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Comparative Study on the Properties of Different Fiber-modified Asphalts

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

As a major cotton planting country, China has abundant green cotton straw resources. If these resources can be skillfully applied to the construction of asphalt pavement, it can not only significantly improve the performance of asphalt and reduce the life cycle cost, but also effectively solve the environmental pollution caused by straw burning and accumulation. The problem of high-value utilization of crop straw contributes to the construction of a sustainable transportation system. Therefore, the main research contents and conclusions are as follows: Fiber blending in asphalt can effectively improve asphalt performance, improve asphalt pavement life. Cotton straw fiber, basalt fiber and polyester fiber fiber were made into different kinds of modified asphalt, its softening point, penetration, ductility of a series of experimental research, compared with different kinds of 3% fiber dosage on the asphalt modification effect. The study proved that cotton straw fiber, basalt fiber and polyester fiber fiber are to a certain extent to enhance the performance of asphalt, the integrated degree of penetration, softening point, ductility data can be seen, cotton straw fiber straw fiber modified asphalt has a more excellent overall performance.

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Keywords: Road material; fiber type; modified asphalt; performance test.

1. INTRODUCTION

Delhi often tops the list of the most polluted cities globally . The rapid increase in the air pollution episodes over Delhi and the National Capital Region (NCR), for the past several years, especially in the post-monsoon and the winter seasons, primarily due to steady growth in a broad range of local emission sources such as transportation, industrial power generation, and construction activities, in addition to the seasonal burning of the crop-residue (stubble) in the upwind regions of the national capital of India, has posed a greater health risk to a large residential population [1].

Asphalt as the most basic road construction materials, in recent years, with the asphalt pavement in the actual use of the process of constantly undergoing the complex climatic environment and heavy traffic load and other conditions of the combined effect, accelerated asphalt aging, viscosity decline and deformation of the pavement structure, resulting in asphalt pavement in the expected use of the life of the pavement before the occurrence of a greater number of roadway diseases, shortening the service life of the asphalt pavement [2]. At the same time, the waste of resources and environmental pollution caused by the burning of crop straw is becoming more and more serious, the utilization of straw is getting more and more attention, crop straw can be used as feed, fuel, but also can be used in the preparation of biomass composites, due to the performance of straw directly affects the performance of the composites it prepares, therefore, the research on the composition and properties of straw has a significant meaning [3-8].

For fiber materials added to asphalt mixtures, can effectively improve the performance of asphalt mixtures. At present, the commonly used fiber types are polymer fibers, mineral fibers and natural fibers. Lignin and corn stover and other natural fibers due to its environmental qualities, become the project commonly used modified fiber. In recent years, agricultural by-products such as cotton stalks have become emerging road fibers, which are more economical than traditional fibers such as lignin.Jianguo Ma optimized the mixing ratios of basalt fibers and boudunite asphalt, and used the hierarchical analysis method to prove that the mixing of basalt fibers and boudunite asphalt can improve the road performance of asphalt mixtures effectively [8]; Chen Zining analyzed the asphalt adsorption test based on the adsorption test of corn stalk fibers, and analyzed the asphalt adsorption test based on the adsorption test of corn stalk fiber with different dosages. The ability of corn stover fiber adsorption asphaltene under different dosage, revealing the dynamic three-stage adsorption mechanism of corn stover fiber adsorption asphaltene, and the study proved that the role of corn stover fiber within the asphalt mechanism [9].

Cotton straw fiber belongs to straw fiber, the main components include cellulose, hemicellulose, lignin, pectin and protein and other impurities. According to the study, the cotton straw content of each component of the ratio were 46% cellulose, hemicellulose 18%, lignin 23%, its cellulose in the asphalt play an important role, so the removal of cellulose in addition to the other components of the straw fiber application test become the top priority [8].

In this paper, through quantitative analysis to select the appropriate cotton straw fiber pretreatment method, the extraction of cellulose and made of fiber-modified asphalt comparative analysis of basalt fiber and polyester fiber modification effect on asphalt [10-18].

2. MATERIALS

2.1 Raw Materials

Selection of an asphalt products company produced by the 70#1 A road is made of asphalt,

Table 1. Basic technical indexes of 70 # A grade asphalt

Pilot project	Test data	Technical requirement
needle penetration（25℃，5s，100g）/(0.1cm)	68.5	60 ~ 80
Softening point (global method) / °C	48.9	≥46
Ductility (15 °C) / cm	106	≥100
Relative density (25 °C)	3.4	实测

technical performance as shown in Table 1. Basalt fiber (hereinafter referred to as BF) provided by a new material technology company, the fiber appearance of brown filament, the average length of 6mm, the diameter of 0.15um, the melting point reaches 1200 ℃, the tensile strength of not less than 3000MPa, the ultimate tensile strain of 3.2%. Polyester fiber is a synthetic polymer that links each link in the macromolecular chain through an aliphatic group, and the polyester fiber used in this paper is Bonifibers polyester fiber. Cotton straw was used as the object of study as the waste cotton straw from Henan Province China.

