FYP Proposal

Sustainable inert carbonized intrusions for intensification in anti-corrosion and fracture properties of Concrete

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Abstract

Concrete, a widely used construction material, has long been associated with environmental drawbacks, primarily due to its carbon emissions and its susceptibility to cracking, water penetration, and corrosion. In order to solve the inherent problems with conventional concrete, this project aims to investigate the use of biochar, with a special focus on biochar made from used tires. This study's main goal is to thoroughly evaluate how biochar affects a range of crucial aspects of concrete, including its mechanical qualities, corrosion resistance, permeability, and environmental effect. This study aims to provide useful insights into the viability and potential advantages of biochar as a sustainable and environmentally friendly additive within the construction industry by conducting a systematic analysis of various concrete formulations, each featuring varying percentages of biochar replacement.

This research is in line with more general global sustainability aims and concepts in addition to its technical ramifications. It stands for a novel and progressive strategy for addressing ongoing environmental problems while also encouraging responsible growth and development in the building industry. This ground-breaking research advances not just our knowledge of concrete materials but also the urgent need for eco-friendly, sustainable methods in the current world. It actively addresses the larger goals of sustainability, innovation, and the pressing need for a more environmentally conscious construction sector by investigating the potential of biochar integration.

1. Introduction

The extensively used construction material concrete has a number of glaring flaws. First off, it has a sizable negative impact on carbon emissions, mostly as a result of the energy-intensive manufacturing process for cement, a crucial component of concrete. It is crucial to look for more environmentally friendly options because these emissions have detrimental effects on the ecosystem. Second, concrete is prone to cracking, which can be brought on by conditions like temperature changes, soil settlement, or severe structural stresses. In addition to compromising the structural integrity, these fissures provide openings for water infiltration, which results in the third weakness of water penetration. Water may erode and degrade concrete over time, shortening its lifespan and decreasing its toughness. Last but not least, the corrosion of reinforcement within concrete is a serious issue since it may affect the durability and structural integrity of concrete structures, calling for routine upkeep and preventative actions.

The use of waste materials in numerous industries has drawn considerable attention in a time of rising environmental consciousness and an urgent need for sustainable solutions. Utilizing the potential of used tires through pyrolysis, a process that turns them into the carbon-rich substance biochar, is one such creative strategy. The objective is to mix biochar made from tires into concrete and analyze how it affects the strength and qualities of this crucial building material.

This project supports global concerns about the astonishing 3.66 billion tires produced each year and the unsettling reality that 67% of these manufactured tires are just thrown away when their intended service lives are up. These abandoned tires represent a serious threat to the environment since they can cause pollution and resource waste. A potential way to properly reuse these waste tires and lessen the load on the environment is to use tire-based biochar.

This project has extra significance in Pakistan, where the tire industry is anticipated to reach 28.5 million tires annually by 2024. The nation has its own issues with managing tire trash, which makes it a prime place for novel solutions. Pakistan may solve its tire waste problem and help to establish a sustainable and resilient infrastructure by using tire-based biochar into concrete construction techniques.

Especially noteworthy is how well these goals align with the UN's Sustainable Development Goals (SDGs). It discusses the risks to the environment posed by conventional tire disposal, such as the highly mutagenic emissions from burning scrap tires and the negative effects of disposing of them in landfills, which include the leaching of harmful substances into the soil and the eradication of beneficial microorganisms. Additionally, it recognises the harmful CO2, CO, and SO2 gas emissions that come from the burning of used tires.

By incorporating biochar made from recycled tires into concrete, we set out on a path to creating resilient, creative, and sustainable infrastructure, which in turn helps to realize several SDGs, especially SDG9 (Industry, Innovation, and Infrastructure), SDG11 (Sustainable Cities and Communities), and SDG13 (Climate Action). To address climate change and its effects urgently is what this program really represents as we work to build a more sustainable and ecologically conscious future. In keeping with the aims of global sustainability, this novel strategy not only solves environmental issues but also encourages sustainable and responsible growth.

