Research

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Performance of Corncob Ash and Anthill Soil in Ternary Concrete Mixes

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1. Abstract
This study examines the feasibility of incorporating corncob ash (CCA) and anthill soil (AHS) as supplementary cementitious materials (SCMs) in ternary concrete mixtures. The materials were combined in equal proportions and used to partially replace cement at levels of 0%, 5%, 7.5%, 10%, 15%, 20%, 25%, and 30%. The investigation focused on key concrete properties including workability, density, compressive strength, splitting tensile strength, and the development of strength over time. These parameters were selected because they represent important performance indicators of SCMs in concrete. Experimental results indicate that the combined use of CCA and AHS can offer advantages compared with binary mixtures in terms of workability and mechanical performance. The ternary system demonstrated improved interaction between the two materials, suggesting their potential as sustainable alternatives for partial cement replacement in concrete production.

2. Introduction
Cement production is widely recognized as a significant contributor to global anthropogenic carbon dioxide emissions. Among all the components of concrete, cement plays the most critical role as the primary binding material. Globally, its consumption is second only to water. Studies have estimated that cement manufacturing accounts for approximately 7% of total global CO_2 emissions, which is considerably higher than the roughly 2% attributed to the aviation industry. Furthermore, it has been reported that the production of one tonne of cement releases nearly an equivalent amount of carbon dioxide into the atmosphere.

In addition to environmental concerns, cement production requires large amounts of energy, making it one of the most energy-intensive industrial processes after steel and aluminum production. Another challenge associated with cement is its relatively high cost, which continues to increase annually. This rise in cost creates a barrier to affordable housing and infrastructure development, particularly in developing countries.

One effective strategy for addressing these environmental and economic challenges is the incorporation of supplementary cementitious materials (SCMs) into concrete mixtures. SCMs are generally locally available materials that require significantly less energy during processing and produce lower carbon emissions than conventional cement. Examples of commonly used SCMs include pulverised fuel ash (PFA), ground granulated blast furnace slag (GGBS), rice husk ash (RHA), and corncob ash (CCA).

Many SCMs originate from agricultural or industrial waste products. Their utilization in concrete not only reduces environmental pollution caused by waste disposal but also lowers the overall cost of concrete production. Additionally, these materials can enhance both the fresh and hardened properties of concrete.

SCMs are defined as materials used in combination with cement that contribute to concrete performance through either pozzolanic or cementitious reactions. Pozzolanic materials contain high amounts of silica (SiO_2) but do not independently form cementitious compounds when mixed with water. Instead, they react with calcium hydroxide produced during cement hydration to generate additional calcium silicate hydrate (C-S-H), which contributes to strength development. Examples include silica fume and Class F pulverised fuel ash.

Other SCMs possess cementitious properties due to higher calcium oxide (CaO) content and can hydrate directly with water. Ground granulated blast furnace slag is a common example of such materials. Some materials display both pozzolanic and cementitious characteristics when the CaO content ranges between approximately 10% and 30% by mass.

For pozzolanic materials, standards such as those specified by ASTM require that the combined percentage of silica (SiO_2), aluminium oxide (Al_2O_3), and iron oxide (Fe_2O_3) be at least 70% by mass. Because pozzolans lack sufficient calcium to form cementitious compounds independently, they rely on calcium hydroxide produced during cement hydration to form additional calcium silicate hydrate.

Due to this mechanism, concrete containing SCMs often exhibits slower early-age strength development. However, as the pozzolanic reaction progresses, the long-term strength can equal or even surpass that of conventional cement concrete. The resulting calcium silicate hydrate structure is typically denser and less permeable, thereby enhancing the durability of the concrete.

Corncob ash is produced from the combustion of corncobs, which are the central cores of maize ears remaining after grain removal. Previous studies have suggested that corncob ash can function as a supplementary cementitious material in concrete. Although a direct comparison of carbon emissions between cement production and

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corncob ash preparation has not been extensively documented, the lower processing temperature required for producing CCA suggests that its environmental impact is significantly lower.

Anthill soil, on the other hand, is composed of fine soil particles that are bound together by secretions produced by ants. These secretions create highly cohesive structures that harden rapidly, giving anthill soil unique binding characteristics. Previous investigations have explored its potential use as a cementitious or pozzolanic material in construction.

Chemical analyses conducted in earlier studies revealed varying results regarding the suitability of corncob ash as a pozzolanic material. Some studies reported that CCA did not fully satisfy the standard requirements for SCMs, although it met the British Standard requirement of at least 25% silica content. Other researchers found that CCA satisfied ASTM requirements, achieving a combined silica, alumina, and iron oxide content above 70%. Differences in results have been attributed to variations in the preparation methods used for producing the ash. Grinding corncobs into smaller particles prior to combustion and performing incineration under controlled conditions have been shown to improve the chemical composition of the resulting ash.

