Study on the properties of different biochar to cement paste

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Abstract: in order to explore the effect of biochar on cement properties, wheat straw biochar (WS) and rice straw biochar (RS) were pyrolyzed at 300 ℃, 500 ℃ and 700 ℃ to replace cement with 1% and 2%, and their compressive strength and thermal conductivity were measured. The results showed that the compressive strength of the cement block with biochar increased significantly at 500 ℃ and 1% cracking temperature, and the compressive strength of the two biochar increased by 31% and 29% respectively. The thermal conductivity and thermal diffusivity of two kinds of biochar are decreased, and the thermal insulation performance is improved. The thermal conductivity of rice biochar at 700 ℃ was the lowest with 2%, and the thermal diffusivity of wheat biochar at 700 ℃ was the lowest with 2%. It provides a new way to predict the thermal properties of cement-based materials with low thermal conductivity. At the same time, these properties and laws of biochar can also be applied to cement processing, cement thermal conductivity research, material preparation and other practical applications, in order to create better social, economic and ecological benefits.

1. introduction
With the development of national economy and the promotion of comprehensive national strength, cement-based materials are widely used in water conservancy engineering, civil engineering, building materials and other fields. In cement-based materials, adding additives or admixtures such as slag, steel fiber, fly ash, rice husk ash, to improve its strength and performance has been the research direction of scholars at home and abroad. Lu Li hua [1] shows that there is a reasonable range of fly ash content and the increase trend of cement strength through the study of fly ash content and cement strength, and the addition of appropriate amount of fly ash in concrete has a good effect on improving the performance of concrete. Liang Shi qing et al[2] studied the addition of rice husk ash into concrete as an additive, and the results show that the concrete strength is enhanced when the amount of fly ash is small; With the increase of rice husk ash content, the setting time of concrete increases, and the compressive strength, splitting tensile strength and flexural strength decrease correspondingly. People pay attention to its strength and durability, at the same time, the heat resistance of ordinary concrete has also been studied. At present, the main way to improve the heat resistance of concrete is to add fiber or industrial waste residue in the concrete, and improve the heat resistance of concrete by trace elements in the admixture.

Straw and other biomass are pyrolyzed under complete or partial anoxic and anaerobic conditions to produce solid substances with high carbon content, insoluble, stable performance and strong aromaticity, which are called biochar at home and abroad [3]. Articles on biochar cement are currently in the development stage. Most of them are concentrated on the improvement of soil fertility and fertilizer utilization ratio[4-6]. by biochar, and the adsorption of heavy metals is relatively less studied on building materials.
In this study, biochar was added to cement as a cement mixture to provide an alternative method for the recovery of wheat and rice agricultural wastes. To explore the effect of straw biochar on compressive strength and thermal conductivity of cement slurry. It is possible to successfully use it as an additive in cement mortar, which will also promote waste recovery and isolate large quantities of carbon in civil infrastructure.

2. Experimental materials and methods

2.1 instruments and materials
Test instruments: high efficiency hay chopper (9FQ), intelligent temperature controlled muffle furnace (KSMF-2000), microcomputer controlled electro-hydraulic servo rock triaxial test machine (TAW-2000), hot Changshu analyzer (hotdisk), electric blast drying box (101-1A) and electronic balance.

P’S-A42.5 slag Portland cement produced by Taihangshan company in Jinyu, Handan, Hebei Province is selected as the cement. Its main components are 3CaO·SiO2, 2CaO·SiO2, 3CaO·Al2O3 and 4CaO·Al2O3·Fe2O3. It has the characteristics of high early strength, fast setting and hardening, good frost resistance, poor corrosion resistance, poor heat resistance, good carbonation resistance, dry shrinkage and good wear resistance.

2.2 preparation of biochar
Wheat straw was taken from Handan, Hebei Province, and rice straw from Bengbu, Anhui Province. Rice straw and wheat straw were packed in crucible, then packed and sealed in muffle furnace. Biochar cracking products were prepared by heating rate of 10 ℃/min, and remained at each final cracking temperature (300 ℃, 500 ℃ and 700 ℃) for 4 hours. After cracking, it will be naturally reduced to room temperature and taken out. After grinding, it will pass through 100 mesh screen and be sealed for preservation. The pyrolysis products of rice and wheat were labeled as rs300, rs500, rs700, ws300, ws500 and ws700 respectively. There were six kinds of biochar, of which WS is the abbreviation of wheat biochar, RS is the abbreviation of rice biochar, and the following figures represent the final temperature during pyrolysis.

2.3 preparation and maintenance of biochar cement block
Six kinds of straw biochar were added into cement according to 1% and 2%. Do the orthogonal experiment. Each group did three parallel experiments, three different temperatures as control. When the cement and biochar are mixed, in order to make them mix evenly, we first pour the biochar into the cement, fully mix it to make it uniform in color, slowly pour and mix the water in the beaker, and finally pour it into the cement mold (70.5mm × 70.5mm × 70.5mm) for human vibration, at this time, it will be found that there will be bubbles from the bottom to the surface, making it dense, until the bubbles are basic. If it doesn't appear, grind its surface flat, then stop vibrating at other temperatures, and repeat the above steps for the production of biochar cement. After 24 hours of curing, remove the test blocks from the mold and label them, and then soak them in water for curing (temperature 23 ℃, humidity 95%) for 28 days.