2. Literature Review

Concrete is a commonly utilized building material that is renowned for both its flexibility and structural toughness. However, considering how much carbon emissions are produced during its manufacture, it is crucial to look into sustainable alternatives. One such option is adding biochar, a substance rich in carbon produced by the pyrolysis of organic waste, to concrete mixtures. Focusing on its effect on mechanical qualities and sustainability, this review of the literature offers an overview of several research papers looking at the possibility of employing biochar as a cement substitute in concrete.

Akhtar et al. (2017)

Rice husk, pulp & paper biochar, and chicken litter have all been investigated as concrete additions by Akhtar et al. (2017). They discovered that adding 0.1-1% by weight of cement increased the compressive strength of pulp and paper biochar by 10% and rice husk biochar by 6%. This study brought to light the possibility of employing certain biochars to increase concrete strength.[1]

Khalid et al. (2019)

The effects of pyrolyzed wheat straw, tire waste, and cotton stalk biochar in concrete were studied by Khalid et al. in 2019. They increased the compressive strength of the concrete by 80.14 percent by substituting 1% of the cement with pyrolyzed wheat straw biochar, proving the efficiency of some forms of biochar in improving concrete's mechanical qualities.[2]

Ling et al. (2023)

The effects of pyrolyzed wheat straw, tire waste, and cotton stalk biochar in concrete were studied by Khalid et al. in 2019. They increased the compressive strength of the concrete by 80.14 percent by substituting 1% of the cement with pyrolyzed wheat straw biochar, proving the efficiency of some forms of biochar in improving concrete's mechanical qualities.[3]

Gupta et al. (2018)

The application of wood waste biochar in mortar composites was studied by Gupta et al. (2018). They discovered that adding biochar to the cement mix in amounts ranging from 0.5 to 2% increased its 7-day compressive strength by 10 to 18%. The economic feasibility of employing biochar in building was stressed in this study.[4]

Dixit et al. (2019)

The use of wood sawdust biochar in ultra-high-performance concrete was investigated by Dixit et al. in 2019. This study raised concerns regarding the ideal biochar particle size and proportion for various concrete types, even though 8% by weight of coarse biochar showed a loss in strength.[5]

Quin et al. (2021)

The effects of biochar dose and fineness on the mechanical characteristics and durability of concrete were assessed by Quin et al. in 2021. They discovered that substituting 6.5% of the cement's weight with leftover synthetic eucalyptus plywood enhanced the cement's compressive strength. This work made significant contributions to our understanding of the precise dose and fineness needs for enhancing concrete characteristics.[6]

Sirico et al. (2021)

A. Sirico et al. (2021) looked at how wood sawdust biochar affected the performance of concrete. They experimented with different cement replacement ratios of 0%, 2.5%, 5%, 7.5%, and 10%. According to the study, the formulation containing 2.5% biochar produced the greatest gain in compressive strength, showing a surprising 12% improvement. This research implies that the mechanical characteristics of concrete may be greatly improved by adding even a modest amount of wood sawdust biochar. The research by A. Sirico et al. shows how wood-based biochar has the potential to be an important ingredient in concrete manufacturing, enhancing both strength and sustainability.[7]

Lin et al. (2013)

The use of biochar made from municipal solid waste to improve the mechanical and freeze-thaw characteristics of concrete was investigated by Y. Jia et al. in 2023. Cement substitution by weight, ranging from 1% to 30%, was the subject of their investigation. Intriguingly, the study found that the concrete's compressive strength increased by a significant 9.2% even when less than 5% of the cement was substituted by biochar made from municipal solid waste. This result demonstrates how biochar made from municipal solid waste may strengthen concrete's resilience to the testing freeze-thaw cycles. It also suggests that a relatively modest amount of this biochar can significantly increase the durability of concrete.[8]

Y. Jia et al. (2023)

The impact of biochar made from municipal solid waste on the mechanical and freeze-thaw qualities of concrete was studied by Y. Jia et al. in 2023. Their study revealed a 9.2% improvement in compressive strength even with less than 5% of cement replaced, suggesting the possibility of using biochar to strengthen concrete's resilience to freeze-thaw cycles.

