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Study on Mechanical Properties of Concrete through the Combined Use of Pozzolonic & Fibrous Materials from Agricultural Waste

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Abstract
The mechanical properties of concrete using pozzolonic and fibrous materials through agricultural waste. In this, the focus was on enhancing the performance of concretes made possible by incorporating by-products of agricultural processes into the mix. The key objective was to investigate the use of rice husk ash, coconut shell powder, and other product-waste streams from agricultural activities in getting the best possible concrete benefits, especially regarding stren gth, durability, and sustainability.

Keywords: Pozzolanic Materials, Fibrous Materials, Concrete

INTRODUCTION

Concrete is the most commonly utilized construction material globally, prized for its high compressive strength, long-lasting durability, and adaptability across a wide range of building projects. It is a mixture of cement, aggregates, and water, with cement acting as the binder that holds the aggregates together.

We believe that the waste Bagasse could be used for more productive and environmental solutions rather than just burning it for electricity. In order to do shift from the current use to our vision, we have to make sure it is more efficient to use in construction rather than burning it.

Agricultural Waste (Pozzolanic) Material

Agricultural waste products, such as rice husk ash (RHA) have gained significant attention due to their high silica content, which contributes to their pozzolanic activity. These by-products are produced in large quantities and often pose environmental disposal challenges. By transforming these wastes into value-added materials for concrete production, their use helps reduce waste and lower the carbon footprint of concrete.

Rice Husk Ash (RHA): Rice husk ash is a well-known agricultural waste that has shown excellent pozzolanic properties. Studies have demonstrated that RHA, when used as a partial replacement for cement, improves concrete's compressive strength, durability, and resistance to aggressive environments like sulfate and chloride attack (Basu, 2017). The amorphous silica in RHA reacts with calcium hydroxide in the cement matrix to form calcium silicate hydrate (C-S-H) gel, which increases strength and density.

Incorporating these materials in concrete not only reduces the consumption of traditional cement but also contributes to the management of agricultural waste. Moreover, these by-products have lower embodied energy compared to conventional cement, making their use an eco-friendly solution for sustainable construction.

Role of Fibers in Concrete

Fibers have been increasingly organized into concrete to improve its mechanical properties, particularly its tensile strength, crack resistance, and post-crack behavior. The addition of fibers to concrete helps controls the development of cracks, enhances its ductility, and improves its toughness.

Types of Fibers:

Fibers can be broadly classified into two categories: synthetic and natural.

1. **Synthetic Fibers:** These include materials such as polypropylene, nylon, and polyester. They are often used to enhance concrete's impact resistance and durability.

- **Polypropylene** (PP) is a widely used thermoplastic polymer that is part of the polyolefin family, which also includes polyethylene. It is made from the polymerization of propylene monomers, a byproduct of petroleum refining.
- **Nylon** is a synthetic polymer, a type of plastic, that belongs to the family of polyamides. It was first developed by chemist Wallace Carothers and his team at DuPont in the late 1930s. Nylon became famous as one of the first fully synthetic fibers, and it is widely used for a variety of applications due to its strength, elasticity, and resistance to wear and tear.
- **Polyester** is a type of synthetic polymer made from petrochemical products, primarily derived from coal, oil, or natural gas. It is one of the most widely used fibers in the textile industry and has a variety of applications across different sectors.

2. **Natural Fibers:** Natural fibers such as Sugarcane, coir jute, and hemp,are being explored for their low environmental impact and potential to reinforce concrete. These fibers are renewable and biodegradable, making them a sustainable option for concrete reinforcement.

- **Sugarcane Bagasse (SCB):** Sugar cane refers to a variety of tall perennial grass species and hybrids used for sugar production. The plants are 2–6 m tall, with robust, jointed, fibrous stalks that are high in sucrose, which accumulates in the internodes of the stalks. The grass family includes sugarcanes. It is endemic to India, Southeast Asia, and New Guinea, where it grows in warm, temperate tropical climates.
- **Coir fibber (Cocos nucifera)** :Coconut Fiber is extracted from the outer shell of a coconut. The common name, scientific name and plant family of coconut fibre is coir, Cocos nucifera and Aceraceae (Palm), respectively There are two types of coconut fibre’s, brown fibber extracted from matured coconuts and white Fibers extracted from immature coconuts. also, weaker.

