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AN EXPERIMENTAL INVESTIGATION ON DEVELOPMENT OF BIOCHAR CONCRETE TO REDUCE CARBON FOOTPRINT

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ABSTRACT
The utilization of biochar in concrete has attracted considerable attention due to its potential in enhancing the properties and sustainability of this construction material. This in-depth review delves into various aspects of biochar-concrete composites. It commences by defining biochar and exploring its production methods, physical and chemical properties. Additionally, the review provides an overview of concrete, emphasizing its composition, properties and the challenges associated with traditional production methods. The incorporation of biochar in concrete brings forth several benefits, such as improved strength and durability, enhanced thermal properties and the potential for carbon sequestration. The paper examines the production process of biochar-concrete composites, covering aspects like incorporation methods, biochar selection, mixing techniques and quality control measures. Furthermore, the sustainability aspects of biochar-concrete are evaluated, considering its environmental impact, life cycle assessment, carbon footprint reduction and economic feasibility. The review also addresses the challenges and future perspectives of biochar-concrete composites, along with opportunities for research and development. This comprehensive review presents valuable insights into the properties, production and sustainability of biochar-concrete composites. It serves as a guide for further advancements in the realm of sustainable construction.

CHAPTER-1
INTRODUCTION
1.1 General

Climate change caused by the anthropogenic emission of greenhouse games poses a severe threat to the earth's ecosystems. Emissions of greenhouse gases such as carbon dioxide (CO2), Methane (CH4), and nitrous oxide (N2O) traps heat in the atmosphere and warm the planet. Among them, carbon dioxide acts as a main greenhouse gas responsible for climate change (Marescaux et al. 2018). CEMENT industry plays a significant role in global carbon emission. Cement industry is a highly energy intensive process. Approximately 1 tonne of CO2 is emitted per tonne of clinker production during the calcination process (Norcem 2021). Other significant amount of emission generates from the burning of fossil fuels to heat the kiln upto extreme temperature. In 2015, cement industry generated around 2.8 billion tonnes of CO2, the equivalent of more than any individual country except China and the US (Housefather 2021). Therefore, it is essential to reduce cement carbon footprint and develop a sustainable method to capture and store CO2 to combat climate change.

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Biochar is a type of black carbon produced from a carbonaceous material through the application of heat or chemicals in an enclosed container with little or no oxygen (Deem &) Crow 2017). Organic materials from agriculture and other forest wastes (biomass) are burned in a zeroor low oxygen environment to produce biochar. Although, biochar looks like common charcoal, it is unique because of its production process and long-term carbon sequestration properties. In addition to carbon capture, biochar also can improve soil fertility, builds nutrient retention capacity in soil, and reduce the need for chemical fertilizers (CharGrow 2019).

Every feedstock and methodology of creating biochar provides different physical and chemical properties of the product (Laine et al. 1991). However, there are some universal physical structures of biochar. The key physical properties are the large surface area (340 m^2/g), water holding capacity and high porosity (0.21 cm^3/g) (Manariotis et al. 2015). Almost 70 percent of biochar composition is carbon whereas the remaining percentage consists of nitrogen, hydrogen, oxygen, ash, and Sulphur.

From a chemical view point, chemical properties of biochar depend highly on feedstock and pyrolysis conditions. The defining characteristic of biochar is its carbon content consisting primarily of aromatic compounds characterized by rings of six C atoms linked together without oxygen (O) and hydrogen (H), the otherwise more abundant atoms in living organic matter (Lehmann & Joseph 2009).