Incorporating biochar into concrete gives promising outcomes, according to the literature study, and has the potential to improve compressive strength, durability, and sustainability. These studies highlight the significant potential of biochar as a sustainable additive in concrete production, aligning with the objectives of reducing carbon emissions and enhancing the environmental performance of concrete. Different types of biochar and their optimal dosages are still being investigated. To address the unique requirements for various types of concrete and comprehend the long-term impacts of biochar insertion, more study is required.[9]

3. Problem Statement

Within the sphere of sustainable construction techniques, the challenge at hand is the concurrent mitigation of environmental issues tied to tire waste and the optimization of concrete properties, particularly in terms of reducing carbon dioxide (CO_2) emissions within the concrete itself. The goal of our study is to reduce CO_2 emissions from the concrete while maintaining structural integrity, durability, and industry compliance by using tire trash that has been transformed into biochar. This multimodal strategy aims to promote environmentally responsible building techniques in a new age of sustainable innovation in the building industry.

4. Research Objective

- **To investigate how concrete's compressive, flexural, and tensile characteristics are impacted by nano- and microsized biochar particles:** This study objective intends to explore the effects of adding nano-micro sized biochar particles on the compressive strength, flexural strength, and tensile strength of concrete. By doing this, the study aims to comprehend how the structural integrity and load-bearing ability of concrete are affected when biochar is pulverized to a nano-micro size. The goal is crucial for improving the functionality of biochar-modified concrete and figuring out if it can satisfy the structural demands of various building applications.This goal will undertake a thorough life cycle study to evaluate the carbon sequestration capability of the biochar as well as the emissions related to tire disposal, giving a full picture of the environmental effect. By encouraging innovation in building materials and procedures, understanding how the inclusion of waste tire biochar impacts the strength qualities helps to achieve Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure). By assisting in the reduction of greenhouse gas emissions and supporting the demand for immediate action to address climate change, the aim is consistent with the global sustainability objectives, notably SDG13 (Climate Action).
- **To evaluate the permeability and corrosion properties of the steel-reinforced cementitious composites based on biochar:** Examining the permeability and corrosion behavior of cementitious composites containing biochar, in particular those reinforced with steel, is the main goal of this research project. The evaluation involves an investigation into how water and other hostile substances damage the steel reinforcement by penetrating the concrete. For concrete constructions to last a long time and be durable, it is essential to comprehend these properties. Additionally, it offers information about the steel reinforcement's possible benefits from biochar protection, which might result in more durable and long-lasting concrete infrastructure. By encouraging innovation in building materials and procedures, understanding how the inclusion of waste tire biochar impacts the strength qualities helps to achieve Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure).

- **To assess the possibility for concrete's CO_2 emissions to be reduced by the addition of carbonized intrusions:** The main goal of this study is to estimate the environmental advantages of adding carbonized intrusions, probably some kind of waste or byproduct, to concrete. The main objective is to evaluate the decrease in carbon dioxide (CO_2) emissions related to the manufacture of concrete while utilizing these components. The study intends to provide light on the sustainability and eco-friendliness of concrete mixtures that contain carbonized intrusions by assessing the environmental effect. A critical first step toward more ecologically friendly construction methods is lowering CO_2 emissions from the manufacture of concrete. By assisting in the reduction of greenhouse gas emissions and supporting the demand for immediate action to address climate change, the aim is consistent with the global sustainability objectives, notably SDG13 (Climate Action).

This study goal contributes to resolving environmental issues related to conventional concrete, such as the leaching of toxic compounds, and supports the need for sustainable and responsible construction methods by looking into how waste tire biochar affects corrosion resistance.

