



(RESEARCH ARTICLE)



Performance evaluation of eco-friendly concrete using neem powder and styrene-butadiene-styrene

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International Journal of Science and Research Archive, 2026, 19(01), 080-083

Publication history: Received on 24 February 2026; revised on 31 March 2026; accepted on 3 April 2026

Article DOI: <https://doi.org/10.30574/ijrsra.2026.19.1.0698>

Abstract

Concrete is one of the most widely used construction materials due to its strength, durability, and versatility in infrastructure development. However, the rapid increase in construction activities has resulted in serious environmental concerns. Cement production contributes significantly to carbon dioxide emissions, which accelerates global warming, while excessive extraction of natural sand leads to ecological imbalance and depletion of natural resources. To address these issues, the development of sustainable concrete using alternative materials has become essential. This study focuses on the use of neem leaf powder as a partial replacement for cement and styrene-butadiene-styrene (SBS) polymer as a partial replacement for fine aggregate. Neem leaf powder, being an agricultural waste, acts as a microfiller and reduces porosity while improving durability. Additionally, it possesses antibacterial properties that enhance the long-term performance of concrete. On the other hand, SBS polymer improves ductility, flexibility, and crack resistance due to its elastic nature. The experimental investigation involves material testing, mix preparation, casting, curing, and evaluation of workability and compressive strength. The results indicate that partial replacement of conventional materials with eco-friendly alternatives reduces environmental impact while maintaining structural performance. The optimum replacement level is observed at 10%, where maximum compressive strength is achieved with acceptable workability. This study highlights the importance of sustainable construction practices and demonstrates the effective utilization of agricultural and polymer waste materials in concrete production. The research contributes to eco-friendly construction and promotes the development of cost-effective and durable building materials.

Keywords: Styrene-Butadiene-Styrene (SBS); Durability; Curing; Workability

1. Introduction

Concrete is one of the most widely used construction materials in the world due to its strength, durability, and versatility. However, the rapid growth of infrastructure development has led to a significant increase in the consumption of cement and natural aggregates, which in turn has resulted in serious environmental concerns. Cement production alone contributes a large amount of carbon dioxide emissions, making it a major factor in global warming and climate change. At the same time, excessive extraction of natural sand and aggregates has caused depletion of natural resources and ecological imbalance. Therefore, there is an urgent need to develop sustainable and eco-friendly alternatives in the construction industry. In this context, the use of recycled and waste materials in concrete has gained considerable attention among researchers and engineers. This study focuses on the development of sustainable concrete by partially replacing conventional materials with environmentally friendly alternatives such as neem leaf powder and styrene-butadiene-styrene (SBS) polymer. Neem leaf powder, an agricultural waste product, has potential benefits such as reducing the heat of hydration, improving durability, and filling micro-voids in concrete. Similarly, SBS polymer, a synthetic rubber material, enhances flexibility, toughness, and resistance to cracking. The combination of these materials not only helps in reducing the dependency on traditional resources but also promotes effective waste

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utilization. The objective of this research is to evaluate the performance of concrete with partial replacement of cement and fine aggregates using these materials. Parameters such as workability, strength, and durability are analyzed through experimental investigations. By integrating sustainable materials into concrete production, this study aims to contribute towards eco-friendly construction practices, reduce environmental impact, and promote the development of cost-effective and durable building materials for future infrastructure.

2. Literature review

2.1. Replacement of fine aggregate by allied materials

This study focuses on replacing natural fine aggregate (sand) with rice husk, an agricultural waste material, to develop sustainable concrete. The researchers experimented with partial replacement levels of 5% and 10%. Results showed that as the percentage of rice husk increased, the workability of concrete decreased due to the lightweight and porous nature of rice husk. However, at 5% replacement, the concrete achieved the required compressive strength for M30 grade concrete, making it a viable alternative. At 10% replacement, strength reduction became more noticeable, indicating limitations in higher replacement levels. The study highlights that rice husk can reduce dependency on natural sand and contribute to eco-friendly construction practices. Additionally, the use of agricultural waste helps in waste management and reduces environmental pollution. Overall, the research concludes that a controlled replacement (around 5%) is optimal for maintaining strength while improving sustainability.

2.2. Investigation of partial replacement of cement with neem leaf ash

This research investigates the use of neem leaf ash as a partial replacement for cement in concrete production. Neem leaves, when burnt, produce ash with pozzolanic properties that can contribute to cementitious reactions. The study found that increasing the percentage of neem leaf ash leads to a gradual reduction in compressive strength due to lower cement content. However, at 10% replacement, the concrete still achieved acceptable strength levels suitable for certain construction applications. One of the key advantages identified is cost reduction, as neem leaf ash is a low-cost material. Additionally, it contributes to environmental sustainability by reducing cement usage, which is a major source of carbon emissions. The study suggests that neem leaf ash can be effectively used in non-structural or low-load applications. It also emphasizes the importance of optimizing replacement levels to balance strength and sustainability. Overall, the research supports the use of agricultural waste as a supplementary cementitious material.

