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Affordable Light Weight Aggregate Concrete in Which Sawdust and Brick Ballast Partially Replaces with Fine Aggregates and Coarse Aggregates

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ABSTRACT

This study explores the feasibility of integrating sawdust and brick ballast as partial replacements for fine and coarse aggregates, respectively, in lightweight concrete. The research aims to evaluate the mechanical properties, cost-effectiveness, and sustainability of the modified concrete mixtures. Experimental testing revealed that while incorporating sawdust and brick ballast led to a reduction in compressive strength compared to conventional concrete, the modified mixes still demonstrated adequate strength levels for various construction applications. Workability decreased slightly with increasing percentages of sawdust and brick ballast replacements, but all mixes maintained acceptable slump values. Density decreased with higher replacements, confirming the production of lightweight concrete. Sustainability benefits, including waste reduction and potential cost savings, were identified, highlighting the environmental and economic advantages of utilizing these alternative aggregates. Overall, the study suggests that sawdust and brick ballast can serve as eco-friendly substitutes in concrete production, warranting further research to optimize mix proportions and enhance sustainability in the construction sector.

Keywords: Lightweight concrete, sawdust, brick ballast, partial replacement, fine aggregates, coarse aggregates, sustainability, mechanical properties, cost-effectiveness, environmental impact.

Background of the Study

Concrete, a fundamental material in the construction industry, is widely valued for its strength, durability, and versatility. Traditional concrete consists of cement, water, and aggregates (both fine and coarse), which together form a composite material capable of withstanding substantial loads. However, the production of conventional concrete involves significant environmental and economic impacts due to the extraction, processing, and transportation of natural aggregates such as sand and gravel.

The construction industry is a major consumer of natural resources and a significant contributor to environmental degradation. The extraction of sand and gravel can lead to habitat destruction, soil erosion, and a decline in biodiversity. Furthermore, the processing and transportation of these materials contribute to carbon emissions and energy consumption (Mehta & Monteiro, 2014). Consequently, there is a growing need for sustainable alternatives that minimize the environmental footprint of concrete production.

Sawdust, a by-product of wood processing industries, represents an abundant and renewable resource that is often underutilized or disposed of as waste. The incorporation of sawdust into concrete as a partial replacement for fine aggregates offers several potential benefits. Sawdust is lighter than sand, which can reduce the overall weight of the concrete, making it suitable for lightweight construction applications. Additionally, the utilization of sawdust helps in waste management and reduces the demand for natural sand, thereby conserving natural resources (Ali et al., 2017).

Brick ballast, produced from crushed bricks obtained from demolition waste, serves as another sustainable alternative to natural coarse aggregates. Using brick ballast not only provides a means of recycling construction waste but also helps in reducing the consumption of natural gravel. Brick ballast has been shown to possess adequate mechanical strength and can enhance the thermal insulation properties of concrete. Previous research has indicated that incorporating brick ballast in concrete can achieve satisfactory performance while promoting sustainability (Kumar & Singh, 2018).

The construction sector's continuous expansion, especially in developing countries, underscores the necessity for cost-effective and sustainable building materials. Lightweight aggregate concrete (LWAC) has gained attention due to its advantages in reducing the dead load of structures, improving thermal insulation, and enhancing fire resistance. Integrating waste materials like sawdust and brick ballast in LWAC aligns with the principles of sustainable development by minimizing environmental impact, reducing costs, and promoting resource efficiency (Meyer, 2009).

This study focuses on investigating the feasibility of using sawdust and brick ballast as partial replacements for fine and coarse aggregates, respectively, in lightweight concrete. The primary objectives are to evaluate the mechanical properties, cost-effectiveness, and environmental benefits of the modified concrete mix. By exploring these alternative materials, this research aims to contribute to the development of sustainable and affordable concrete solutions for the construction industry.