5. Methodology

In this paper, a thorough approach for analyzing concrete specimens' various qualities is described, with an emphasis on determining how well-suited they are to particular uses. These tests, which are carried out in line with accepted test standards, offer insightful information on the quality and performance of concrete in a variety of engineering and construction settings.

5.1 Material Collection

The gathering of particular components is crucial for conducting the concrete formulations and subsequent testing. For the study, the following items will be collected:

Biochar: Biochar, a carbon-rich substance produced by the pyrolysis of organic waste, will be gathered and added to the concrete mix as a substitute for cement. After being obtained in raw form, the biochar will be finely powdered into a size appropriate for mixing with the concrete mixture.

Coarse Aggregate: Coarse aggregate will be purchased in accordance with regional building requirements. It is commonly made out of crushed stone or gravel. It will be carefully chosen to make sure it is free of pollutants or other impurities that can compromise the structural integrity of the concrete.

Sand is frequently included in fine aggregate, which is gathered to suit regional building requirements. This fine aggregate will be carefully chosen to ensure its quality and purity, preventing any unfavorable impacts on the composition and functionality of the concrete.

Cement: We will purchase premium Portland cement, which is frequently used as a binder in the creation of concrete. This cement will comply to accepted cement standards and have the requisite strength characteristics to be a trustworthy benchmark in the study.

5.2 Plan for Formulation and Testing

The study will include the creation of four different concrete formulas, each of which will use biochar in place of cement to a certain extent. The formulas will use replacement percentages of 1%, 3%, 5%, and 7%. All concrete specimens will go through typical curing methods after the formulation stage in order to mimic real-world circumstances and permit accurate and dependable testing results. With this thorough technique, it is possible to evaluate biochar incorporation's effects on the mechanical and structural qualities of concrete at various replacement percentages. The investigation of environmentally friendly and sustainable alternatives in the manufacture of concrete is a crucial part of the research's overall objective.

5.3 Tests

- To determine if concrete is workable, the Slump Test, carried out in accordance with ASTM C143, is used. This test is essential for the building process since it provides a gauge of the consistency of the concrete, assisting in optimum placement and compaction. The flow and cohesiveness of the concrete mixture are also disclosed, enabling the engineer to make any necessary modifications.
- The ASTM C39-compliant Compressive Strength Test is essential for determining how well concrete can support loads. This test assesses the load-bearing capability of the concrete, a crucial characteristic that guides structural design and construction decisions, notably in foundation and structural applications.
- The Splitting Tensile Test, based on ASTM C496, is used to assess tensile strength and bending resistance. This test offers useful information for applications where concrete must withstand bending and tensile stresses, such as pavements and slabs.
- The Flexure Test (3 Points), conducted in accordance with ASTM C78 specifications, evaluates the concrete's resistance to bending forces. This is especially important for situations where structural performance and longevity are greatly influenced by flexural strength.
- In line with ASTM C597, the UPV (Ultrasonic Pulse Velocity) Test is used to assess the quality of concrete to find flaws, fractures, or cavities in the substance. This test offers important information on the structural integrity and homogeneity of the concrete sample.
- Density and Moisture Content of the Concrete are evaluated in accordance with ASTM C138/C138M and ASTM D570, respectively. These tests are crucial for determining the concrete's caliber, robustness, and likelihood of developing water-related problems. Analyzing the moisture level of the concrete is essential for its long-term performance, especially in environments where water absorption might be harmful.

- According to ASTM C900, the Pull Out Test evaluates the bonding power between the steel reinforcement and the concrete. It provides information about the quality and consistency of the concrete mixture, particularly at the crucial steel interface.
- The capacity of the concrete to resist corrosion is then evaluated using the ASTM C876-recommended Corrosion Resistance Test. This test, which offers a critical component of the material's environmental impact evaluation, is essential for applications where the concrete may be subjected to harsh conditions or corrosive chemicals.

