

Research on the Compatibility of Bamboo and Portland Cement

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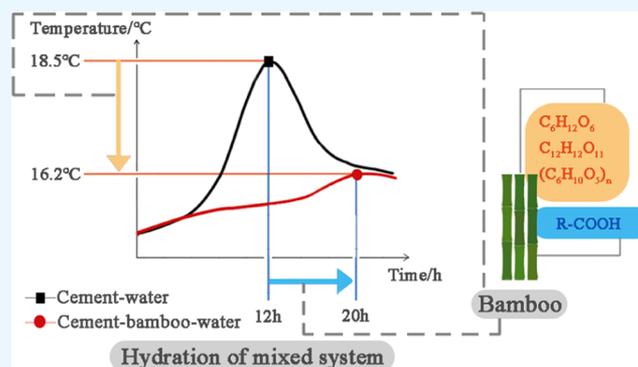
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ABSTRACT: This paper researches the compatibility of bamboo and Portland cement by measuring the hydration temperature of Portland cement. Meanwhile, bamboo shavings and Portland cement, which were utilized as main raw materials, were prepared into bamboo Portland cement particle boards through cold compression forming, so as to further verify the compatibility of bamboo and Portland cement and research the practicability of preparing bamboo Portland cement particle boards by using bamboo. Research studies show that bamboo contain water-soluble saccharides, such as polysaccharide, disaccharide, and glucose, and organic carboxylic acids, such as formic acid and acetic acid. Water-soluble saccharides are converted into saccharic acid after dissolving in water, then a saccharide–calcium complex with a pompon-like structure is formed through a reaction between saccharic acid and calcium ions of Portland cement hydrates, and the saccharide–calcium complex covers the surfaces of the cement particles and prevents further hydration of the cement, achieving a certain anticoagulation effect on Portland cement; a chelation reaction between the carboxyl of the organic carboxylic acid and the calcium ions of Portland cement hydrates takes place and the concentration of calcium ions in the hydration system is reduced, which exerts an influence on further hydration process of Portland cement and achieves a certain anticoagulation effect. Because of the poor compatibility of Portland cement and bamboo, the physical and mechanical properties of bamboo Portland cement particle boards prepared from bamboo shavings and Portland cement directly cannot meet the requirements of the national standards (GB/T24312-2009) of cement particle boards.



1. INTRODUCTION

Portland cement clinker mainly contains tricalcium silicate (37–60%), dicalcium silicate (15–37%), tricalcium aluminate (7–15%), and tetracalcium aluminoferrite (10–18%). When Portland cement is mixed with water, these four ingredients can undergo a hydration reaction and release a lot of heat; but these four ingredients are different in their structures, corresponding hydrate property, and hydration rate or strength. Tricalcium silicate (C_3S) is one of the main ingredients of the Portland cement clinker, and the products of its hydration reaction (Formula 1) are calcium silicate hydrate (C–S–H) and calcium hydroxide (CH). A lot of hydration heat, of which the released amount is in positive correlation with the hydration degree, is released during the hydration process, and the hydration heat release rate and the amount of heat released reflect the hydration process to a certain extent. After coming in contact with water, dicalcium silicate (C_2S) undergoes a hydration reaction and produces C–S–H and CH, but its hydration reaction rate and hydration heat release rate are lower than those of C_3S . The hydration reaction (Formula 3) product of tricalcium aluminate is hydrated calcium aluminate crystals; their hydration reaction rate is high, and a lot of heat is released. Calcium

sulfoaluminate hydrate acicular crystals are produced from the hydration reaction (4) of tetracalcium aluminoferrite. This substance is poorly soluble in water, but it can cover the surface of the cement clinker so as to form a protective film and prevent water molecules from entering the Portland cement, so that further cement hydration is delayed, and a rapid coagulation phenomenon of Portland cement is prevented.^{1–4} It can be seen that the hydration reaction of Portland cement is an exothermic reaction, and the heat released during the reaction process can increase the temperature of the cement–water mixed system. The hydration process and the degree of cement in the mixed system can be judged according to the temperature variation of the mixed system.

