# Green and environmental-friendly material for sustainable buildings

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**Abstract.** In construction, incorporating waste materials such as bio-binders and fine aggregates plays a vital role in promoting environmentally friendly building methods. Utilizing these materials for a second time reduces waste generation, contributing to conserving valuable natural resources. This underscores the importance of sustainable construction practices. This study outlines the experimental results concerning the mechanical attributes when employing a combination of micro sand silica and a bio-binder, specifically Abelmoschus esculentus. The investigated mechanical properties in this study encompass modulus, strength, and toughness. The experimentation involved mixing Abelmoschus esculentus with varying weight percentages and three distinct micro-size particles and then compressing them into cylindrical samples. Abelmoschus esculentus demonstrated favorable adhesion properties with sand silica particles, and the findings suggest a noteworthy impact on the mechanical properties upon its addition. Overall, it was observed that the optimal mechanical properties were attained with a 15% weight ratio of Abelmoschus esculentus bio-binder at a particle size of 250 µm.

## Introduction

Eco-friendly building materials could be created by combining aggregates with bio-binders derived from natural resources, such as agricultural waste. This eco-friendly strategy reduces landfill trash in addition to carbon emissions. This environmentally conscious alternative to conventional cement manufacturing has the potential to make a substantial impact on mitigating global warming. The conversion of biomass stands out as a promising alternative energy solution because of its minimal greenhouse gas emissions and the generation of substitutes for petroleum. This renders it a valuable, abundant, cost-effective renewable energy source [1]. The adaptability of biomass utilization, enabling its direct use as a fuel source and transformation into diverse forms of energy, stands out as a significant advantage. In 2030, biomass is expected to ncrease for the world energy supply, making it the leading renewable energy source, according to IRENA research on the subject [2]. In light of the current imperative for environmental sustainability amid escalating energy demands, biomass emerges as an alternative fuel capable of displacing fossil fuels and promoting sustainability. Wood, agricultural and animal waste, energy crops, and industrial waste are examples of potential biomass sources for renewable energy [3]. One way to limit the use of natural resources and reduce energy usage is to produce eco-friendly construction materials from agricultural waste [4]. Furthermore, one effective way to use agricultural waste is to use plant leftovers as a bio-binder. This knowledge is anticipated to lead to a broader acceptability of using agricultural wastes in construction applications [5]. Different research has called building materials with minimal carbon emissions, sustainability, and many uses "agricultural concrete" [6]. Building waste, in particular, has a significant percentage of heavy metals, including massive solid garbage. Consequently, increased soil heavy metal concentration risks soil quality due to various biochemical processes [7]. Furthermore, the accumulation of waste generated from construction projects leads to the decomposition of specific organic substances, emitting harmful gasses that add to environmental pollution. Furthermore, air quality can be negatively impacted by pathogens and particles from garbage spreading through the atmosphere [8]. Consequently, choosing agricultural materials like Abelmoschus esculentus can help diminish the generation of construction waste, exercising control over releasing dangerous compounds into the environment and damaging pollutants. Since silica dioxide ($SiO_2$) makes up the majority of sand, it is frequently included as a filler in studies. When creating composite materials, one or several filler substances are combined with a matrix material, such as ceramic or polymer, sand is typically used as a filler. Strength, stiffness, toughness, and thermal stability are among the mechanical and physical properties of the composite that are improved by the use of sand as a filler. Sand is a valuable filler material in many industrial and scientific applications because of its availability, affordability, and compatibility with various matrix substances. Composite materials' mechanical and physical characteristics can be improved by adding sand as a filler, making them more appropriate for a broader range of uses. Despite its crystalline form, $SiO_2$, considered physiologically benign, finds uses in the pharmaceutical and agricultural industries with no known health hazards. In general, silica has qualities that allow it to work well with various polymeric materials, improving their overall qualities. Furthermore, a lot of filler is made of silica to improve the mechanical performance of polymeric substances [9]. $SiO_2$ nanoparticles are easily synthesized and are reasonably priced, making them useful in chromatography, chemical sensors, catalysts, and ceramics. Abelmoschus esculentus gum, commercially known as Abelmoschus esculentus, demonstrated noteworthy results as a tablet binder, suggesting its viability as an alternative for compositions [10]. Abelmoschus esculentus, a plant commonly cultivated in Africa and Asia, offers a natural, cost-effective, and non-toxic extract, showing promise across various industries. This plant's various components have long been used in medicine traditionally as fight cancer medication, antibacterial, and antidiabetic [11]. This reseasrch aims to evaluate the effects of various Abelmoschus esculentus weight percentages on the mechanical characteristics of a composite containing sand silica particles of various sizes. This study aims to evaluate this composite's potential as an ecologically friendly building material. Furthermore, TGA, XRD, and SEM investigations were performed to characterize the produced materials.

**Materials and Process**

The research examined the compressive strength of multiple samples produced by mixing silica sand with Abelmoschus esculentus at several ratios (five, ten, and 1fiftenn percent). The silica sand samples were placed on an automatic sieve shaker to remove impurities from their surfaces and allowed to sit for ten minutes. A range of sieves with square mesh sizes of 250 µm, 425 µm, and 850 µm were used in this shaker. A volume of $15x10^4$ Liter was achieved by adding deionized water. After agitating the mixture for five minutes at room temperature, the mixture was poured into a precisely cylindrical mold with a 0.5-inch diameter and 1-inch height made of stainless steel base don ISO 604 [12]. A mold releaser was applied to prevent adhesion to the mold surfaces, and the samples were cured for 30 minutes at 176 °F with a 49 $N/mm^2$ load using a heated mechanical press. After adopting a drying process by an oven, the samples were placed in glass incubators for cooling, and their compressive mechanical properties were examined using a general Tensile Testing Machine at a 0.4 mm/min load rate.

