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An Overview of the Performance of Concrete using Sugarcane Bagasse Ash and Granite Waste as Fine Aggregate

Bhuvesh Bansal[1], Sougata Chattopadhyay[2]

[1]M.Tech Student, Department of Civil Engineering, Faculty of Engineering Technology and Computing, Desh Bhagat University, Mandi Gobindgarh, Punjab-147301, India
[2]Assistant Professor, Department of Civil Engineering, Faculty of Engineering Technology and Computing, Desh Bhagat University, Mandi Gobindgarh, Punjab-147301, India

ABSTRACT

Concrete is the homogeneous mixture of cement, fine aggregate, and coarse aggregate added with water. Aggregates constitute 75-80% of the total concrete volume andplay a critical role in determining its mechanical properties. Fine aggregate makes up approximately 25-30% of the overall volume. Optimising the particle packing of aggregates can significantly enhance concrete performance by reducing voids and minimizing their connectivity. Also, Degradation of the environment takes place mainly due to the accumulation of industrial waste products becoming an environmental nuisance for the surrounding community and excessive use of natural resources, which are depleting gradually. Sugarcane bagasse ash (SCBA) and granite waste (GW) are two such particles both sustainable and waste by-products from their respective industries. This paper presents a comprehensive review on the performance of concrete using SCBA and GW as fine aggregate.The primary objective of this study is to assess the potential of incorporating SCBA and GW as fillers in structural concrete, contributing to improved performance and eco-friendly construction practices. The results revealed that adding granite waste could substantially improve the carbonation and water resistance, and reduce the ultimate shrinkage strain and shrinkage rate.In addition, reduce the cement content by up to 25%. However, very fine GW particles could act as nuclei for the precipitation of CSH and thus increase the degree of cement hydration. Also, the concrete containing bagasse ash and granite waste demonstrated more durabilitycompared to conventional concrete and better permeation characteristics. The mechanical properties of BAGW concrete are comparable to those of conventional concrete.

Keywords: Sugarcane Bagasse Ash, Granite Waste, Sustainable Concrete, Mechanical Characteristics, Durability.

INTRODUCTION

One of the most often utilized building materials worldwide is concrete. Cement, fine and coarse aggregates, and water are the ingredients of conventional concrete. Aggregates make up 75–80% of the overall volume of concrete, compared to all other ingredients, and have an impact on both the fresh and cured concrete's characteristics. The fine aggregate made approximately 25–30% of the volume of the concrete's overall composition.

Sugarcane bagasse ash is the byproduct formed when the fibrous waste left after juice extraction from sugarcane—known as bagasse—is burned, typically for energy production. This ash is usually fine and gray in color and contains a high amount of silica, which gives it pozzolanic properties, meaning it can react with lime in the presence of water to form compounds with cement-like qualities. Because of this, it's often used as a partial replacement for cement in concrete, helping to improve strength while also making construction more eco-friendly. Additionally, it finds use in making sustainable bricks, enhancing soil stability, and managing agricultural waste more efficiently.

Granite waste is the leftover material that results from cutting, shaping, and polishing granite stones, mainly during their use in construction and decorative projects. This waste often appears as fine powder, small chips, or slurry and is usually discarded in large amounts, which can lead to environmental concerns if not properly managed. Instead of letting it pile up in landfills, granite waste can be reused in a variety of ways—like making concrete, bricks, tiles, or even as filler in road construction—offering a more sustainable approach to both construction and waste management. India holds over 20% of the world's granite resources.

This research aims to investigate the use of sugarcane bagasse ash and granite waste, as substitutes for river sand in construction applications. The study includes a detailed review of the studies which have already been done on both of these, so that a conclusion can be made and research gaps can been found out so that a further study can be done. By exploring these alternatives, the research supports the sustainable use of industrial waste to reduce environmental impact and conserve natural resources.