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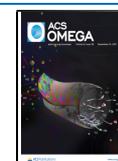
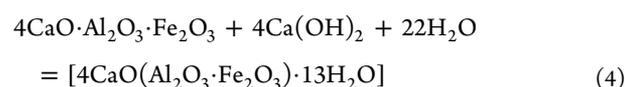
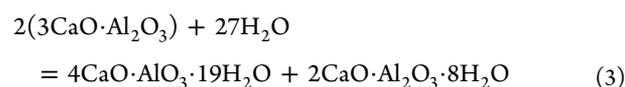
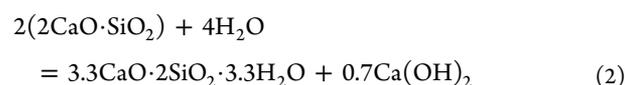
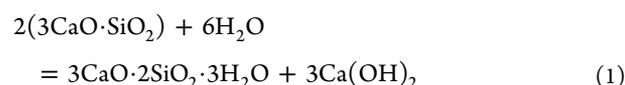


Table 1. Contents of Water-Soluble Saccharides and Carboxylic Acids in Bamboo

ingredients	polysaccharide (g/100 g)	disaccharide (g/100 g)	glucose (g/100 g)	formic acid (mg/100 g)	acetic acid (mg/100 g)
content	3.549	1.372	1.175	293.4	830.7



Bamboo Portland cement particle boards are a kind of inorganic wood-based panels prepared by using Portland cement and bamboo shavings as main raw materials. Bamboo Portland cement particle boards have excellent characteristics such as high strength, being waterproof and fire resistant, and no free formaldehyde emission. They have broad development prospects, which can be widely used in furniture manufacturing, indoor and outdoor decoration, building wall materials, and other fields. As for the inorganic adhesive for preparing bamboo cement particle boards, Portland cement in the bamboo undergoes a hydration reaction, which glues the bamboo shavings to boards. The physical and mechanical properties of bamboo Portland cement particle boards are related to the hydration reaction process and the degree of Portland cement. The better the process and the degree of the hydration reaction, the more the substances with cementation effect can be generated in cement particle boards, and the better the physical and mechanical properties of the bamboo Portland cement particle boards are. During the preparation of the bamboo cement particle board, after mixing the Portland cement, bamboo shavings, and water, the water-soluble saccharides and carboxylic acids in the bamboo shavings dissolved and led to a coagulation-delaying or anticoagulation effect on the hydration reaction of Portland cement, thereby influencing the Portland cement hydration reaction.^{5–8} This paper researches the hydration reaction process and the degree of Portland cement in the mixed system by measuring the temperature of the mixed system of bamboo shavings, Portland cement, and water, so as to research and judge the compatibility of bamboo and Portland cement. Meanwhile, the bamboo shavings and Portland cement, which were utilized as main raw materials, were prepared into bamboo Portland cement particle boards through cold compression forming, so as to further verify the compatibility of bamboo and Portland cement and discuss the practicability of preparing cement particle boards by using bamboo.

2. RESULTS AND DISCUSSION

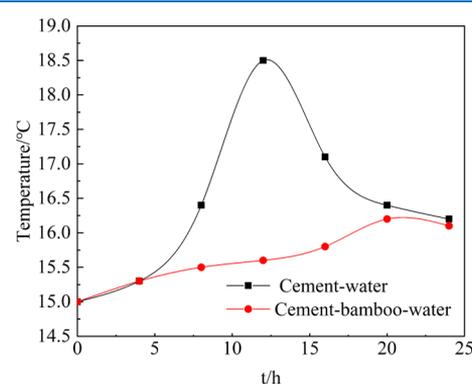
2.1. Analysis of Water-Soluble Saccharides and Organic Acids. The types and contents of water-soluble saccharides and organic carboxylic acids in bamboo are listed in Table 1. It can be seen from Table 2 that there is 3.549 g of water-soluble polysaccharide, 1.372 g of disaccharide, 1.175 g

Table 2. Highest Hydration Temperature and Time for Achieving the Highest Hydration Temperature

	cement–water	cement–bamboo powder–water
highest hydration temperature/°C	18.5	16.2
time for achieving the highest hydration temperature/h	12	20

of glucose, 293.4 mg of formic acid, and 830.7 mg of acetic acid per 100 g of bamboo powder.