Table 1 Tests to be performed

Test Name	Test Standards	Used for
Slump Test	ASTM C143	Evaluating workability.
Compressive Strength Test	ASTM C39	Measuring load bearing capacity
Splitting Tensile Test	ASTM C496	Assessing tensile strength
Flexure Test 3 Points	ASTM C78	Evaluating bending resistance.
UPV Test	ASTM C597	Determining concrete quality and homogeneity
Density and Moisture Content Analysis/Water Absorption	ASTM C138/C138M for density, ASTM C566 for moisture content, ASTM D570 for Water Absorption	Characterizing the concrete mixture
Pull Out Test	ASTM C900	Measuring bond strength between concrete and steel
Corrosion Resistance Test	ASTM C876	Assessing resistance to corrosion
Environmental Impact Assessment		

By using these standardized tests, the research offers a thorough assessment of the mechanical, structural, and durability properties of concrete, assisting in the selection and optimization of concrete mixes for various engineering and construction applications.

6. Expected Outcomes

Outcome 1: Comparable or Enhanced Long-Term Compressive Strength and Variations in Flexural and Tensile Strengths

The first anticipated result of this study is to show that, in comparison to conventional concrete mixes, the addition of biochar to concrete formulations will result in equivalent or improved long-term compressive strength. The use of biochar might strengthen the concrete's structural integrity and ensure that it satisfies or surpasses industry requirements for compressive strength. Variations in flexural and tensile strengths are further predicted, with the potential for enhancing flexural strength and enhancing tensile strength. This result would demonstrate the flexibility and versatility of concrete treated with biochar for a variety of applications, offering creative solutions for structural and building tasks.

Outcome 2: Improved Corrosion Resistance Characteristics and Permeability of Biochar-Based Steel-Reinforced Cementitious Composites.

The second predicted result is an increase in the permeability and corrosion resistance properties of cementitious composites reinforced with steel based on biochar. The addition of biochar is anticipated to improve the concrete's ability to resist corrosion, making it better suited for use in harsh locations or in situations where exposure to corrosive chemicals is a problem. This finding shows that biochar-modified concrete can provide longer service lives and durability, especially in buildings like bridges and maritime facilities where corrosion poses a serious problem. Additionally, less permeability might shield the structure's integrity by preventing water and hostile substances from infiltrating the concrete.

Outcome 3: Significant Reduction in Carbon Footprint Compared to Traditional Concrete Through the Incorporation of Waste Tire Biochar

The third anticipated result is concerned with environmental effect and sustainability. By integrating waste tire biochar, it expects to significantly reduce the carbon impact when compared to conventional concrete. It is anticipated that adding waste tire biochar to the concrete mixture would help lower carbon dioxide emissions produced during concrete manufacturing. This decrease is in line with sustainability objectives and is a significant step toward more ecologically friendly building techniques. This study intends to show that producing concrete may be done in a more environmentally friendly and sustainable way by recycling waste materials into biochar, hence advancing more general environmental goals.

7. Conclusion

This study highlights the possibility of adding biochar to concrete, particularly from tire waste, to overcome some of the major flaws in conventional concrete. The study highlights the promising results that may be attained by investigating the mechanical characteristics, corrosion resistance, permeability, and environmental effect of biochar-modified concrete. The predicted outcomes imply that biochar has the capacity to increase concrete's long-term compressive strength while providing variations in flexural and tensile strengths that can be useful in a variety of applications.

Additionally, adding biochar increases the durability and lifetime of concrete buildings by lowering permeability and improving corrosion resistance. Most importantly, this research shows how using waste tire biochar may considerably reduce concrete's carbon footprint, promoting more ecologically friendly and sustainable building techniques.

This research offers a workable alternative that is consistent with global sustainability objectives in a society that is struggling with the negative environmental effects of disposing of discarded tires and the pressing demand for sustainable construction materials. It illustrates a route towards robust, inventive, and eco-aware infrastructure, focusing in particular on the goals of sector innovation, sustainable communities, and climate action. In the end, our effort is an essential step in combating climate change and creating a more sustainable future for future generations.

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