Effects of Sugarcane Baggase Ash

- Cordeiro et al. (2008) investigated the pozzolanic nature of sugarcane bagasse ash (SCBA) and determined that it can be considered a pozzolanic material. However, their study emphasized that its reactivity is not uniform and is highly dependent on particle size and fineness. They concluded that finer particles of SCBA exhibit greater pozzolanic activity, which enhances its potential for use in cementitious applications. This highlights the importance of proper processing and grinding of SCBA before it is incorporated into concrete or mortar mixes.
- Almir Sales and Sofia Araujo Lima (2010) focused on the physical characteristics of SCBA and found them to be closely comparable to those of natural river sand. Their research showed promising results when SCBA was used to partially replace sand in mortar mixes. Specifically, they observed that when 20% and 30% of the natural sand was replaced with SCBA, the resulting mortars displayed improved mechanical strength in comparison to conventional mixtures. These findings suggest that SCBA can serve not just as a sustainable substitute but also as a performance-enhancing additive in construction materials.
- Prashant O. Modani and Vyawahare (2013) examined the effects of increasing SCBA content in concrete mixtures. They discovered that while the material could be effectively used up to a certain percentage, increasing the substitution level beyond 30%—particularly at 40%—led to a significant decrease in workability. The concrete became difficult to handle and place, suggesting that higher SCBA content might require the addition of water-reducing agents or other adjustments to the mix design to maintain proper consistency and performance on-site.
- Fernando C.R. Almeida et al. (2015) conducted research on the impact of SCBA on the durability and pore structure of mortars. Their results indicated that a 30% replacement of traditional materials with SCBA did not compromise the mechanical properties of the mortar. In fact, it led to an improvement in durability. This enhancement was attributed to the finer particle size of SCBA, which helped reduce the number of larger pores and resulted in a denser, more compact microstructure. Pore sizes below 150 microns were significantly reduced, which is beneficial for long-term performance and resistance to environmental factors.
- Elisabeth Arif et al. (2016) explored SCBA as a potential partial replacement for cement and found it to be beneficial due to two key mechanisms: its pozzolanic activity and its filler effect. The pozzolanic reaction helps in the formation of additional cementitious compounds, while the filler effect contributes to the densification of the concrete matrix by filling voids between particles. Together, these properties make SCBA a valuable addition to sustainable cement production, especially in reducing cement consumption without compromising strength or performance.
- Vasudha D. Katare and Mangesh V. Madurwar (2017) analyzed the behavior of concrete blended with SCBA, particularly looking at its setting time and heat of hydration. Their study noted a delay in the setting time of SCBA-blended concrete, which can be advantageous for applications requiring extended workability. Additionally, the research found that SCBA helped lower the heat of hydration, which is beneficial in minimizing thermal cracking and improving the durability of concrete in large-scale pours or hot climates. These findings further support the use of SCBA as an environmentally friendly and technically viable construction material.
- Juliana Moretti et al. (2016) explored the potential of combining industrial waste materials in concrete and found promising results. Their study revealed that when 30% construction waste and 30% sugarcane bagasse ash (SCBA) were used together as partial replacements in concrete, the resulting mix achieved approximately 93% of the compressive strength compared to the control concrete. This suggests that even with a high level of substitution using recycled and waste materials, it is possible to retain most of the mechanical strength, making it a sustainable option for structural applications.
- Elisabeth Arif et al. (2017) investigated the influence of SCBA on the mechanical performance of concrete, focusing particularly on compressive strength. Their findings indicated that incorporating SCBA up to 20% by weight contributed significantly to strength improvement. This positive outcome is likely due to SCBA's pozzolanic properties and its ability to act as a fine filler, enhancing the overall microstructure of the concrete and contributing to better packing of particles.
- Alireza Joshaghani and Mohammad Amin Moeini (2017) conducted a study examining the effects of SCBA at various dosage levels in concrete mixes. They observed that while SCBA can be beneficial at moderate levels, its inclusion beyond 20% of the binder weight resulted in reduced compressive strength. This decline was attributed to the relatively slow reactivity of SCBA compared to traditional cementitious materials. However, they also noted that SCBA played a valuable role in improving transport properties in mortar, such as flow and pumpability, making it advantageous for specific construction scenarios.
- Kittipong Kunchariyakun et al. (2018) compared the performance of SCBA with that of black rice husk ash in autoclaved aerated concrete (AAC) samples. Their research showed that SCBA outperformed rice husk ash in terms of strength development, leading to additional strength gains in AAC specimens. This suggests that SCBA could be a more effective alternative in lightweight concrete production, offering better mechanical performance while utilizing an agricultural byproduct.
- Juliana P. Moretti et al. (2018-A) examined the use of SCBA in self-compacting concrete (SCC) and found that it performs well as a filler material. Their study demonstrated that SCBA-enhanced SCC not only maintained good flowability and self-compacting characteristics but also achieved satisfactory strength and durability levels. This

supports the use of SCBA in advanced concrete technologies, especially where workability and performance must be balanced with sustainability.