2.3. Partial replacement of cement in concrete

This paper reviews various waste materials used as partial replacements for cement, including fly ash, waste glass, and industrial sludge. The study emphasizes that these materials can improve sustainability while maintaining acceptable mechanical properties. Fly ash, a byproduct of thermal power plants, enhances workability and long-term strength due to its pozzolanic nature. Waste glass, when finely ground, can act as a cementitious material but requires proper processing to avoid alkali-silica reaction. Industrial sludge can also be utilized, although its performance depends on chemical composition. The research highlights that partial replacement reduces cement consumption, thereby lowering carbon emissions and construction costs. However, excessive replacement may negatively affect early strength and durability. The study concludes that combining different waste materials can offer better performance compared to using a single material. It provides a broad understanding of sustainable alternatives in concrete and encourages further research in multi-material replacement strategies.

2.4. Experimental analysis on waste foundry sand

This study examines the use of waste foundry sand as a partial replacement for natural fine aggregate in concrete. Foundry sand is a byproduct of metal casting industries and is often disposed of as waste. The researchers found that replacing fine aggregate with foundry sand improves compressive strength up to a certain percentage due to better particle packing and bonding. The material also enhances durability within acceptable limits. However, excessive replacement can reduce workability and may introduce impurities affecting long-term performance. The study demonstrates that foundry sand can be a sustainable alternative to river sand, helping to conserve natural resources and reduce industrial waste. It also highlights economic benefits, as foundry sand is readily available at low cost. The research concludes that controlled usage of foundry sand can produce durable and eco-friendly concrete suitable for construction applications.

2.5. Effect of banana leaves ash on durability

This research explores the use of banana leaf ash as a supplementary cementitious material in concrete. The study focuses on durability aspects, particularly resistance to sulphate and acid attacks. Results indicate that replacing up to 10% of cement with banana leaf ash improves both strength and durability. The ash contributes to the formation of additional binding compounds, enhancing the concrete's resistance to chemical attacks. This makes it suitable for structures exposed to aggressive environments. The study also highlights environmental benefits, as banana leaves are an agricultural waste material. Using them in concrete reduces waste disposal issues and lowers cement consumption. However, higher replacement levels may negatively affect strength. The research concludes that banana leaf ash is a promising eco-friendly material for improving durability and sustainability in concrete construction.

2.6. Partial replacement using fly ash and glass aggregate

This paper discusses the combined use of fly ash and glass aggregate in concrete as partial replacements for cement and fine aggregate. Fly ash improves workability and long-term strength, while glass aggregate enhances aesthetic and structural properties when used in controlled amounts. The study emphasizes the importance of proper proportioning to avoid strength reduction. It also highlights the role of journals like IJRET in promoting research in sustainable construction materials. The research supports the idea that combining materials can yield better results compared to single replacements. Overall, it contributes to the development of eco-friendly concrete with reduced environmental impact.

2.7. Recycled glass as fine aggregate in SCC

This study investigates the use of recycled glass as a replacement for fine aggregate in self-compacting concrete (SCC). Results show that increasing glass content improves flowability due to its smooth surface texture. However, strength decreases at higher percentages because of weak bonding between glass particles and cement paste. Despite this, moderate replacement levels can still produce acceptable strength. The research highlights the importance of recycling waste glass to reduce environmental pollution. It concludes that recycled glass can be effectively used in SCC when properly proportioned, balancing workability and strength

3. Observation and results

The observation and results obtained from the experimental study provide a clear understanding of the behavior of concrete when modified with neem leaf powder and SBS polymer. The workability of concrete was observed to decrease gradually with an increase in the percentage of replacement materials. This reduction is mainly due to the fine particles of neem leaf powder, which tend to absorb more water, and the presence of SBS polymer, which alters the flow characteristics of the mix. The slump value for conventional concrete was recorded as 80 mm, indicating high workability, whereas mixes with higher replacement percentages showed reduced slump values. However, at 10% replacement, the workability remained within acceptable limits for practical applications. The compressive strength results revealed that the strength of concrete increased at lower replacement levels. At 5% and 10% replacement, the compressive strength was higher compared to conventional concrete, indicating improved bonding and reduced porosity. The microfilling effect of neem leaf powder and the elastic properties of SBS polymer contributed to this improvement. The maximum compressive strength was achieved at 10% replacement, which is considered the optimum level. Beyond this level, particularly at 15%, the strength decreased due to excessive replacement, which weakened the bonding between particles and increased voids within the concrete structure. These results clearly indicate that an optimum balance between replacement materials is necessary to achieve desirable strength and workability in sustainable concrete.

4. Conclusion

The study concludes that sustainable concrete can be successfully developed by incorporating neem leaf powder and SBS polymer as partial replacements for cement and fine aggregate, respectively. The use of these materials contributes to reducing environmental pollution and conserving natural resources while maintaining the required performance of concrete. The experimental findings indicate that workability decreases slightly with increasing replacement levels, but remains acceptable at lower percentages. The compressive strength of concrete improves up to an optimum replacement level of 10%, beyond which it starts to decrease due to reduced bonding and increased porosity. This highlights the importance of maintaining an appropriate balance between replacement materials to achieve the desired properties. The study also emphasizes the potential of utilizing agricultural and polymer waste materials in construction, promoting sustainability and cost-effectiveness. Furthermore, the results suggest that such modified concrete can be effectively used in non-structural applications and low-cost construction projects. Future research can

focus on evaluating long-term durability, higher replacement percentages, and applications in structural elements such as beams and slabs. Overall, this study contributes to the advancement of sustainable construction practices and encourages the use of eco-friendly materials in the civil engineering industry, thereby supporting environmental conservation and sustainable development.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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