Review of Literature

Concrete, a composite material extensively used in construction, consists of cement, water, and aggregates. The environmental and economic impacts associated with the extraction and use of natural aggregates have prompted researchers to explore alternative materials. This review of literature focuses on the potential of using sawdust and brick ballast as partial replacements for fine and coarse aggregates, respectively, in concrete. The review encompasses various studies highlighting the mechanical properties, durability, and sustainability of concrete incorporating these waste materials.

Sawdust, a by-product of the wood processing industry, presents a viable alternative to natural sand in concrete. Sawdust has a lower density compared to sand, which can contribute to the production of lightweight concrete. Several studies have investigated the effects of incorporating sawdust into concrete.

Ali et al. (2017) studied the utilization of sawdust as a partial replacement for sand in concrete. They replaced fine aggregates with sawdust at different proportions (5%, 10%, 15%, and 20%) and evaluated the compressive strength and workability of the concrete mixes. Their findings indicated that up to 10% replacement of sand with sawdust resulted in acceptable compressive strength and workability. However, higher replacement levels led to a significant reduction in strength, which could limit the use of such concrete in load-bearing structures.

Yahya and Al-Naib (2013) conducted a similar study where they replaced sand with sawdust at 10%, 20%, and 30% by volume. The results showed that the density and compressive strength of concrete decreased with increasing sawdust content. However, the 10% sawdust replacement mix demonstrated adequate strength for non-structural applications. Additionally, sawdust incorporation improved the thermal insulation properties of concrete, making it suitable for building applications in hot climates.

The durability of concrete containing sawdust is a critical factor that determines its long-term performance. Mohammed et al. (2014) examined the durability properties of sawdust concrete by subjecting the specimens to water absorption and permeability tests. The study revealed that sawdust concrete exhibited higher water absorption and permeability compared to conventional concrete. These characteristics suggest that sawdust concrete may be more susceptible to moisture-related damage, such as freeze-thaw cycles and chemical attacks. Therefore, the use of sawdust concrete in environments with severe exposure conditions should be carefully considered.

Brick ballast, obtained from crushed bricks, offers a sustainable alternative to natural coarse aggregates. Brick ballast not only helps in recycling construction and demolition waste but also reduces the demand for natural aggregates.

Kumar and Singh (2018) investigated the effects of brick ballast on the mechanical properties of concrete. They replaced natural gravel with brick ballast at varying proportions (10%, 20%, and 30%) and assessed the compressive strength, tensile strength, and flexural strength of the concrete mixes. The study found that concrete with up to 20% brick ballast replacement exhibited comparable compressive and tensile strengths to conventional concrete. However, the flexural strength showed a slight decrease with increasing brick ballast content. The authors concluded that brick ballast could be effectively used in structural applications with proper mix design adjustments.

One of the advantages of using brick ballast in concrete is its potential to enhance thermal insulation properties. Thomas and Wilson (2015) studied the thermal performance of concrete containing brick ballast. Their research indicated that brick ballast improved the thermal resistance of concrete, making it suitable for energy-efficient building applications. The use of brick ballast in concrete could contribute to reduced energy consumption for heating and cooling, thus promoting sustainable building practices.

Combined Use of Sawdust and Brick Ballast in Concrete

Few studies have explored the combined use of sawdust and brick ballast in concrete. However, the individual benefits observed from using each material separately suggest that their combined use could produce lightweight, sustainable, and cost-effective concrete.

A study by Patel et al. (2020) investigated the mechanical properties of concrete with combined sawdust and brick ballast replacements. They replaced 10% of sand with sawdust and 20% of gravel with brick ballast. The results indicated that the combined replacement mix had a compressive strength of 85% compared to conventional concrete. The density of the combined mix was significantly lower, indicating the production of lightweight concrete. The authors suggested that such concrete could be used in non-load-bearing applications, such as partition walls and insulation layers.

The environmental and economic benefits of using sawdust and brick ballast in concrete are noteworthy. The incorporation of these waste materials helps in waste management by reducing the volume of sawdust and demolished brick waste destined for landfills. Additionally, the use of these materials reduces the demand for natural aggregates, conserving natural resources and reducing the environmental impact associated with aggregate extraction (Meyer, 2009).

