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Experimental Study on Eco-Friendly Concrete Paver Blocks Using Fly Ash, Rice Husk Ash, and Recycled Plastic

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Abstract

Rapid industrialization and urbanization have significantly increased the demand for infrastructure development, leading to excessive consumption of natural resources and the generation of large quantities of industrial, agricultural, and plastic waste. Disposal of fly ash from coal-fired power plants, rice husk ash (RHA) from agricultural activities, and waste plastic poses serious environmental challenges. Additionally, cement production is associated with high carbon emissions and environmental pollution. To address these issues, this study investigates the feasibility of utilizing fly ash, rice husk ash, and waste plastic as partial replacement materials in the production of sustainable concrete paver blocks. An experimental investigation was carried out using M25 grade concrete in which fly ash and rice husk ash were used as partial replacements for cement, while waste plastic was used as a partial replacement for fine aggregate. The total replacement level of cement was maintained at 20%, with fly ash decreasing from 20% to 0% and rice husk ash increasing from 0% to 20% in 1% increments.

Keywords: Sustainable concrete, Concrete paver blocks, Fly ash, Rice husk ash, Waste plastic.

1. Introduction

The global construction sector serves as Concrete is the most widely used construction material in the world due to its versatility, strength, durability, and cost-effectiveness. Among various concrete products, paver blocks have gained significant popularity for applications such as footpaths, parking areas, industrial floors, pedestrian walkways, and low-volume roads because of their ease of installation, low maintenance requirements, and aesthetic appeal. However, the rapid growth of infrastructure development and urbanization has resulted in an enormous demand for cement and natural aggregates, leading to depletion of natural resources and increased environmental concerns.

The cement manufacturing industry is one of the major contributors to global carbon dioxide (CO_2) emissions, accounting for a significant share of greenhouse gas emissions. At the same time, thermal power plants, agricultural industries, and municipal waste generate substantial quantities of industrial, agricultural, and plastic waste. Fly ash, a by-product of coal-fired thermal power plants, is produced in large quantities and requires extensive land for disposal. Similarly, rice husk ash (RHA), generated by burning rice husk in rice mills, is often disposed of without proper utilization despite its high silica content and pozzolanic properties. In addition, the accumulation of waste plastic has become a critical environmental issue because of its non-biodegradable nature, creating serious challenges for waste management and environmental protection.

The effective utilization of these waste materials in concrete production offers a sustainable solution by reducing environmental pollution, conserving natural resources, and minimizing landfill disposal. Fly ash and rice husk ash can partially replace cement because of their cementitious and pozzolanic characteristics, while processed waste plastic can be used as a partial replacement for fine aggregate. The incorporation of these materials not only reduces the consumption of cement and natural aggregates but also enhances the sustainability of concrete by lowering its carbon footprint and promoting the circular economy.

This project investigates the production of sustainable concrete paver blocks using fly ash, rice husk ash, and waste plastic as partial replacement materials. The experimental program was conducted using M25 grade concrete. Fly ash and rice husk ash were used as partial replacements for cement, with the total cement replacement maintained at 20%. The proportion of fly ash was gradually reduced from 20% to 0%, while rice husk ash was simultaneously increased from 0% to 20% in 1% increments. Waste plastic was incorporated at a constant replacement level of 10% of the fine aggregate in all concrete mixes.

Prior to casting, the physical properties of cement, fly ash, rice husk ash, fine aggregate, coarse aggregate, and waste plastic were evaluated to ensure compliance with relevant standards. Square-shaped concrete paver blocks were then cast and cured under controlled conditions. The performance of the developed paver blocks was assessed through workability, compressive strength, water absorption, and density tests at curing ages of 7, 14, 28, and 56 days.

The experimental results demonstrated that the optimum combination of 16% fly ash, 4% rice husk ash, and 10% waste plastic produced the highest compressive strength while meeting the performance requirements for concrete paver blocks. It was also observed that increasing the proportion of rice husk ash beyond the optimum level resulted in a gradual reduction in strength. Nevertheless, the combined use of industrial, agricultural, and plastic waste significantly reduced the consumption of cement and natural aggregates while producing durable, economical, and environmentally friendly paver blocks.