3. EXPERIMENTAL INVESTIGATION

In this paper, cotton straw fibers were prepared by the wet method [18], and the main influencing factors on the preparation of straw fibers were the duration of soaking, the weight of feed and the duration of crushing. According to the mechanism of the role of fiber adsorption of oily substances in asphalt, the oil absorption rate of the fiber was selected as an important indicator to evaluate the fiber's excellence. Since the crushing instrument is a small high-speed shear crusher, through several tests and observations, the optimal feeding quality of 50g was determined, leaving a certain space to facilitate effective crushing, at which time the fiber has the most ideal external morphology.

First of all, the waste cotton straw into warm water to clean, the straw surface easily soluble in water impurities cleaned off, and then boiled in hot water for one hour, after which it is soaked and manually cut to a length of 6 ± 2mm (due to the asphalt pavement fiber specification requirements less than or equal to 6mm, so cut to a small section of the convenience of the crushing), the use of small high-speed shear crusher crushing, and then dried and sifted to get Qualified straw fiber.

3.1 Determine the Optimum Soaking Time of Cotton Straw Fiber

The effect of duration of immersion and duration of crushing on the oil absorption of fibers was analyzed, respectively. It was determined that the material was given a mass of 50g, the length of crushing was at 1.5min, and the length of soaking was prepared at 1d, 2d, 3d, 4d, and 5d, respectively, and the oil absorption rates of the fibers were calculated, respectively, and are shown in Table 2, Fig. 1.

According to the analysis of the chart, with the change of fiber immersion length, the trend of oil absorption rate of the prepared cotton straw fibers showed a rapid decline after the first growth, in the immersion length of 3d, the highest value of oil absorption rate of cotton straw fibers is 47.02%, which determines the optimal immersion length of cotton straw fibers is 3d.

3.2 Determine the Optimal Crushing Time of Cotton Straw Fiber

Cotton straw was selected to be soaked for 3d, given 50g, and the fiber was prepared by crushing for 1min, 1.5min, 2min, 2.5min, and 3min, and the fiber oil absorption rate was calculated, respectively, and the results are shown in Table 3 and Fig. 2.

According to the analysis of the chart, with the increase of the crushing length of cotton straw fiber, the prepared cotton straw fiber oil absorption rate trend shows the first growth after the downward trend, when the crushing length of 2min, the fiber oil absorption rate to the maximum value of 48.52%, which determines that the optimal crushing length of cotton straw fiber for 2min.

Table 2. Effect of soaking time on oil absorption rate of fiber

Soaking time/d	1	2	3	4	5
Oil absorption ratio/%	38.19	42.41	47.02	44.12	32.56

Table 3. Effect of crushing time on extraction rate of fiber

Breaking time length/min	1	1.5	2	2.5	3
Oil absorption ratio/%	41.45	44.65	48.52	43.91	40.27