2.2. Analysis of the Hydration Temperature of Portland Cement. Figure 1 shows the 24 h hydration-

**Figure 1.** Hydration temperature of a mixed system.

temperature-changing trend chart of Portland cement in the Portland cement–water mixed system and the Portland cement–bamboo powder–water mixed system. The highest hydration temperature and the time for reaching the highest hydration temperature of the two mixed system are shown in Table 2. It can be seen from Figure 1 and Table 2 that, within 24 h, the hydration temperatures of the two mixed systems first increased and then decreased with the increase of time, but the two mixed systems have different temperature peak values and times of temperature peak values. It can be observed from Figure 1 and Table 2 that the hydration reaction of Portland cement is delayed and the highest hydration temperature is reduced obviously because of the addition of bamboo powder. The highest hydration temperature of the Portland cement–water mixed system is 18.5 °C, and the time for achieving the highest hydration temperature is 12 h; the highest hydration temperature of the Portland cement–bamboo powder–water mixed system is 16.2 °C, and the time for achieving the highest hydration temperature is 20 h. Compared with the Portland cement–water mixed system, the Portland cement–bamboo powder–water mixed system has the characteristics that the time for achieving the highest hydration temperature is delayed for 8 h, and the highest hydration temperature is reduced by 2.3 °C. The above results show that the bamboo powder has an obvious anticoagulation effect on the hydration reaction of Portland cement, and the compatibility of bamboo and Portland cement is relatively poor.

According to the results of high-performance liquid chromatography analysis shown in Section 2.1, the bamboo

powder contains a certain amount of water-soluble polysaccharide, disaccharide, glucose, formic acid, and acetic acid. In the Portland cement–bamboo powder–water mixed system, the water-soluble polysaccharide in the bamboo powder is possibly hydrolyzed to generate saccharose (disaccharide), glucose (monosaccharide), and so forth, which are then converted to saccharic acid together with the disaccharide and glucose in the bamboo powder. Then, the saccharic acid reacts with calcium ions of Portland cement hydrates and forms a pompon-like saccharide–calcium complex (Formulas 5 and 6); the saccharated lime covers the cement particles and retards further hydration of the cement, thereby achieving an anticoagulation effect; on the other hand, saccharides can influence the crystal nucleus of the cement hydrate (calcium hydroxide) and prevent its growth and also retards further hydration of the cement, thereby achieving the anticoagulation effect.^{9–12} Meanwhile, the fluidity of the mixing system will also be reduced due to the water-soluble saccharides, which has an influence on the hydration reaction of Portland cement in the mixed system.¹³ The carboxyls of organic carboxylic acids such as formic acid and acetic acid in bamboo and calcium ions of the cement hydrates undergo a chelation reaction (Figure 2) and reduce

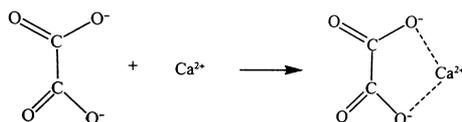
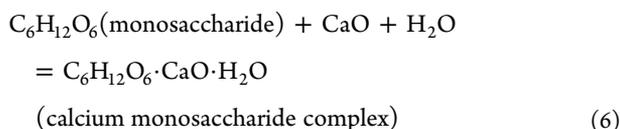
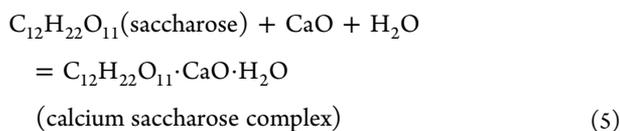


Figure 2. Chelation reaction between carboxyl and calcium ions.

the concentration of calcium ions in the hydration system, thereby influencing the hydration process of the cement and achieving a certain anticoagulation effect.^{14–16} The above results demonstrate well that Portland cement and bamboo have relatively poor compatibility.