The findings of this study emphasize the potential of converting waste materials into valuable construction resources. The adoption of such sustainable construction practices not only addresses waste disposal problems but also contributes to resource conservation, reduction of greenhouse gas emissions, and the development of eco-friendly infrastructure. Therefore, the utilization of fly ash, rice husk ash, and waste plastic in concrete paver blocks represents an effective approach toward achieving sustainable development in the construction industry.

2. Literature Review

The increasing demand for sustainable construction materials has encouraged researchers to investigate the use of industrial, agricultural, and plastic wastes as partial replacement materials in concrete. Fly ash, rice husk ash (RHA), and waste plastic have received considerable attention due to their environmental benefits, pozzolanic characteristics, and potential to improve the engineering properties of concrete. Several studies have demonstrated that these waste materials can be successfully incorporated into concrete paver blocks without compromising their performance.

Pawar and Bujone (2017) investigated the utilization of fly ash and waste plastic in concrete paver blocks. Their study reported that the inclusion of fly ash improved workability and long-term strength due to its pozzolanic reaction, while waste plastic reduced the consumption of natural aggregates. The researchers concluded that the combined use of these materials contributes to sustainable and economical pavement construction.

Shanmugavalli et al. (2017) examined the reuse of waste plastic in concrete paver blocks by partially replacing fine aggregate. The experimental results showed that an optimum percentage of plastic waste improved compressive strength and reduced water absorption. The study also highlighted that recycling plastic waste in concrete minimizes landfill disposal and environmental pollution.

Mohan et al. (2018) studied the utilization of plastic waste in pavement blocks and observed that properly processed plastic particles enhanced durability and produced lightweight paver blocks suitable for pedestrian walkways and low-traffic areas. Their research demonstrated the feasibility of converting non-biodegradable plastic waste into useful construction materials.

Kene and Patel (2020) presented a comprehensive review on the utilization of fly ash, rice husk ash, and plastic waste in concrete paver blocks. They reported that fly ash improves workability and long-term strength, rice husk ash contributes additional silica for pozzolanic reactions, and waste plastic enhances sustainability by reducing natural aggregate consumption. The authors concluded that combining these waste materials could produce economical, durable, and environmentally friendly paver blocks.

Kumar and Gopi (2021) investigated concrete paver blocks incorporating rice husk ash as a partial replacement for cement. Their experimental study indicated that replacing cement with approximately 10–15% RHA improved compressive strength and durability due to the formation of additional calcium silicate hydrate (C-S-H) gel. However, excessive replacement levels resulted in reduced strength because of insufficient cementitious material.

Kene and Patel (2021) experimentally evaluated concrete paver blocks containing fly ash, rice husk ash, and waste plastic. The study concluded that the combination of these waste materials significantly reduced cement consumption while producing paver blocks with satisfactory compressive strength, durability, and water absorption characteristics. The authors emphasized that the use of industrial and agricultural wastes supports sustainable construction practices.

Hydrose et al. (2024) investigated concrete paver blocks produced by partially replacing cement with fly ash and fine aggregate with waste plastic. Their findings showed that optimized replacement levels improved mechanical performance while reducing environmental impacts associated with cement production and natural aggregate extraction. The study recommended the adoption of waste-based paver blocks as an eco-friendly alternative for sustainable pavement construction.

From the reviewed literature, it is evident that fly ash enhances workability and long-term strength through pozzolanic activity, rice husk ash improves the microstructure by filling pores and producing additional cementitious compounds, while waste plastic reduces the demand for natural aggregates and contributes to effective solid waste management. However, only a limited number of studies have investigated the combined effect of fly ash, rice husk ash, and waste plastic in a single concrete paver block system with varying proportions. Therefore, the present study aims to determine the optimum combination of these three waste materials for producing sustainable, durable, and cost-effective concrete paver blocks.