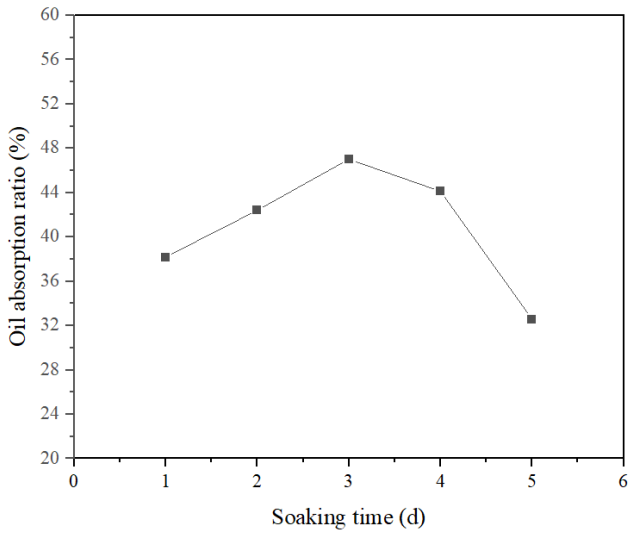

Fig. 1. Relationship between fiber oil absorption rate and soaking time

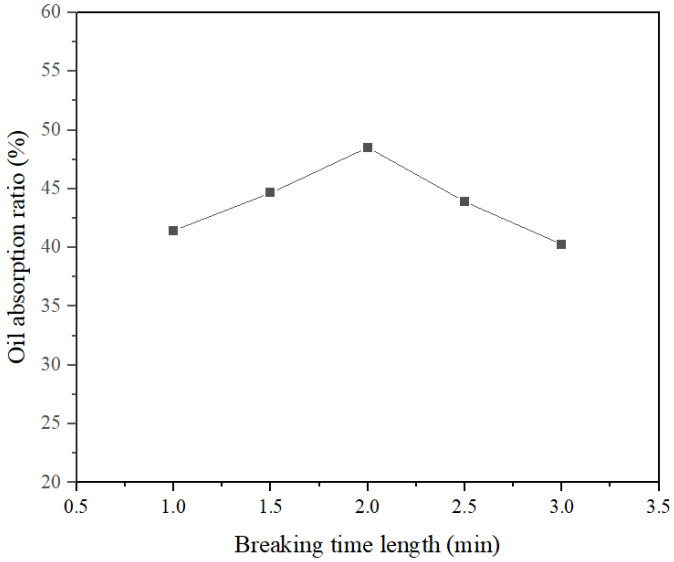

Fig. 2. Relatio11nship between fiber oil absorption rate and crushing time

Table 4. Basic performance index of fiber

Parameters	Basalt fiber	polyester fiber	cotton stalk fiber
color	golden brown	milk white	beige
Fiber length (mm)	6	6	5.8
Ash content (%)	—	—	14.8
Diameter (μm)	14	21	—
Tensile strength (MPa)	3.811	530	—
Elongation at break (%)	3.7	27	—

In summary, when the cotton straw is given 50g, the best preparation process is 3d soaking time and 2min crushing time, Table 4 shows the basic performance indexes of cotton straw fiber.In summary, the best treatment process is that the soaking time is 3d, the material feeding quality is 50g, and the crushing time is 2min.

Table 5. Basic properties of different types of fiber modified asphalt

Pilot project	Basalt fiber modified asphalt	Polyester fiber modified asphalt	Cotton straw fiber modified asphalt
Penetration (0.1 mm)	53	58	64
Softening point (°C)	63.0	61.2	59.7
Ductility (cm,15 °C)	54	66	71

4. RESULTS AND DISCUSSION

Pre-treated cotton straw fibers, basalt fibers and polyester fibers were selected to prepare fiber modified asphalt at a doping level of 3%, and their properties were tested respectively, and the results are shown in Table 5.

The lower needle penetration indicates that the asphalt is more viscous and more resistant to shear. The data in Table 5 show that at 3% dosage, cotton straw fiber has the largest degree of penetration, 64mm; polyester fiber is the second largest, 58mm; basalt fiber has the smallest average degree of penetration, 53mm, which can be inferred that basalt fiber modified asphalt has the largest viscosity and the strongest shear resistance, but this will lead to poor construction and ease of use. Taken together, cotton straw fiber has better ease of use, viscosity and shear strength.

Softening point can reflect the high temperature esistance of asphalt, the larger the softening point, indicating that the asphalt's high temperature performance is better. Through Table 5 can be seen, basalt fiber modified asphalt softening point is the largest, cotton straw fiber modified asphalt softening point is small, it can be inferred that the basalt fiber modified asphalt has a lower temperature sensitivity, while the cotton straw fiber modified asphalt high temperature performance is weaker, which may be related to the material properties of the fibers themselves, the basalt has a good adiabatic properties, which will change the thermodynamic properties of asphalt, thereby increasing Its high temperature resistance, but considering the construction and ease of use is relatively poor, so when considering the high temperature performance, you can consider the economic cotton straw fiber modified asphalt.

The ductility can reflect the low-temperature resistance of asphalt, and the greater the ductility, the better the low-temperature performance of asphalt. In the paper, the elongation of three kinds of fiber-modified asphalt was tested in the environment of 15℃. As can be seen through Table 5, the three kinds of modified asphalt ductility size in order of cotton straw fiber modified asphalt > polyester fiber modified asphalt > basalt fiber modified asphalt. Therefore, cotton straw fiber modified asphalt has the best low-temperature plastic properties, combined with the analysis of the paper for the needle penetration and softening point, the paper concluded that cotton straw fiber modified asphalt has more excellent overall performance.

5. CONCLUSION

Fiber treatment and preparation of natural cotton straw was carried out to determine the best treatment process for cotton straw fibers, and the basic properties of three different fiber-modified asphalt were experimentally analyzed.