**Results and Discussion**

As depicted in Figure 1, adding Abelmoschus esculentus at weight percentages of five, ten, and fifteen percent addition by weight led to an approximately thirty-five percent increase in compressive strength due to the increased number of granules of silica sand in a medium size. The silica sand mixture's compressive strength was increased by the addition of Abelmoschus esculentus, which also enhanced sand particle adherence. This enhancement can be attributed to the high concentration of galactose, rhamnose, and galacturonic acid in Abelmoschus esculentus, which enhance adhesive qualities and have crosslinking characteristics. Furthermore, for all weight percentages of additional Abelmoschus esculentus, it was depicted that the strength dropped by forty percent between 250 µm and 425 microns. The adhesion between particles can be affected by the size of the particles and the applied constant load. Unexpectedly, 850-micron silica sand particles had the lowest compressive strength, even with Abelmoschus esculentus injected in trace amounts. Evidence shows that the silica particle size noticeably affects the composite's overall strength. A noteworthy discovery was made when it was discovered that adding ten percent by weight of Abelmoschus esculentus to 850 µm silica sand may boost compressive strength by twenty-one percent. There appears to be a correlation between the amount of Abelmoschus esculentus added and the silica sand mix particle size in the elastic modulus section. An average of twinty seven percent less Abelmoschus esculentus is added to the mixture as the particle size increases from 425 to 850 microns. Including Abelmoschus esculentus raises the elastic modulus of silica sand because it strengthens the links between the particles in the composite. Particle size, in particular, does not affect a composite's Young's modulus, especially when working with micron-sized particles, as this instance shows [13]. At the nanoscale, the composite's Young's modulus may be enhanced by reducing the size of the particles [14]. The 850 µm silica sand had the lowest elastic modulus of all sizes of silica particles, mainly due to the large dust particles that affected its mechanical properties. By contrast, regardless of the amount of Abelmoschus esculentus added to the combination, the silica particle size of 250 microns demonstrated the highest elastic modulus.

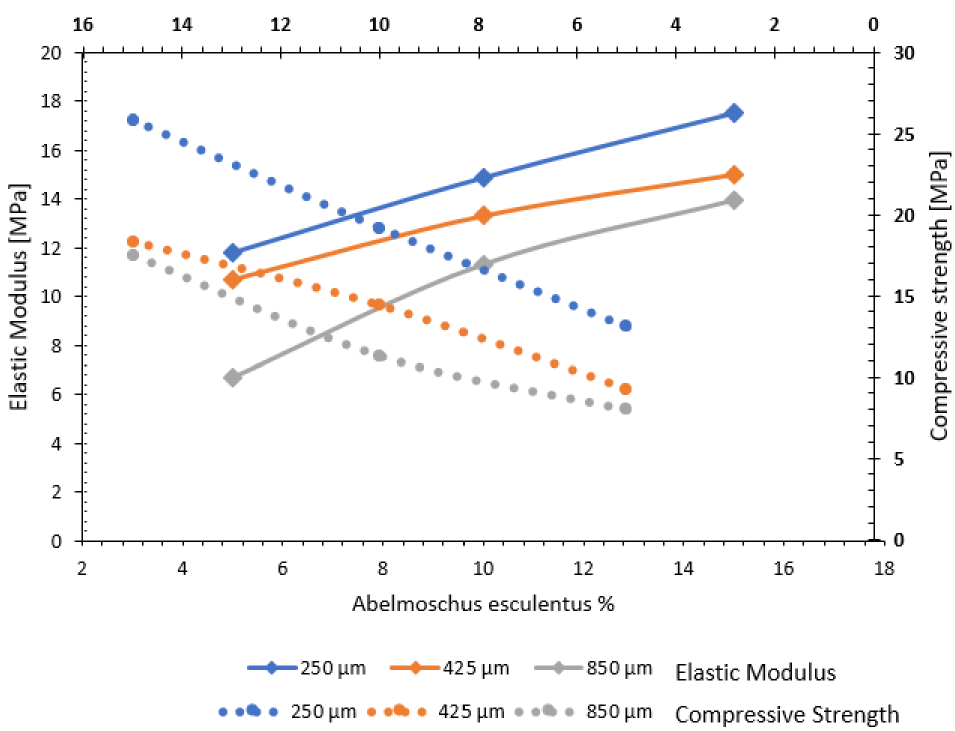


*Figure 1 Elastic Modulus and Compressive Strength*

## Conclusion

The modulus and compressive strength of Abelmoschus esculentus, as well as the mechanical characteristics of micro silica sand, were thoroughly examined in the experiment findings. The particle size emerged as a crucial factor influencing the strength of particulate composites. Specifically, the composite exhibited the highest compressive mechanical properties at fiftenn percent by weight of Abelmoschus esculentus with a particle size of 250 microns. The maximum recorded compressive strength reached 26 MPa, while the peak elastic modulus reached 178 MPa. The potential of silica sand and Abelmoschus esculentus composites in creating environmentally friendly building materials is highlighted by this study.

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