2.3. XRD Analysis. In order to further research and analyze the compatibility between the bamboo powder and Portland cement in the production of bamboo cement particle boards, X-ray diffraction (XRD) analysis of the hydrates of the two mixed systems at different time periods was performed, and Figure 3 shows the XRD patterns of hydrates of different mixed systems. It can be seen from Figure 3a that the $Ca(OH)_2(CH)$ diffraction peak 1 ($2\theta = 17.8^\circ$) occurs at 4 h but is not obvious in the XRD pattern of the cement–water mixed system; the CH diffraction peak becomes obvious at 12 h, which indicates that the hydration reaction process of Portland cement in the mixed system becomes rapid at 12 h, and the result is consistent with the hydration temperature study. In the XRD pattern of the cement–water mixed system, the ettringite (AFt) diffraction peak 4 ($2\theta = 49.6^\circ$) also occurs at 4 h, and this diffraction peak intensity increases gradually with the increase of time. Meanwhile, the intensity of the C_3S diffraction peak 2 and the C_2S diffraction peak 3 ($2\theta = 29.2, 32.1, \text{ and } 33.8^\circ$) decreases gradually with the increase of time; thus, it can be seen that C_3S and C_2S in the Portland cement–water mixed system undergo the hydration reaction and generate CH and AFt. The above results are consistent with those of Mingyou Yu.¹⁷

It can be seen from Figure 3b that no obvious CH diffraction peak occurs in the 24 h XRD pattern of the Portland cement–bamboo powder–water mixed system. This indicates that the water-soluble polysaccharide, disaccharide, glucose, and organic carboxylic acids in the bamboo powder possibly have obvious inhibition effects on the Portland cement hydration reaction in which CH was generated. In addition, it can be seen from the XRD pattern of the cement–water–bamboo powder system that the AFt diffraction peaks with different intensities begin to appear at 4 h, but they belong to obvious diffuse peaks. This indicates that the water-soluble polysaccharide, disaccharide, glucose, and organic carboxylic acids in the bamboo powder have certain obvious inhibition effects on the Portland cement hydration reaction in which AFt is generated. The intensity of C_3S diffraction peak 2 and C_2S diffraction peak 3 in the mixed system decreases gradually, and this is caused by consumption due to the hydration reaction of C_3S and C_2S in the mixed system. The result of this analysis is consistent with the result of the Portland cement hydration temperature analysis in Section 2.2.

2.4. Fourier Transform Infrared Spectroscopy. In the Fourier transform infrared (FTIR) spectrum of organic compounds, the wave crest height, which is relevant to the molecular vibration mode, is mainly determined from the

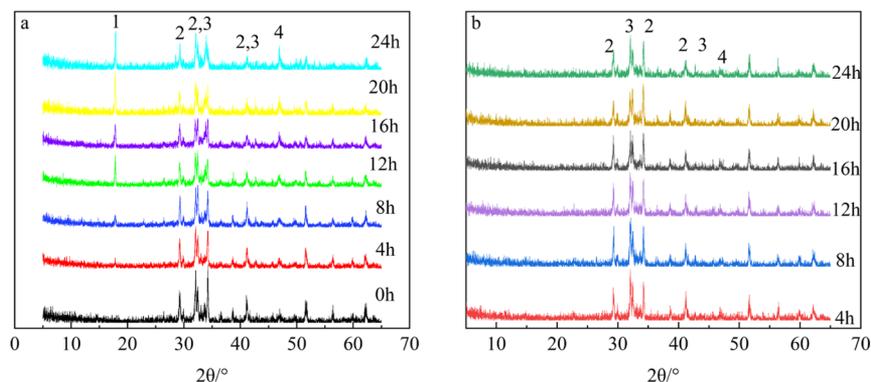


Figure 3. XRD drawing of hydrates of mixed systems (1-CH; 2- C_3S ; 3- C_2S ; and 4-AFt): (a) cement–water and (b) cement–bamboo–water.

