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Building Better Roads with BioChar: A Review on Modified Bituminous Concrete for Sustainable Infrastructure

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ABSTRACT

The rise in the world's population has led to an increase in waste production, which is often burned or deposited in public landfills, causing adverse effects on both the environment and human health. To reduce the negative environmental impacts, pyrolysis is a process that recovers valuable materials from waste. This technique results in the formation of Biochar, a material with exceptional physical and chemical properties that make it suitable for use as an asphalt modifier. Moreover, Biochar can help mitigate environmental hazards, making it an ideal option for sustainable waste management.. A renewable biomass resource called biochar has been used to produce environmentally friendly and long- lasting roads. This research particularly shoots on the effect of biochar as an asphalt modifier on raising the performance of asphalt at high temperatures. The performance of bituminous concrete and the physical, chemical, and natural aspects of biochar are all examined in this research. The impact of biochar on the rheological characteristics, mechanical strength, and duration of bituminous concrete is also covered in the review. Also, by utilising organic waste materials, biochar can serve as an alternative to conventional additives. The exploration estimated in this study shows that adding biochar as an component to bituminous concrete mix can enhance its performance by lowering warping and cracking, adding stability, and b resistance against humidity damage. Overall, the results point to the great possibility of biochar as a useful component in the blend design of bituminous concrete, with implicit advantages for both performance and sustainability. In conclusion, Biochar is workable as a modifier for binders owing to its high- temperature properties.

Keywords- Biochar, asphalt modifier, rheological characteristics, binder modifier, sustainability

1.INTRODUCTION

Pavement material known as bituminous concrete is created by combining aggregates, bitumen, and additives to improve performance and durability. As a sustainable way to enhance bituminous concrete's qualities and reduce the harmful effects of waste disposal, the use of biochar as an ingredient in the mix has been studied. The substance with a high carbon content is called BioChar (BC) . Inorganic elements, traces of heavy metals, nitrogen (N), hydrogen (H), and hydrogen are also present. It is produced through the heat decomposition of biomass starting from upto 900 °C in an inert environment without oxygen. In addition, Biochar can be generated via gasification, a process in which biomass is thermally decomposed at temperatures ranging from 200 to 300°C, with the application of air pressure but without the use of oxidizing agents. Gasification is mainly carried out with ligneous biomass that is subjected to high temperature pressured water. Biomass, which is derived from living beings or industrial waste, is used to produce Biochar. This implies that a wide variety of waste products, including organic waste, municipal sludge, food scraps, and animal or human manure, can be employed to generate Biochar. The physical and chemical characteristics of Biochar like water retention, and pore size and distribution, are influenced by the type of biomass used. The performance of Biochar during pyrolysis is inversely impacted by temperature, but carbon content and porosity increase. The properties of Biochar are influenced by the H/C and O/C ratios, both of which decrease as pyrolysis temperature increases. A low O/C ratio and low polarity are indicators of high stability and long-term viability.

BioChar is an economical alternative to activated carbon, with a greater and particular surface area, a porous structure characterized by high carbon content, and a plethora of surface functional groups. Moreover, it has a significantly lower environmental impact than activated carbon and exhibits low conductivity, good stability observed, and including with non-flammability also observed in it. It is a sustainable material with a positive environmental impact that can help reduce the release of different organic compounds. BioChar also has exceptional resistance to chemical and biological degradation, adding to its appeal as an environmentally sound option.

The environment is a topic of great concern globally, with CO_2 emissions rising due to increased industrialization and construction. The growth of the global population has also led to a surge in waste and leftovers, which are often kept in land, causing harm to the environment and human body. As a result, issues such as pollution, climate change, waste generation, energy use, and deforestation have become high-priority concerns that require significant resources and efforts to address. To combat these problems, many countries are now favoring the use of renewable biological resources for energy and fuel production rather than fossil fuels. They are also turning to composting and anaerobic digestion to transform waste into biogas or other resources as part of a circular economy approach. Pyrolysis is another way to handle biomass waste, which eliminates the need for landfills and reduces pollutants from incineration. The process produces BioChar, a valuable material that can aid in carbon sequestration and minimize the release of greenhouse gases. According to authors ,BioChar can save 870 kg of CO2 equivalent pollutant and emission's per dry ton of raw material. It has capacity of absorbing CO2 from the atmosphere and can have capacity to inhibit it in pores for several decades. Furthermore, converting outdoor landfill waste into biomass can help eliminate the environmental and social problems associated with this waste disposal method. The potential of BioChar is enormous, making it an effective tool in the fight against climate change.