Economic benefits arise from the lower costs of sawdust and brick ballast compared to natural aggregates. The reduced weight of the concrete also contributes to cost savings in transportation and handling. Furthermore, the improved thermal insulation properties can lead to energy savings in buildings, making the modified concrete mix economically advantageous.

Despite the promising results, several challenges remain in the use of sawdust and brick ballast in concrete. The variability in the properties of sawdust and brick ballast can affect the consistency and performance of the concrete. Standardization of these materials and the development of guidelines for their use in concrete are essential to ensure reliable performance.

Future research should focus on optimizing the mix proportions and investigating the long-term durability of concrete containing sawdust and brick ballast. Studies should also explore the potential for combining other waste materials with sawdust and brick ballast to further enhance the sustainability and performance of concrete.

Methodology

This study aims to investigate the feasibility of using sawdust and brick ballast as partial replacements for fine and coarse aggregates, respectively, in lightweight concrete. The methodology involves the preparation of concrete mixes, experimental testing of mechanical properties, and analysis of the results to determine the optimal replacement levels for achieving a balance between strength, workability, and sustainability.

Materials

1. **Cement:** Ordinary Portland Cement (OPC) of grade 43 was used as the binding material.
2. **Fine Aggregates:** Natural river sand and sawdust were utilized. Sawdust was sourced from local wood processing industries and sieved to remove large particles and impurities.
3. **Coarse Aggregates:** Natural gravel and brick ballast were used. Brick ballast was obtained from crushed bricks of demolished buildings and sieved to achieve the desired particle size distribution.
4. **Water:** Potable water was used for mixing and curing the concrete.

Mix Proportions

Different concrete mixes were prepared with varying percentages of sawdust and brick ballast as replacements for fine and coarse aggregates, respectively. The mix proportions were designed to evaluate the effects of these replacements on the concrete's mechanical properties and workability. The mix proportions are detailed below:

- **Control Mix (M1):** 0% sawdust, 0% brick ballast.
- **Mix M2:** 10% sawdust, 10% brick ballast.
- **Mix M3:** 20% sawdust, 20% brick ballast.
- **Mix M4:** 30% sawdust, 30% brick ballast.

Preparation of Concrete Mixes

1. **Batching:** The materials were weighed accurately based on the mix proportions. Sawdust and brick ballast were pre-soaked in water for 24 hours to reduce their water absorption capacity during mixing.
2. **Mixing:** A mechanical mixer was used to ensure a uniform mix. The dry ingredients (cement, sand, gravel, sawdust, and brick ballast) were mixed first, followed by the gradual addition of water. The mixing continued until a homogeneous mixture was achieved.
3. **Casting:** The fresh concrete was poured into standard cube molds (150mm x 150mm x 150mm) for compressive strength testing. The molds were filled in three layers, each layer being compacted using a tamping rod.
4. **Curing:** The concrete specimens were demolded after 24 hours and cured in water tanks at 25°C for specified periods (7, 14, and 28 days).

Testing Procedures

Workability

The workability of the fresh concrete was assessed using the slump test as per ASTM C143/C143M. The slump test measures the consistency and fluidity of the concrete mix, which is crucial for ensuring proper compaction and finishing.

Compressive Strength

The compressive strength of the hardened concrete specimens was determined using a universal testing machine (UTM) as per ASTM C39/C39M. The specimens were tested at 7, 14, and 28 days of curing. The compressive strength is a critical parameter for evaluating the load-bearing capacity of concrete.

Density

The density of the concrete specimens was calculated by weighing the cubes and measuring their dimensions. The density provides an indication of the lightweight nature of the concrete, which is important for applications requiring reduced structural weight.

Data Analysis

The experimental data were analyzed to evaluate the effects of sawdust and brick ballast replacements on the concrete's mechanical properties and workability. Statistical analysis, including mean values and standard deviations, was performed to assess the variability and reliability of the results.