CHAPTER-2
LITERATURE REVIEW

Sachini Supunsala Senadheera and Souradeep Gupta

The review is on the application of biochar in concrete. The continous rise in global temperatures is an evidence of climate change. CO_2 emissions have caused major problems owing to its contribution to climate change. In particular, the construction industry has a considerable carbon footprint. Therefore, investigations into climate change mitigation are indeed a priority. This can be mitigated to a certain extent by incorporating bio-based constituents into construction materials. Biochar, a carbon-rich product of biomass pyrolysis, is considered a potential substitute for cement replacement. Although biochar has conventionally been used as a soil amendment in the agricultural industry, researchers have recently investigated its applicability in concrete. Importantly, the results thus far have reported its contribution to the enhancement of the mechanical, thermal and physical properties of cement. Biochar is considered the most promising approaches for carbon sequestration because it can absorb more than twice its own weight in CO_2.

According to statistics, the production of Portland cement, which is considered a main material for construction, contributes to 8% of the global CO_2 emissions. As the cement industries play a major role in the production of GHGs, efforts are being made to reduce its impact on the environment using sustainable materials and practices.

Kafkova et al.

He revealed that 2.72 tonnes CO2 could be sequestered using one ton biochar. Biochar has been proven to improve the quality of materials, such as asphalt used for road construction.

Wang et al.

He suggested that accelerated carbonation, also known as CO_2 curing, can generate hydrated products that can subsequently transform stable carbonates. The introduction of biochar can accelerate the carbonation process because of its enhanced pore structure, which aids in diffusion of CO_2.

CHAPTER 3
PROPERTIES OF MATERIALS

1. **Cement** They are finely ground powders that when mixed with water set to a hard mass. Ordinary Portland Cement is the most common type of cement and is made by heating limestone with other materials to 1450º Celsius in a kiln in a process called calcination.

The most important use of cement is production of mortar and concrete which is important for stronger buildings. It is used in manufacture of some products like bricks, shingles, beams, tiles, pipes, railroads, etc.

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2. Sand

Sand is a mixture of small grains of rock and granular materials which is mainly defined by size, being finer than gravel and coarser than slit. And ranging in size from 0.06 mm to 2 mm.

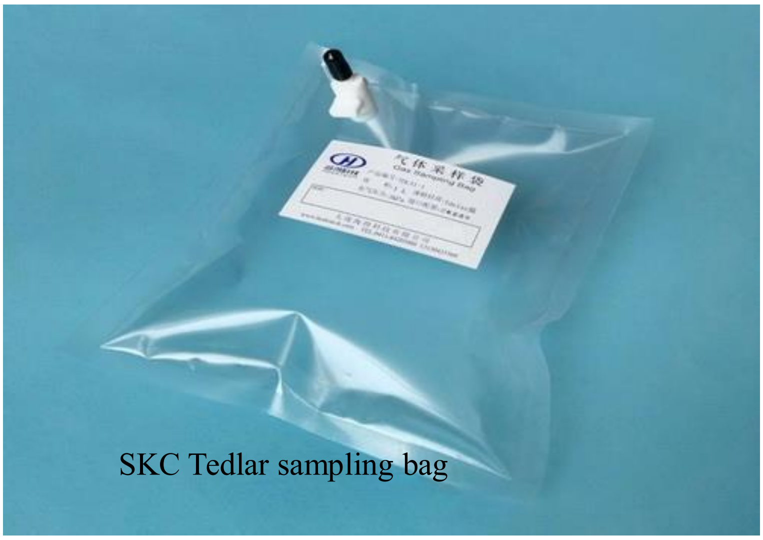
3. Biochar

The biochar sample was produced by pyrolysis of pine wood, birch wood and pine wood chips.

CHAPTER 4
TYPES OF TESTS

1. Carbon dioxide sequestration test

SKC Tedlar sampling bag (Figure 9) made of ethylene polymer plastic with maximum capacity of 5litres was used as a container.



SKC Tedlar sampling bag

The edge of the sampling bag was cut open, so that the concrete cubes and loggers could be placed inside it. Different percentage of biochar amended cubes were placed inside the sampling bags. After concrete cubes and loggers were positioned inside the bags, the cut was thermally laminated leaving a small cut to inject the CO2 gas pipe. After injecting some amount of CO2, the cut was covered with a Gaffer tape making sure no air could escape. The containers were checked manually to ensure that there were no leaks in order to measure CO2 strictly within the container.