LITERATURE REVIEW

The construction industry is one of the largest global consumers of resources, and cement production plays a key role in its environmental footprint. Cement, while providing high strength and durability, is responsible for approximately 7-8% of global carbon dioxide (CO_2) emissions due to its energy-intensive production process As a result, there has been a growing emphasis on developing more sustainable concrete production methods.[1] One approach that has been widely studied is the use of pozzolanic & fibrous materials from agricultural waste, which can partially or fully replace traditional cement, thereby reducing its environmental impact.[2]

Agricultural waste is a valuable resource in sustainable concrete production due to its pozzolanic properties, which are beneficial in improving the mechanical properties of concrete.[3] The use pozzolanic & fibrous materials from agricultural waste helps to reduce the environmental impact of cement production, enhance concrete's strength, and improve its durability.

Rice husk Ash is produced by the combustion of rice husks, which are a waste product in rice milling.[5] The silica content of RHA is a key factor that makes it an effective pozzolan. The pozzolanic reaction occurs when the silica in RHA reacts with calcium hydroxide $Ca (OH)_2$), a by-product of cement hydration, to form calcium silicate hydrate (C-S-H) gel, which increases the strength of the concrete matrix.[7]

Several studies have examined the effect of RHA on concrete properties.[8] Showed that replacing up to 20% of cement with RHA resulted in significant improvements in compressive strength, particularly in mixes cured for 28 and 56 days.[10] Furthermore, the use of RHA improved the durability of concrete, offering enhanced resistance to chemical attacks, such as sulfate and chloride exposure. The pozzolanic activity of RHA also reduced the permeability of concrete, which is critical in preventing the ingress of harmful substances into the material, thus increasing its service life.[9]

However, the efficiency of RHA depends on factors such as the temperature at which the rice husks are burned and the particle size of the ash. At high combustion temperatures (over 600°C), RHA exhibits a higher pozzolanic reactivity, as the silica is better activated.[10]

Fibers are commonly used in concrete to improve its mechanical properties, particularly in terms of its tensile strength, crack resistance, and toughness. Fibers are small, discrete pieces of material that are embedded into concrete to enhance its structural performance. There are two main categories of fibers used in concrete: synthetic fibers (e.g., polypropylene) and natural fibers (e.g., jute, sisal, hemp, Sugarcane Bagasse, Coir fiber).[5]

Steel fibers are among the most widely used types of fibers in concrete due to their strength and ability to significantly improve flexural and tensile strength. Steel fibers prevent the formation of cracks, enhance impact resistance, and increase the overall toughness of concrete. Steel fiber-reinforced concrete (SFRC) exhibited superior performance in terms of compressive and flexural strength, as well as impact resistance, compared to conventional concrete.[1]

Steel fibers are particularly useful in structural applications, such as pavements, bridge decks, and industrial flooring, where resistance to cracking and fatigue is crucial. However, the inclusion of steel fibers may increase the cost of concrete, and it may also reduce workability, which needs to be carefully managed in the mix design.[6]

Natural fibers, such as jute, coir, Sugarcane Bagasse, and hemp are increasingly being studied as sustainable alternatives to synthetic fibers due to their low cost and biodegradability.[7] Natural fibers can enhance concrete's resistance to cracking and improve its ductility, which is critical for applications in seismic zones. Natural fiber-reinforced concrete (NFRC) also provides excellent workability, as the fibers help improve the cohesiveness of the mix and reduce segregation.[9]

Studies on NFRC have shown that incorporating fibers such as jute and sisal improves the post-crack behavior of concrete, enhancing its toughness and reducing the risk of catastrophic failure. According to natural fibers contribute to increasing the flexural and tensile strength of concrete, although their effectiveness varies depending on fiber type, content, and treatment methods.[3]

The incorporation of coconut fiber in the mixture of concrete, at a certain quantity, can improve the mechanical properties of the concrete. • The optimal use of the coconut fiber in concrete equals to 1.82 %, 1.94 %, 1.63 % and 1.80 % by volume of concrete respectively for compressive strength, flexural strength, split tensile strength and modulus of elasticity. have investigated tensile behaviors of the coir fiber and related composites after NaOH treatment. Brown coir fibers were treated by NaOH solution with concentrations from 2% to 10% separately. In the case of NaOH density with 10%, lower tensile strength of the composite was noticed compared to the cases of 2%, 4%, 6% and 8%.[5] They concluded after alkali treatment the elongation at break of the composites. The objective of the present work is to study the impact of (water extractives, hemicellulose, cellulose and lignin) botanical components on setting properties of bagasse/cement composites in a bid to harness these as building materials in saving energy, if their mechanical characteristics are not too poor.[6].

CONCLUSION

Integrated use of pozzolanic and fibrous materials from agricultural waste may be promising for stronger, more durable, and environmentally friendly concrete production. Optimization in the proportion a composition could be required for future studies in order to elevate performance levels further and assist with practical challenges toward large-scale applications.

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