Biochar (BC) is currently widely used in agriculture, but its potential extends beyond that. In the construction industry, it has been studied as a alternative for mortar and concrete, as well as a modifier for asphalt binders. While carbonaceous compounds, have shown promise as asphalt mix modifiers, their low-temperature fatigue and fracture resistance remain a concern. BC's diverse range of applications includes improving soil composition, restoring degraded soils, water treatment and purification, and serving as a mineral padding or cover for cement in construction materials. Additionally, it can be used as a diet supplement for animals, a substitute for activated carbon, and a material for removing radioactive contaminants from wastewater in the nuclear industry. In construction, BC has potential as a cement cover in mortar or concrete, which can reduce capillary absorption, expedite cement hydration, minimize cracking, and lower cement production while promoting biomass recycling. Furthermore, studies have investigated the use of BC in asphalt mixtures.

BioChar offers several advantages as a material, but there are also some drawbacks that have been identified in the literature. Many of these limitations can be attributed to the fact that BioChar is a relatively new area of research. Some studies have pointed out the need to better understand the physical and chemical properties of BioChar, including factors like particle size, pore size, and pore volume. This will require detailed analyses of how BioChar interacts with different types of feedstock and production processes, as well as assessments of its potential impacts and recyclability. Additionally, it will be important to investigate the presence of any harmful chemical compounds and explore safe methods for using and disposing of BioChar**.**

1.2. Objective

The major purpose of this research was to evaluate the use of BioChar in asphalt mixes and/or asphalt mixtures. The authors want to utilise this evaluation as a springboard for further research into the influence of BioChar in asphalts. They will also be a consultative and research resource for students, academics, and experimenters in construction management, sidewalks, roads, knowledge of the specific, materials, and related subjects. They can also be referenced by realities that support the development of ecologically responsible for transportation of building solutions.

2. LITERATURE SURVEY

Biochar has been investigated as an additive to bituminous concrete to improve its properties and sustainability. Several researches had been reported that the addition of biochar can enhance the performance of bituminous concrete by increasing its stiffness, reducing deformation, and improving its resistance to moisture damage, fatigue cracking, and rutting. The use of biochar also reduces the carbon footprint of road construction and improves the long-term sustainability of the infrastructure.

Çeloğlu et al. [2019] (2) conducted an experiment to modify an bitumen mix using two types of BioChar extracted from different crusts and shells. The asphalt mixture was treated at a temperature of 180 °C. The study showed that BC enhances the performance grade and stiffness of the asphalt mixture at high temperatures. However, the study only conducted conventional characterization and rheological properties tests for binders. The temperature of the mix with BioChar was varied significantly, and it is unclear whether the hardening of the asphalt is due to the temperature or the BioChar used (10). Additionally, there were no studies conducted to predict the responsiveness at low and intermediate service temperatures.

Zhao et al. [2014] conducted an experiment to modify a asphalt mix by adding range of upto 10 BioChar , which was produced through gradual pyrolysis at 400°C for 60 minutes with temperature increments of 15°C/min and included particles smaller than 75 micro meters. The addition percentages were chosen based on a previous study done by the same team. The modified binder was used to create six different types of hot bitumen mix. Results showed that BC improved the resistance to permanent deformation, especially at a 10% BioChar concentration. The researchers claimed that BC also increased resistance to moisture damage, but the indirect tensile strength readings and tensile strength rate did not show significant differences when it is compared to the original mix. Furthermore, as the amount of BC increased, the moisture damage resistance tended to decrease. The study had some limitations such as using only two addition percentages in the binder, unclear methods for combining asphalt with BC, unclear methods for producing HMA with the modified asphalt, obtaining only flexible modulus at 25°C, and not performing any fatigue resistance tests. These findings can serve as a basis for future research in civil engineering, materials, and related fields.

Kumar et al. [2018] conducted an experiment in which they used BioChar obtained by pyrolyzing to modify two different asphalt binders (with penetration grades of 51.6 and 47.3 mm/10, obtained from different refineries). BioChar was added in increments of 5, 10, 15, and 20 based on the weight of the asphalt binders and mixed using an increased shear mechanical blender for 30 minutes at 160 °C. The pyrolysis process details can be found in reference 70. The study only involved physical and rheological characterization of the different asphalt binders. According to the findings, the addition of BioChar increased the density of the asphalt binder, enhanced its resistance to infinite distortion, and reduced its susceptibility to aging.