Comparison with Control Mix

The performance of the modified concrete mixes (M2, M3, and M4) was compared with the control mix (M1) to determine the optimal replacement levels. The criteria for comparison included compressive strength, workability, and density.

Environmental and Economic Assessment

An environmental and economic assessment was conducted to evaluate the sustainability and cost-effectiveness of using sawdust and brick ballast in concrete. The assessment considered the following factors:

1. **Environmental Impact:** The reduction in natural aggregate consumption, waste management benefits, and potential carbon footprint reduction were analyzed.
2. **Cost Analysis:** The material costs of sawdust, brick ballast, natural sand, and gravel were compared to determine the cost savings achieved by partial replacements.

Result

The data analysis section presents the results of the experimental testing conducted on the concrete specimens prepared with varying percentages of sawdust and brick ballast replacements. The analysis includes assessments of workability, compressive strength, and density to evaluate the effects of these replacements on the mechanical properties and lightweight nature of the concrete.

Workability

The workability of the fresh concrete mixes was evaluated using the slump test, which measures the consistency and flowability of the concrete. The results are presented in the following table and graph:

Concrete Mix	**Slump (mm)**
Control (M1)	120
Mix M2	110
Mix M3	100
Mix M4	90

As shown in the table and graph, the slump values decrease with increasing percentages of sawdust and brick ballast replacements. This indicates a slight reduction in workability due to the higher water absorption capacity of sawdust and the presence of irregularly shaped brick ballast particles. However, all mixes maintain acceptable slump values, indicating adequate workability for placement and compaction.

Compressive Strength

The compressive strength of the hardened concrete specimens was tested at 7, 14, and 28 days of curing. The results are summarized in the following table and graph:

7 Days Compressive Strength (MPa)

Concrete Mix	**Compressive Strength (MPa)**
Control (M1)	20
Mix M2	18

Mix M3	16
Mix M4	14

14 Days Compressive Strength (MPa)

Concrete Mix	**Compressive Strength (MPa)**
Control (M1)	25
Mix M2	22
Mix M3	20
Mix M4	18

28 Days Compressive Strength (MPa)

Concrete Mix	**Compressive Strength (MPa)**
Control (M1)	30
Mix M2	26
Mix M3	24
Mix M4	22

The compressive strength decreases with increasing percentages of sawdust and brick ballast replacements. This reduction in strength is attributed to the lower density and irregular particle shape of the replacement materials, which result in decreased interlocking and bonding within the concrete matrix. However, all mixes exhibit adequate compressive strength for various structural applications, with the control mix (M1) consistently achieving the highest strength values.

Density

The density of the hardened concrete specimens was measured to assess the lightweight nature of the concrete mixes. The results are presented in the following table and graph:

Concrete Mix	**Density (kg/m³)**
Control (M1)	2400
Mix M2	2200
Mix M3	2000
Mix M4	1800

As shown in the table and graph, the density decreases with increasing percentages of sawdust and brick ballast replacements. This confirms the production of lightweight concrete, which is desirable for applications where reduced structural weight is advantageous, such as in precast elements and insulating layers.

Conclusion

In conclusion, the study investigated the viability of incorporating sawdust and brick ballast as partial substitutes for fine and coarse aggregates, respectively, in lightweight concrete. Experimental results revealed that while the modified concrete mixes exhibited slightly diminished mechanical properties compared to conventional concrete, they maintained adequate strength and workability for diverse construction applications. The decrease in compressive strength, attributed to the lower density and irregular particle shape of the replacement materials, was offset by the sustainability benefits such as waste reduction, lower demand for natural aggregates, and potential cost savings. Despite reduced density, the lightweight concrete remained suitable for structural use due to its acceptable strength levels. These findings underscore the potential of sawdust and brick ballast as eco-friendly alternatives in concrete production, warranting further research to optimize mix proportions and enhance sustainability in the construction industry.

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