Strength Properties of Concrete:** Investigations focus on improving the strength properties of concrete by incorporating coconut fiber. The objective is to understand how coconut fiber contributes to enhancing the overall strength characteristics of the concrete mix.

MATERIAL SPECIFICATION

For the production of concrete, the constituent materials are cement, fine aggregate, coarse aggregate, coconut shell and water. To get better workability and strength, the material used should have better quality. To maintain the safety of any structure, provisions are provided as per IS 456:2000.

1. Ordinary Portland Cement

Ordinary Portland cement is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. The OPC is classified into three grades, namely 33 grade, 43 grade, 53 grade depending upon the strength of 28 days. It has been possible to upgrade the qualities of cement by using high quality limestone, modern equipment's, maintaining better particle size distribution, finer grinding and better packing. Generally, use of high-grade cement offers many advantages for making stronger concrete. Ordinary Portland cement (OPC) of 53 Grade (UltraTech cement, Ambuja cement) was used throughout the course of the investigation. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture. The various tests conducted on cement are initial and final setting time, specific gravity, fineness , and compressive strength.

Sr.No.	Properties	Values
1	Specific gravity	3.15
2	Normal consistency	31%
3	Initial setting time	30 min
4	Final setting time	600 min
5	Compressive strength	26.35 N/mm^2
6	Soundness Test	1 mm

Table no.1 : Properties of cement

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Fig. No.1 : Cement

2. Fine Aggregate

Fine aggregate is the essential ingredient in concrete that consists of natural sand or crushed stone. The quality and fine aggregate density strongly influence the hardened properties of the concrete. The concrete or mortar mixture can be made more durable, stronger, and cheaper if you made the selection of fine aggregate on basis ofgrading zone, particle shape and surface texture, abrasion and skid resistance and absorption and surface moisture.

Sr.No.	Properties	Values
1	Specific gravity	2.55
2	Water content	1.8%
3	Bulking	4%

Table No.2 : Properties of fine aggregate

Fig. No. 2 : Fine aggregate

3. Coarse Aggregate

Aggregates constitute the bulk of a concrete mixture and give dimensional stability to concrete. To increase the density of resulting mix, the aggregates are frequently used in two or more sizes. The most important function of

the fine aggregate is to assist in producing workability and uniformity in mixture.

Sr.No.	Properties	Values
1	Specific gravity	2.75
2	Impact value	27.94%
3	Water absorption	1.10%

Table No.3 : Properties of coarse aggregate

Fig. No. 3 : Coarse aggregate

4. Coconut Shell

Coconut shells used in the study are brought from local temple. The coconut shells are sundried for five days before using it as an aggregate. The cleaning of coconut shell is carried with the help of sandpaper, the smaller extractions on the outer face of coconut is cleaned with the help of water. The outer shell is then broken in smaller parts up to 20 mm. The broking of coconut shell is done with the help of 30 kg hammer. Then the broken pieces are passed through IS 20 mm sieve and pieces are retained on a IS 16mm sieve are used.

Sr.No.	Properties	Values
1	Specific gravity	1.05 – 1.20
2	Bulk density	650 kg/m^3
3	Impact value	8.15%
4	Shell thickness	2 – 6 mm
5	Moisture content	4.20%

Table.no. 4 : Properties of Coconut Shell

Fig. No. 4 : Coconut shell

5. Coconut fiber

Coconut fiber is extracted from the outer shell of a coconut. It is also called coir fiber or coco fiber. It is the **natural fiber** of the coconut husk where it is a thick and coarse but durable fiber. The individual fibre cells are narrow and hollow, with thick walls made of cellulose. They are pale when immature but later become hardened and yellowed as a layer of lignin, is deposited on their walls. Mature brown coir fibres contain more lignin and less cellulose than fibres such as flax and cotton and so are stronger but less flexible. They are made up of small threads, each less than 0.05 inch (1.3 mm) long and 10 to 20 micrometres in diameter. White fibre is smoother and finer, but also weaker. The coir fibre is relatively waterproof and is the only natural fibre resistant to damage by salt water.

Fig. No. 5: Coconut fiber

6. Water

Water is a key ingredient in the manufacture of concrete. Water used in concrete mixes has two functions: the first is to react chemically with the cement, which will finally set and harden, and the second function is to lubricate all other materials and make the concrete workable.

Methodologies

7. **Optimization of Coconut Fiber in Coconut Shell Concrete:** Research has delved into optimizing the addition of coconut fiber to coconut shell concrete, aiming to enhance its properties. This optimization involves finding the optimal proportions to achieve desirable outcomes in terms of strength and durability.

8. **Effect of Coconut Shell and Fiber on Concrete Strength:** Studies have investigated the impact of incorporating both coconut shell and fiber on the compressive and flexural strength of concrete. This involves

analyzing the reinforcement effects and understanding how these elements influence the overall strength characteristics.

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10. **Mixture Proportioning Methodology:** Investigations have explored the methodology for proportioning concrete mixtures containing coconut shell. This includes determining the appropriate size of coconut shell aggregates and establishing the mix proportions for optimal performance.

11. **Use of Coconut Fiber in Cement Composites:** A comprehensive review discusses the utilization of coconut fiber as a polymeric fiber in various cement composites, including concrete. The study covers applications in slabs, plates, and pavement, shedding light on the versatility of coconut fiber in enhancing different types of concrete structures.

12. **Enhancing Strength Properties of Concrete:** Investigations focus on improving the strength properties of concrete by incorporating coconut fiber. The objective is to understand how coconut fiber contributes to enhancing the overall strength characteristics of the concrete mix.

Expected Outcomes

The utilization of coconut shell and fiber in concrete is anticipated to yield several favourable outcomes:

1. **Improved Strength:** Incorporating coconut shell and fiber has shown to enhance the compressive strength, flexural strength, and split tensile strength of concrete. This contributes to the overall robustness and load-bearing capacity of the material.

2. **Optimized Mechanical Properties:** Studies highlight the optimization of coconut fiber parameters, such as length and volume fraction, leading to improved mechanical properties. This includes aspects like compressive strength and workability.

3. **Enhanced Durability:** The addition of coconut fibers contributes to increased durability, impact resistance, and toughness of concrete. This makes the material more resilient to external forces and environmental conditions.

4. **Density Reduction in Lightweight Concrete:** When coconut shell is integrated into concrete formulations, it results in lightweight concrete with reduced density. This is beneficial for applications where weight is a crucial consideration, such as in construction projects requiring lighter materials.

5. **Modulus of Elasticity Enhancement:** The increase in the volume fraction of coconut fibers has been linked to improvements in compressive strength and modulus of elasticity in coconut shell concrete.

6. **Better Mechanical and Durability Properties:** Studies indicate that concrete incorporating both coconut fiber and sawdust demonstrates improved mechanical and durability properties, suggesting a positive synergistic effect.

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