- In another study by Juliana P. Moretti et al. (2018-B), the microstructural impact of SCBA was investigated. It was found that replacing 30% of fine sand with SCBA significantly altered the pore structure of the concrete, leading to a 44% reduction in pores larger than 0.1 micrometers. This refinement of the pore network enhances the concrete's durability by limiting the penetration of moisture and harmful chemicals, which can lead to long-term degradation.
- Fernando C.R. Almeida et al. (2019) analyzed the dual impact of SCBA on both strength and durability. Their results showed that incorporating SCBA in concrete not only improved compressive strength but also increased resistance to chloride ion penetration. This suggests that SCBA contributes to a denser concrete matrix and enhances long-term durability, particularly in environments prone to aggressive chemical exposure, such as coastal or industrial areas.

Effects of Granite Waste

- Bacarji et al. (2013) investigated the use of Marble and Granite Residue (MGR) as a partial cement replacement and found a strong correlation between the effectiveness of MGR and the contact area in the concrete mix. Their research confirmed that MGR could be considered a sustainable material for reducing cement content in concrete, contributing to environmentally friendly construction without significantly compromising strength.
- Vijayalakshmi et al. (2013) studied the mechanical performance of concrete containing varying percentages of granite waste (GW). Their results showed that at early ages, specifically at 7 days, the compressive strength of concrete mixes improved in comparison to standard cement mortar. For split tensile and flexural strength, mixes with 5%, 10%, and 15% granite waste showed similar or slightly lower values than the control mix. However, when the substitution exceeded 15%, the losses in tensile and flexural strength became more pronounced, suggesting an optimal threshold for effective replacement.
- Shehdeh Ghannam et al. (2016) explored the effect of substituting fine aggregate with granite waste and found that a 10% replacement level was most effective. At this rate, both compressive and flexural strengths increased by approximately 30% compared to conventional concrete. This indicates that a moderate inclusion of granite waste can significantly enhance structural performance.
- Malkit Singh et al. (2014) analyzed the compressive and flexural strength of concrete with different granite waste substitution levels. The study revealed that replacing fine aggregate with 30% granite waste resulted in improved compressive strength, while a 50% replacement still maintained compressive strength comparable to that of the control mix. In addition, the flexural strength consistently improved as the percentage of granite waste increased, suggesting enhanced crack resistance.
- Joel (2010) examined the workability of concrete mixes with granite waste and found that slump values remained similar to those of the conventional mix up to a 50% replacement level. However, at higher substitution levels, the slump increased noticeably, indicating a rise in workability due to the smoother and finer texture of granite waste particles.
- Adigun (2013) also studied workability and reported a similar trend, where the slump value increased as more crushed granite waste was added to the mix. This suggested improved flow and ease of placement, which could be beneficial in applications requiring high workability.
- In contrast, Sarbjeet Singh et al. (2016) observed a different behavior in slump values, noting that workability decreased as the granite waste content increased. This variation in findings suggests that factors such as particle size, mix design, and water content play critical roles in determining the workability outcomes when using granite waste.
- Abhishek Jain et al. (2019) focused on the compressive strength of concrete with granite waste and found that strength peaked at a 20% replacement level. Beyond this percentage, a decline in compressive strength was observed, indicating that while granite waste can enhance concrete performance to a certain point, excessive use may have adverse effects on strength.

CONCLUSIONS

Sugarcane Bagasse Ash (SCBA) and Granite Waste (GW) have great potential as sustainable alternatives in concrete production. Used in the right proportions, these materials don’t just help reduce the environmental impact of construction-they can actually enhance the performance of concrete.

SCBA, when finely ground, shows strong pozzolanic properties. It reacts well with the other components in concrete, helping to improve strength, reduce large pores, and increase durability. Studies have shown that replacing cement or sand with SCBA-typically up to 20-30%can boost long-term performance. It also helps lower the heat of hydration and delays setting time, which is useful in hot climates or large concrete pours. However, going beyond that range might reduce workability, so proper mix adjustments are needed. Granite waste, on the other hand, performs best when used as a partial replacement for fine aggregate. At levels up to 30%, it tends to improve strength and workability, depending on its particle size and the overall mix. Some studies found that it even helps control cracking and increases flexural strength. But similar to SCBA, too much granite waste can lead to drops in performance, so finding the right balance is key.

Together, these materials support more eco-friendly construction by reducing the need for natural resources like cement and river sand. They also help manage industrial and agricultural waste more effectively. When used properly, SCBA and GW can contribute to durable, cost-effective, and sustainable concrete, making them excellent choices for future building projects.

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