Dong et al .(2020) conducted a study where they utilized to modify an asphalt mixture with a penetration grade of 63 mm/10. The addition of BC was carried out at 145 °C for 45 minutes using a high-speed shearing mixer, and five different BC amounts were used in relation to the asphalt mixture mass (5, 7.5, 10, 12.5, and 15). Based on the experiments performed on the modified mix , the researchers concluded that BC contributed to increased resistance. However, the study also found that the low-temperature performance of the biochar-modified asphalt binder was slightly affected, and there was no information provided on the BC biomass or details of the pyrolysis process.

Saadeh et al. [2020] (5) conducted an experiment where BioChar obtained from swine excrement was blended with a bitumen mix and crumb rubber. The particle size of BioChar used in the experiment was not specified. The asphalt mixtures were tested using the method (SCB) to study and performed the tests . The findings indicated that while BioChar reduced the mixture's fracture resistance, it helped to maintain it after development. The researchers suggest that BC has the potential to enhance the efficiency and consistency of HMA over time, primarily by improving its resistance to rutting. However, the experimental data is insufficient to support this claim as the modified asphalt was not physically or chemically characterized in this study.

Zhou et al. [2021] (6) conducted a study to explore the impact of pyrolysis parameters and different temperatures on the physical and chemical properties of two different types of biochar obtained from animal waste and woody biomass, when used as additives in bio-asphalt. The study involved conducting chemical and physical and mutual characterization tests are done. The primary focus of the investigation was the analysis of the modified bio-bitumen. The findings showed that BC significantly altered the properties of the bituminous concrete mix , including different tests were performed. Overall, the binder was observed to be hardened.

Liu et al. [2021] (7) investigated the effectiveness of BioChar in purifying runoff using a pervious bitumen additive (PA). The study employed three different types of BioCharpadding to create the combination. A modified asphalt was used as a binder, and BC was used to replace PA's mineral filler. The sourcing process of BioChar is not specified, and the effect of BC on the mechanical properties of PA was not determined. The researchers identified the presence of lixiviable ammonia and phosphorus pollutants in BC. However, the study found that adding BC as a filler in PA reduced the leaching of these substances.

3. Conclusion

There are various advantages of incorporating biochar in bituminous concrete. For starters, the addition of biochar to concrete can improve its mechanical characteristics, resulting in more robust and long-lasting roadways. Second, by isolating carbon in the soil, biochar can operate as a carbon sink, minimising the environmental implications of road building. Moreover, the use of biochar can minimise the requirement for virgin materials, resulting in less resource usage and the accompanying environmental implications.

While the use of biochar in bituminous concrete is a novel concept, previous research emphasises its potential for contributing towards a more resilient and environmentally friendly transportation system. However, further study is needed to optimise the use of biochar in bituminous mix, including an examination of its influence on the longevity and performance of roads in various situations and climates.

In conclusion, the application of biochar in modified bituminous concrete is a viable technique for developing better roads and sustainable infrastructure, according to the list of reference sources. Not only can biochar improve the mechanical qualities of bituminous concrete, but it also has the ability to reduce environmental implications by c sequestration and lowering the requirement for virgin materials.

While further study is needed to optimise the use of biochar in bituminous mix, this review demonstrates how this technique has the potential to contribute to a more resilient and environmentally friendly transportation infrastructure. As we continue to face climate change and infrastructure vulnerability concerns, adding biochar into road construction might provide a route ahead for developing infrastructure that is both durable and ecologically beneficial.

4.REFERENCES

1. Zhao, S.; Huang, B.; Shu, X.; Ye, P. Laboratory investigation of biochar-modified asphalt mixture. Transp. Res. Rec. 2014, 2445, 56–63.
2. Çeloglu, M.E.; Mehmet, Y.; Kök, B.V.; Yalçin, E. Effects of Various Biochars on the High Temperature Performance of Bituminous Binder. In Proceedings of the 6th Euraphalt&Eurobitume Congress, Prague, Czech Republic, 1–3 June 2016.
3. Kumar, A.; Choudhary, R.; Narzari, R.; Kataki, R.; Shukla, S.K. Evaluation of bio-asphalt binders modified with biochar: A pyrolysis by-product of Mesuaferrea seed cover waste. *Cogent Eng.* **2018**, *5*, 1548534.
4. Dong, W.; Ma, F.; Li, C.; Fu, Z.; Huang, Y.; Liu, J. Evaluation of anti-aging performance of biochar modified asphalt binder. *Coatings* **2020**, *10*, 1037.
5. Saadeh, S.; Al-Zubi, Y.; Zaatarah, B. *Performance Testing of Hot Mix Asphalt Containing Biochar*; Final Report 20–28; Mineta Transportation Institute: San Jose, CA, USA, 2020.
6. Zhou, X.; Moghaddam, T.B.; Chen, M.; Wu, S.; Zhang, Y.; Zhang, X.; Adhikari, S.; Zhang, X. Effects of pyrolysis parameters on physicochemical properties of biochar and bio-oil and application in asphalt. *Sci. Total Environ.* **2021**, *780*, 146448.
7. Liu, J.; Li, H.; Harvey, J.; Zhang, H.; Tian, Y. Application of Biochar on the runoff purifification performance of porous asphalt pavement. *Transp. Saf. Environ.* **2021**, *3*, tdab026