3. Achievements and conclusions
In the compression test of biocarbon cement block, TAW-2000 microcomputer controlled electro-hydraulic servo rock triaxial testing machine is used to carry out the compression strength test

3.1 compressive strength test results
After curing for 28 days, the compressive strength of the test block shall be tested. According to the national standard GB / t7617-1999 test method for cement mortar strength, the compressive strength of biocarbon cement shall be calculated as 3-1.

\[ R_c = \frac{F_c}{A} \quad (3-1) \]
Rc is the compressive strength (Mpa); Fc is the maximum load force (N) when the specimen is destroyed; A is the area of the compression surface (mm²).

The results are shown in Figure 3-1

![Figure 3-1 compressive strength of different cement blocks](image)

According to Fig. 1, the compressive strength of cement block is significantly increased when RS and ws of different temperature lower limit oxygen cracking are added at 1%, and the compressive strength of cement block increases first and then decreases with the increase of cracking temperature when RS is added. When rs500 of 1% is added, the compressive strength is the largest, reaching 53mpa; the strength of cement block increases with the increase of WS cracking temperature, increasing The increase range is 18% - 29%. The compressive strength of the two kinds of straw biochar is similar to that of CK when cement is added with 2% of them. Rs500 and ws500 both increase the compressive strength by 31% and 29% compared with CK. To sum up, rs500 and ws500 can effectively improve the compression resistance of cement block by adding 1% and 2% of them. This is because when two kinds of straw biomass are cracked at 500 °C in muffle furnace, its loose silicon dioxide is transformed into stable crystalline silicon dioxide. At the same time, the fiber degree and half fiber in straw biomass have been largely decomposed at 500 °C, leaving porous SiO2 skeleton, when mixed with cement, is fully filled by cement grinding, which makes the whole structure more compact and becomes an important reason for improving the strength of cement. At the same time, crystalline SiO2 can react with calcium hydroxide, the main product of secondary hydration of cement, to produce stronger calcium silicate, which is also one of the reasons for the increase of cement strength.

3.2 heat conduction test results

Firstly, put the cement blocks cured for 28 days into the electric blast drying oven at 35 °C for 24 hours, and then test the thermal conductivity. The instrument hotdisk used in this paper is a tester based on the transient plate heat source method produced by hotdiskab company of Sweden [7]. Select
three smooth surfaces for each cement test block to measure and record the data. If the parallelism of the measured data is poor, repeat the measurement. The experimental results are shown in Figure 3-2.

![Figure 3-2 thermal conductivity](image)

**Figure 3-2 thermal conductivity**

It can be seen from Fig. 2 that the thermal conductivity of the two kinds of straw biochar decreased with the addition of 1% and 2% into the cement, of which the thermal conductivity of rs700 with the addition of 2% was the smallest, which was about 21% lower than that of CK, and the thermal conductivity of the two kinds of cement blocks with the addition of RS and wheat biochar WS with the addition of 1% was not much different, and the thermal conductivity decreased with the increase of the addition of biochar; this is because the two kinds of straw after pyrolysis, straw biomass contains abundant amorphous carbon, which is very stable. The combination of biochar and cement makes the internal structure of cement change, and the cement block with biochar is more compact to block the heat transmission. Two kinds of different amount of biochar are floating after 500 ℃, which may be caused by the heterogeneity of carbon produced by the rapid cracking of muffle furnace.
The coefficient of thermal diffusion is also called the coefficient of thermal conductivity. For the coefficient of thermal diffusion, it can be seen that when the amount of biochar in wheat is 2%, it is the smallest, which is about 24% lower than the blank, and the coefficient of thermal diffusion of biochar is decreasing. However, there is an increasing trend in the temperature range of 300 ℃ - 500 ℃. The lower the diffusivity is, the smaller the temperature change from the surface to the interior, the better the heat preservation performance is.

4. Conclusion
1. The strength of cement paste with two kinds of biochar was increased, and the compressive strength of both biochar was the best at 500 ℃. When rice biochar was added with 1% of the amount of biochar, the strength of cement block was increased by about 32% compared with the blank control group, and the same amount of wheat biochar was also increased by about 29% at 500 ℃.
2. The thermal conductivity and thermal diffusivity of two kinds of biochar are decreased, and the thermal insulation performance is improved. Among them, the thermal conductivity of rice biochar at 700 ℃ was the lowest with 2%, and the thermal diffusivity of wheat biochar at 700 ℃ was the lowest with 2%.

In this experiment, two kinds of biochar with three temperatures and two mixing ratios are selected for analysis, which provides a way to find an optimal scheme that can not only meet the strength requirements but also have a good insulation performance. However, the durability after adding biochar has not yet been done, and whether adding aggregate will affect the performance of concrete remains to be studied.

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