(1) The wet method was used to treat the prepared cotton stalk fibers to derive the optimal treatment process, with a soaking time of 3d, a material feed mass of 50g, and a crushing time of 2min, all of which were in line with the requirements of the basic performance indexes of the fibers.
(2) Data from the three indicators can be obtained, three different types of road fibers on the degree of impact on the needle penetration: cotton straw fiber modified asphalt> polyester fiber modified asphalt> basalt fiber modified asphalt; on the softening point: Yu basalt fiber modified asphalt> polyester fiber modified asphalt> cotton straw fiber modified asphalt; on the impact of ductility: polyester fiber modified asphalt> basalt fiber modified asphalt> cotton straw fiber Modified asphalt, which can be obtained, wet method of cotton straw fiber for qualified and excellent performance of road fiber.

(3) Basalt fiber modified asphalt has the best high-temperature rheological properties, cotton straw fiber modified asphalt has the best low-temperature toughness, and the combination of the three major indicators of the data can be obtained, it is considered that cotton straw fiber modified asphalt has a more excellent overall performance.

(4) Compared with matrix asphalt, it is found that fiber can improve the performance of modified asphalt by physical adsorption and reinforcement.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sourangsu Chowdhury, Sagnik Dey, Larry Di Girolamo, Kirk R. Smith, Ajay Pillarisetti, Alexei Lyapustin,Tracking ambient PM2.5 build-up in Delhi national capital region during the dry season over 15 years using a high-resolution (1 km) satellite aerosol dataset,Atmospheric Environment. 2019; 204:142-150.
   ISSN 1352-2310.
2. Kaiwen Zhao, Hongwei Zhang, Yuwen Quan. Optimization of design indicators and explorationof reasonable thickness of asphalt pavement structure [J]. Highway Transportation Science and Technology. 2022;39(06):9-16.
3. He Liu, Yang Liu, Bowen Niu, etc. Experimental study on mechanical properties of straw foamed concrete [J/OL].Journal of Qiqihar University (Natural Science Edition). 2024;(04):1-5[2024-06-27].
4. Maocai Huang, Xiaolin Zhang, Xing Chang, etc. Research progress of different plant fiber reinforced PLA/PBAT/PBS composites [J /OL]. Journal of Composites, 1-13 [2024-06-27 \.
5. Duanyang Wang, Zhong Bi, Xiubin He, etc. Study on compression and frost resistance of corn straw-tire steel wire hybrid fiber concrete [J]. Journal of Liaoning University of Technology (Natural Science Edition), 2024;44(02):100-104.
6. Liguang Xiao, Xu Zhang, Shiqi Peng. Effect of straw treatment methods on the performance of corn straw adhesive free artificial board [J]. Journal of Jilin Jianzhu University. 2023;40 (06):23-27.
7. Sunjian Nie, Hui Xu, Guanchen Zhou and so on. Research Progress of Straw Fiber in Material Field [J]. Agriculture and Technology. 2020;40(03):28-32.
8. Qingshun Liu, Zhuang Zhao, Junlong Shi. Present status of application of straw resources in concrete [J]. Northern Architecture. 2018,3(01):71-73.
9. Ma J, Cui Y, Xing Y. Optimization and pavement performance of buton-rock-asphalt modified asphalt mixture with basalt-fibre [J]. Case Studies in Construction Materials, 2024;21:e03429-e03429.
10. Zining Chen.Study on the adsorption mechanism of corn straw fiber asphalt and its SMA road performance [D]. Harbin Institute of Technology; 2022.
11. Xuexia Yu. Study on road performance of cotton straw fiber modifiedmicro-surfacing mixture [D]. Shihezi University; 2023.
12. Xiaoxia Huang. Experimental and applied research on straw fiber modified asphalt mixture [J]. Western Transportation Science and Technology. 2019;(12):22-25+115.
13. Qinghua Gao. Study on road performance of asphalt mortar modified with cotton stalk fiber [D].Chang 'an University; 2015.
14. Di Feng, Xinjie Gao, Baolin Zhang and so on. Research on mechanical properties of basalt fibre modified asphalt and its mixture [J]. Jiangxi Building Materials. 2023;(11):16-19.
15. Xingyan Wu. Study on road performance of basalt fiber asphalt mixture [J]. Guangdong Building Materials. 2023; 39(03):29-32.
16. Shihong Rao, Sword of Enemy. Application of polyester fiber modified asphalt in highway pavement

construction [J]. Transport World.2022; (26):70-72.

17. Guibin,Wang. Study on road performance of modified asp.
18. Zhenxia Li, Yuanzhao Chen, Jianbin Zhou,. Road performance and mechanism analysis of corn straw fiber asphalt mixture [J]. China Highway Journal, 2019;32(02): 47-58. halt mixture mixed with polyester fiber and SBS [J]. Transport World, 2022;(32):23-25+28.

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