TGE-0011 CO2 data logger as shown in Figure 10 with measuring range 0-2000 pmm (Parts Per Million) and 0-5000 ppm were fixed inside each container to monitor the concentration of carbon dioxide. The logger uses an independently calibrated dual wavelength Non-Dispersive Infrared (NDIR) sensor to measure the CO2 concentration inside the container. Since the logger had its measuring range limitation, a small amount of nitrogen was injected inside the container so that it would dilute the content of CO2 and the logger would be able to read the starting level of CO2 inside the container (Lehesvaara 2022).

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Figure 10 TGE-0011 carbon dioxide sensor (Gemini Data Loggers 2017).

The test was carried out for approximately 7 days. Next, the loggers were stopped and connected to the computer to download the results.

2. Compressive strength test

Compressive strength was measured at 28-day age of concrete. The specimen selected for testing were water cured according to standard SFS-EN 12390-2:2019. The cubes were gently placed in the loading unit. The load was applied to the top surface of concrete cubes with the rotary grinder. The maximum load of the machine applied to the specimen is expressed in kilonewton and the compressive strength is reported in MPa. For the test, three specimens from each concrete batch were used and the average value was calculated from the results. Also, the effect of biochar addition at different water-cement ratio (W/C) on compressive strength of hardened concrete was also assessed.

CHAPTER 5
RESULTS AND DISCUSSION

One of the main challenges of CO2 sequestration experiment was selecting the right device for the experiment. The logger used for the experiment had its limitations i.e., the range was 0-5000 ppm. In the experiment we had injected some amount of CO2 gas inside the container. The gas concentration exceeding the logger range were not detected by the logger. Therefore, the initial concentration was only recorded when the gas concentration inside the container is within the logger range. Similarly, the CO2 instrument did not measure pressure variations. As we injected the gas inside the container, the pressure was assumed to be higher and during the adsorption the pressure was expected to decrease. A pressure sensor could have been used to support the assumption and study the relationship between pressure and CO2 gas inside the container.
However, the device was suitable for first time user and was effective in measuring CO2 concentration in PPM despite of few challenges. Another challenge of this experiment was finding the right container. The Tedlar PVF gas sampling bag that was cut and later thermally laminated and taped were meant to be airtight. However, there was a chance of air leakage. Two blanks (see Appendix 1/5, Appendix 1/6) were prepared for the test among which one showed a slow reduction of CO2 after 27 hours of observation whereas the other remained airtight throughout the experiment. The reason for gas reduction might be an accidental leak in the container. Also, the loggers were extremely sensitive, and the experiment was needed to be performed in a regulated conditions as recommended by the logger manual (Gemini Data Loggers 2017).

6. CONCLUSION

Using biochar as an additive or replacement to cement allows the use of agriculture and forestry waste to sequester carbon in concrete. Biochar utilization in construction sector also represents a potential alternative to reduce carbon footprint of cement industry. Addition of 2 wt% biochar utilization in concrete was found competent in terms of carbon adsorption potential and compressive strength.

Addition of biochar more than 2 wt% has decreased the compressive strength of the concrete. However, it is interesting to note that despite the decrease in compressive strength on the 5 wt% biochar concrete sample, it still fulfilled the compressive strength requirement for residential concrete i.e., > 17 MPa (Nevada Ready Mix 2022). Moreover,10 wt% biochar concrete that has low compressive strength compared to plain concrete can be possibly utilized in other civil infrastructure where strength and durability considerations are less important than structural materials such as yard tiles, flowerpots, concrete bowls, door stop and so on to reduce the carbon footprint of construction industry.

In summary, it can be concluded that a "regulated amount" of biochar as replacement to cement in concrete not only improves the carbon sequestration potential but also the compressive strength of the concrete. The mix of biochar in concrete has achieved the objective of this research.

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