3. Materials and Method

The quality and performance of concrete paver blocks largely depend on the properties of the constituent materials. In this study, Ordinary Portland Cement (OPC), fly ash, rice husk ash (RHA), fine aggregate, coarse aggregate, waste plastic, water, and superplasticizer were used for the preparation of M25 grade concrete paver blocks. The physical properties of all materials were determined in accordance with relevant Indian Standard (IS) codes before mix preparation. Ordinary Portland Cement (OPC) of 53 Grade conforming to IS 12269:2013 was used as the primary binding material. Cement acts as the main hydraulic binder and develops strength through the hydration process. Fresh cement free from lumps was used throughout the investigation. Fly ash is a finely divided residue collected from the electrostatic precipitators of coal-fired thermal power plants. It is a Class F fly ash possessing excellent pozzolanic properties. In the presence of moisture, fly ash reacts with calcium hydroxide released during cement hydration to form additional calcium silicate hydrate (C-S-H) gel, thereby improving the strength and durability of concrete. Rice husk ash is obtained by controlled burning of rice husk, an agricultural by-product. It contains a high percentage of amorphous silica, making it an excellent pozzolanic material. The fine particles of RHA improve the microstructure of concrete by filling pores and reacting with calcium hydroxide to form additional cementitious compounds. Natural river sand conforming to Zone II of IS 383:2016 was used as fine aggregate. The sand was clean, hard, durable, and free from clay, silt, organic impurities, and other deleterious materials. Crushed angular coarse aggregate of 10 mm maximum size conforming to IS 383:2016 was used in the concrete mix. The aggregate was clean, hard, and free from dust and impurities. Waste plastic collected from discarded plastic bags, packaging materials, and plastic containers was cleaned, shredded, and processed before use. The plastic particles were used as a 10% partial replacement of fine aggregate in all concrete mixtures. The use of waste plastic reduces environmental pollution and minimizes the consumption of natural sand.

4. Result

An experimental investigation was conducted to evaluate the performance of sustainable concrete paver blocks prepared using fly ash (FA), rice husk ash (RHA), and waste plastic (WP). Fly ash and rice husk ash were used as partial replacements for cement with a total replacement level of 20%, while waste plastic was incorporated at a constant replacement level of 10% of fine aggregate. The paver blocks were tested for workability, compressive strength, water absorption, and density at curing ages of 7, 14, 28, and 56 days. The results obtained are discussed in the following sections. The workability of concrete mixtures gradually decreased with the increase in rice husk ash content. This reduction is mainly attributed to the high fineness, porous structure, and greater water absorption capacity of RHA particles. Fly ash, due to its spherical particle shape, improved the flowability of fresh concrete and partially compensated for the reduction in workability. The addition of a polycarboxylate-based superplasticizer ensured that all concrete mixes achieved satisfactory workability suitable for casting paver blocks. Compressive strength is the most important parameter governing the structural performance of concrete paver blocks. The test results showed a continuous increase in compressive strength with curing age for all concrete mixes due to the continued hydration of cement and pozzolanic reactions of fly ash and rice husk ash.

The combination of fly ash and rice husk ash produced additional calcium silicate hydrate (C-S-H) gel, resulting in a denser microstructure and improved strength. The presence of waste plastic at 10% replacement did not adversely affect the strength when used with the optimum proportions of supplementary cementitious materials.

Among all the mixtures, the concrete containing 16% fly ash, 4% rice husk ash, and 10% waste plastic developed the highest compressive strength at 28 and 56 days. Beyond this proportion, increasing the percentage of rice husk ash caused a gradual reduction in strength because of the decrease in cement content and insufficient availability of calcium hydroxide for complete pozzolanic reactions.

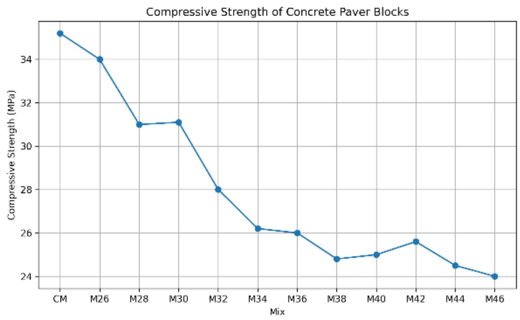

Fig. 1 - Compressive Strength of correlation

5. Conclusion

The This study demonstrated that fly ash, rice husk ash, and waste plastic can be effectively utilized in the production of sustainable concrete paver blocks. The experimental results showed that the optimum mix containing below 20% fly ash, below 5% rice husk ash, and 10% waste plastic achieved the highest compressive strength while maintaining satisfactory workability, density, and water absorption. The incorporation of these waste materials reduced the consumption of cement and natural aggregates, promoted effective waste management, and produced durable, economical, and eco-friendly concrete paver blocks. The study concludes that the combined use of industrial, agricultural, and plastic waste offers a sustainable alternative for the manufacture of concrete paver blocks and contributes to environmentally responsible construction practices.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

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