8. Walters, R.C.; Fini, E.H.; Abu-Lebdeh, T. Enhancing asphalt rheological behavior and aging susceptibility using biochar and Nano-clay. Am. J. Appl. Sci. 2014, 7, 66–76.
9. Zhao, S.; Huang, B.; Ye, P. Laboratory evaluation of asphalt cement and mixture modified by bio-char produced through fast pyrolysis. Pavement Materials. In Proceedings of the Structures, and Performance, GSP 239, ASCE, Shanghai, China, 26–28 May 2014; pp. 140–149.
10. Rondón, H.A.; Bastidas, J.G.; Chavez, S. Inflfluence of mixing time and temperature in hot mix asphalt stiffness during asphalt modifification. *Int. J. Civ. Eng. Technol.* **2019**, *10*, 215–228.
11. Amalina, F.; Abd Razak, A.S.; Krishnan, S.; Zularisam, A.W.; Nasrullah, M. A comprehensive assessment of the method for producing biochar, its characterization, stability, and potential applications in regenerative economic sustainability—A review. *Clean. Mat.* **2022**, *3*, 100045.
12. Marzeddu, S.; Cappelli, A.; Ambrosio, A.; D'ecima, M.A.; Viotti, P.; Boni, M.R. A life cycle assessment of an energy-biochar chain involving a gasification plant in Italy. *Land* **2021**, *10*, 1256.
13. Khosla, N.P. Effect of the use of modifiers on performance of asphaltic pavements. *Transp. Res. Rec.* **1991**, *1317*, 10–22.
14. Chaala, A.; Roy, C.; Ait-Kadi, A. Rheological properties of bitumen modified with pyrolytic carbon black. *Fuel* **1996**, *75*, 1575–1583.
15. Jahromi, S.G.; Khodai, A. Carbon fifiber reinforced asphalt concrete. *Arab. J. Sci. Eng.* **2008**, *33*, 355–364.
16. Xie, Y.; Wang, L.; Li, H.; Westholm, J.; Carvalho, L.; Thorin, E.; Yu, Z.; Yu, X.; Skreiberg, Ø. A critical review on production, modification and utilization of biochar. *J. Anal. Appl. Pyrolysis.* **2022**, *161*, 105405.
17. Brewer, C.E.; Schmidt-Rohr, K.; Satrio, J.A.; Brown, R.C. Characterization of biochar from fast pyrolysis and gasification systems. *Environ. Prog. Sustain. Energy* **2009**, *28*, 386–396.
18. Zhao, S.; Huang, B.; Ye, P. Laboratory evaluation of asphalt cement and mixture modified by bio-char produced through fast pyrolysis. Pavement Materials. In Proceedings of the Structures, and Performance, GSP 239, ASCE, Shanghai, China, 26–28 May 1.2014; pp. 140–149.
19. Ma, F.; Dai, J.; Fu, Z.; Li, C.; Wen, Y.; Jia, M.; Wang, Y.; Shi, K. Biochar for asphalt modification: A case of high-temperature improvement. *Sci. Total Environ.* **2022**, *804*, 150194.
20. Zhou, X.; Zhao, G.; Wu, S.; Tighe, S.; Pickel, D.; Chen, M.; Adhikari, S.; Gao, Y. Effects of biochar on the chemical changes and phase separation of bio-asphalt under different aging conditions. *J. Clean. Prod.* **2020**, *263*, 121532.
21. Zhou, X.; Moghaddam, T.B.; Chen, M.; Wu, S.; Adhikari, S.; Xu, S.; Yang, C. Life cycle assessment of biochar modified bio asphalt derived from biomass. *ACS Sustain. Chem. Eng.* **2020**, *8*, 14568–14575.
22. Zhou, X.; Moghaddam, T.B.; Chen, M.; Wu, S.; Adhikari, S. Biochar removes volatile organic compounds generated from asphalt. *Sci. Total Environ.* **2020**, *745*, 141096