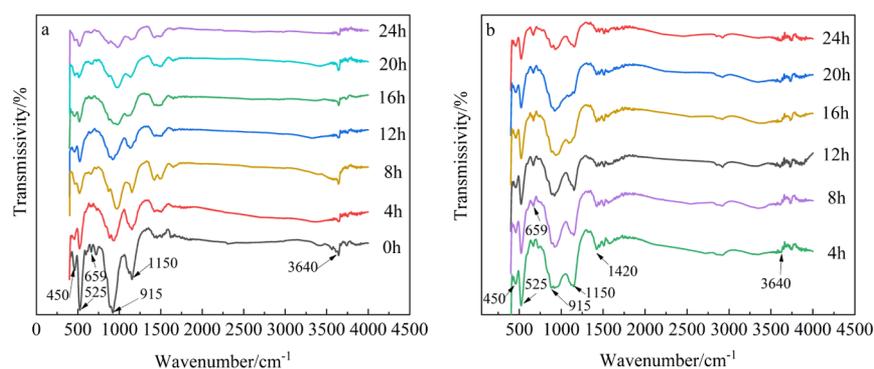


Figure 4. FTIR spectra of Portland cement hydrates: (a) cement–water and (b) bamboo–cement–water systems.

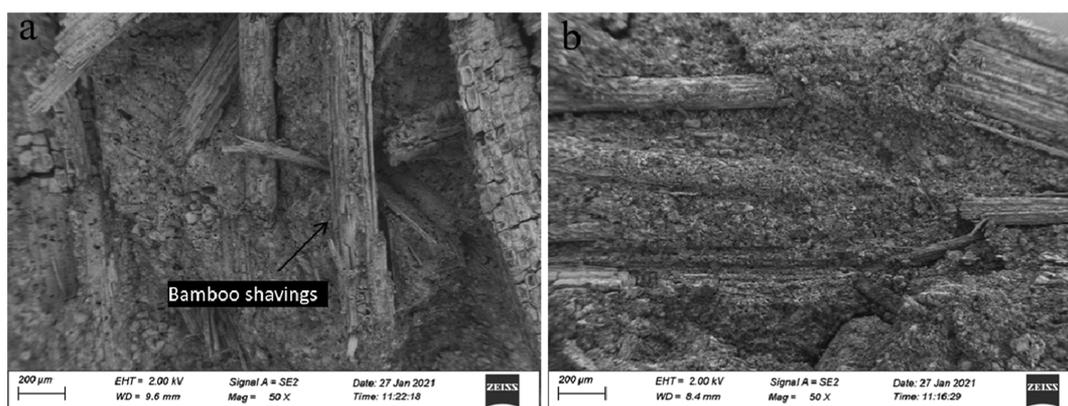


Figure 5. Profile SEM graph of the bamboo Portland cement particle board.

geometric configuration and symmetry of complex anions in inorganic compounds. Compared with organic compounds, the inorganic compounds have relatively less “functional groups”, and when the crystallinity of the inorganic hydrates is poor, gene sequencing is irregular, and the symmetry is lowered. Furthermore, the vibration frequencies are not fixed values but are within a relatively large variation range. The spectrum shows that the absorption bands are widened, and even adjacent bands are linked and combined; the hydration system and the ingredients of Portland cement are complex. The hydrates of Portland cement are diverse in shape. The absorption bands of different inorganic compounds at the same area or adjacent areas are stacked, but the absorption bands of Portland cement with different structures are quite approximate. The amount of absorption bands is reduced due to stacking and combination of absorption peaks, and a wide and obtuse absorption band is formed; generally speaking, the stronger the chemical bonds are and the less the atomic mass is, the higher the vibration frequency is. For Portland cement, absorption peaks within the 4000–1200 cm^{-1} range are relatively simple, and vibrations are relevant to a small amount of groups with relatively light OH^- , CO_3^{2-} , and so forth; absorption peaks within the 1200–400 cm^{-1} range are relatively complex and can be considered as the main fingerprint regions of Portland cement. In the spectrum, the main peaks are approximately the same but different in distribution and shape; thus, it can not only reflect the basic rules of the Portland cement hydration process but also reflect the respective characteristics and information of the hydration process.