Anthill soil, in contrast, has been reported to meet the ASTM chemical requirements for pozzolanic materials. Previous experimental studies also indicated that concrete specimens containing anthill soil replacements achieved acceptable compressive strength levels suitable for structural applications.

Because pozzolanic reactions progress gradually, concrete containing SCMs is often cured for extended periods beyond the conventional 28-day curing duration. During this time, silica present in the SCM reacts with calcium hydroxide produced during cement hydration, forming additional calcium silicate hydrate that contributes to long-term strength development.

3. Research Significance

Supplementary cementitious materials can be used individually or in combination with other materials to form binary or ternary concrete mixtures. In such combinations, different materials may complement each other by compensating for individual limitations. Previous studies have demonstrated that combining SCMs can produce synergistic effects that enhance workability and mechanical strength.

Another consideration is the availability of anthill soil, which may be limited in certain regions. Combining it with corncob ash could provide a practical approach to maximizing the utilization of both materials while maintaining desirable concrete properties. Therefore, investigating the combined performance of CCA and AHS in ternary concrete systems is important for developing sustainable construction materials.

4. Methods

The performance of corncob ash and anthill soil in ternary concrete mixtures was evaluated through a series of laboratory experiments. In addition to chemical composition analysis, tests were conducted to determine workability, density, compressive strength, splitting tensile strength, and the development of strength over time. These parameters represent key indicators used to assess the effectiveness of supplementary cementitious materials.

In this study, CCA and AHS were combined in equal proportions (50% each) and used as partial replacements for cement at replacement levels of 0%, 5%, 7.5%, 10%, 15%, 20%, 25%, and 30%. The mixture containing 0% replacement served as the control specimen. The performance of the ternary mixtures was also compared with previously reported binary mixtures containing only CCA or only AHS.

Concrete was prepared using a mix ratio of 1:2:3 (cement : fine aggregate : coarse aggregate) following ASTM standards. The water-cement ratio was maintained at 0.5. The mixing process lasted eight minutes, with a three-minute pause midway through the mixing operation. The selected water-cement ratio was based on Abram’s law, which states that the strength of concrete is strongly influenced by the water-cement ratio. Lower ratios generally produce higher strength, while higher ratios improve workability but reduce strength.

Workability was evaluated using the slump test procedure described in British Standard specifications. A slump cone mold was filled with concrete in three layers, each compacted with 25 strokes of a tamping rod. After leveling the top surface, the mold was carefully removed and the slump value was measured as the vertical difference between the height of the mold and the highest point of the slumped concrete.

Compressive strength specimens were prepared using cube molds measuring 100 mm × 100 mm × 100 mm. Cylindrical molds with a diameter of 150 mm and a height of 300 mm were used for splitting tensile strength tests. Before casting, the molds were coated with a release agent to prevent adhesion.

Concrete specimens were demolded after 24 hours and placed in a water curing tank maintained at approximately 20°C with a neutral pH of 7. The curing period extended to 91 days to allow sufficient time for the pozzolanic reactions to occur.

Density measurements were obtained by weighing specimens in both air and water. Compressive strength tests were conducted at curing ages of 7, 28, 56, and 91 days using a compression testing machine. Each result represents the average of three specimens to ensure reliability.

Splitting tensile strength tests were conducted according to standard procedures. The cylindrical specimens were placed between loading plates, and a controlled load was applied until failure occurred. The tensile strength was then calculated using the standard formula based on the maximum load and specimen dimensions.

5. Conclusion

This study evaluated the performance of corncob ash and anthill soil when used together as supplementary cementitious materials in ternary concrete mixtures. Based on the experimental results, the

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following conclusions were drawn:

1. The presence of corncob ash improved the workability of mixtures containing anthill soil. However, slump values decreased as the percentage of cement replacement increased.
2. The density of ternary concrete mixtures was generally lower than that of binary mixtures, indicating a potential advantage in producing lighter concrete with a greater volume per unit mass.
3. Anthill soil contributed to improved compressive and tensile strengths when combined with corncob ash, demonstrating that the two materials can work synergistically in concrete.
4. Overall compressive strength tended to decrease as the level of cement replacement increased, although slight improvements were observed at lower replacement levels.
5. The ternary mixtures exhibited significant strength development at replacement levels up to approximately 10%. Beyond this level, the rate of strength gain gradually declined.

In summary, the combined use of corncob ash and anthill soil shows promising potential as an environmentally friendly alternative to conventional cement in concrete production, particularly at moderate replacement levels.

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