In the FTIR spectra of the cement–water mixed system shown in Figure 4a, the band peaks at 915, 525, and 450 cm^{-1}

are the characteristic peaks of C_3S in the cement clinker; thus, it can be seen that the mixed system contains a mass of C_3S at the beginning. With the increase of the cement hydration time, the characteristic peaks of C_3S become weak gradually, and the peak maximum shifts left or right, thus indicating that C_3S in the cement clinker undergoes the hydration reaction gradually and a hydrate, namely, calcium silicate hydrate (C-S-H), is generated.¹⁸ The band peak at 659 cm^{-1} is a C_4AF characteristic peak, and this peak weakens gradually with the increase of hydration time, thus showing that C_4AF is consumed in the hydration reaction and calcium sulfoaluminate hydrate acicular crystals (ettringite, AFt) are generated; the band peak at 1150 cm^{-1} is the characteristic peak of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), and this peak weakens gradually and disappears finally with the increase of the hydration time, thus showing that gypsum is consumed in the hydration reaction and AFt is generated; the band peak at 3640 cm^{-1} is a hydroxyl vibration band spectrum of cement hydrate calcium hydroxide (CH), and the hydroxyl vibration band spectra of CH at different time periods can be seen from the spectra but are not obvious, thus showing that a relatively small amount of CH is generated by the hydration reaction of the cement in the mixed system within 24 h.

Figure 4b shows the FTIR chart of Portland cement hydrates of the bamboo powder–cement–water mixed system. Compared to Figure 5a spectra, in the spectra presented in Figure 4b the main band peaks of C_3S , C_4AF , gypsum, and so forth except for an obvious Al_2O_3 band peak at 1420 cm^{-1} are basically in the same position but are different in strength and variation. It can be seen from Figure 5b that the band peak change speeds and change rates of C_3S , C_4AF , and gypsum in the mixed system added with bamboo powder are lower than

those of the mixed system without bamboo powder, which is possibly because of the reason that the water-soluble polysaccharide, disaccharide, glucose, and organic carboxylic acids in the bamboo powder have certain anticoagulation effects on Portland cement. Furthermore, in Figure 4b, the hydroxyl vibration band peak at 3640 cm^{-1} nearly disappears; thus, it further verifies that the water-soluble saccharides and organic carboxylic acids in the bamboo powder have obvious inhibition effects on the hydration reaction in which CH is generated by the Portland cement. The above results are consistent with the results of XRD analysis in Section 2.3.

2.5. Analysis of the Mechanical Properties of Bamboo Cement Particle Boards. Table 3 presents the comparison

Table 3. Comparison between the Mechanical Properties of the Bamboo Portland Cement Particle Board and Standard Values

test item	P (g/cm^3)	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)
standard value	1.2 ± 0.05	≥ 9.0	≥ 3000	≥ 0.35	< 1.5
test value	1.21	4.6	1300	0.18	2.1

between the mechanical properties of the bamboo Portland cement particle board prepared in this experiment and the national standard values. It can be seen from Tables 1–3 that the static bending intensity (MOR), elasticity modulus (MOE), and internal bonding strength (IB) of the bamboo Portland cement particle board prepared in this experiment are greatly lower than the national standard values of cement particle boards, and the thickness swelling rate of water absorption (TS) is also higher than the national standard value of cement particle boards. In the bamboo Portland cement particle board, Portland cement serves both as a base material and an inorganic bond material, and bamboo shavings serve as a reinforcing material. Compared with Portland cement, the bamboo shavings have good stiffness and tenacity, so that one can say that the adopted bamboo shavings are capable of improving the bonding strength and non-deformability of Portland cement. By virtue of the sufficient hydration reaction of Portland cement, hydrates such as calcium silicate hydrate (C–S–H) and calcium hydroxide (CH) can be generated. These hydrates are capable of covering the bamboo shavings effectively while imparting the internal bonding strength of the bamboo Portland cement particle board, and adhesive forces form between the hydrates and the surfaces of the bamboo shavings, so that the bamboo shavings are capable of effectively transferring the breakdown stress when the board is subject to an external breakdown stress, thus the board shows good bending strength, and the board is inhibited from undergoing water absorption expansion deformation.

However, because the bamboo shavings contain water-soluble saccharides and carboxylic acids, the above organic ingredients in the bamboo shavings dissolve rapidly when Portland cement and the bamboo shavings are mixed with water, inhibiting the hydration reaction of Portland cement in the board (especially Portland cement adjacent to the bamboo shavings). No effective hydrate is formed in the board, and no adhesive force can be formed between the bamboo shavings and Portland cement. Therefore, the bamboo Portland cement particle board shows extremely low physical and mechanical properties. Figure 5 shows the profile scanning electron microscopy (SEM) graph of the bamboo Portland cement

particle board. It can be seen from Figure 6a that the bamboo shavings are distributed uniformly in the Portland cement base

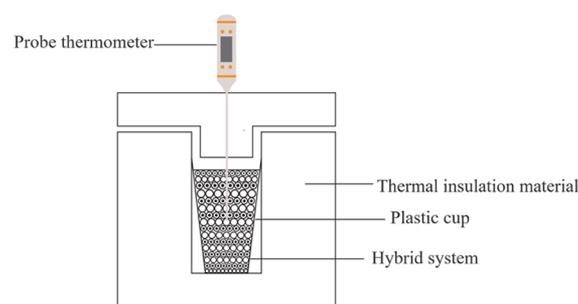


Figure 6. Portland cement hydration heat-measuring device.

material and form a mutually crossed structure, which is quite beneficial to improving the mechanical properties of the board. However, the bonding interface of the bamboo shavings and Portland cement is relatively poor, obvious gaps can be seen, and the surfaces of the bamboo shavings are nearly not clad with Portland cement, showing that no adhesive force is formed between the bamboo shavings and Portland cement. The bamboo shavings do not achieve a favorable enhancement effect in the board and thus the MOR and MOE of the bamboo Portland cement particle board are far less than the national standard values of the cement particle board. This is because the concentrations of water-soluble saccharides and carboxylic acids on the surfaces of bamboo shavings are relatively high and the hydration reaction of Portland cement on the surfaces of the bamboo shavings is retarded to a greater extent. It can be seen from Figure 6b that the hydration degree of Portland cement in the board is incomplete, and no dense hydrate is formed; thus, effective internal bonding strength for the board is not achieved and the water absorption thickness swelling of the board cannot be retarded effectively. Thus, it can be seen that the water-soluble saccharides and carboxylic acid of bamboo have a certain anticoagulation effect on the hydration reaction of Portland cement in the whole board. According to the above results, it can be judged that bamboo shavings cannot be used for preparing the bamboo Portland cement particle board directly.

3. CONCLUSIONS

- (1) Bamboo contains a certain amount of water-soluble polysaccharide, disaccharide, and glucose. The water-soluble saccharide of the bamboo powder hydrolyzed to generate saccharic acid after dissolving in water. The saccharic acid reacts with calcium ions of the Portland cement hydrates and forms a pompon-like saccharide–calcium complex. Saccharated lime covers the cement particles and retards further hydration of the cement, thereby achieving an anticoagulation effect on Portland cement; on the other hand, saccharides can influence the crystal nucleus of the cement hydrate (calcium hydroxide) and prevent its growth and also restrict further hydration of the cement, thereby achieving an anticoagulation effect.
- (2) Bamboo has a certain amount of organic carboxylic acids such as formic acid and acetic acid; a chelation reaction between the carboxyls of the organic carboxylic acids and the calcium ions of Portland cement hydrates takes

place, which reduces the concentration of calcium ions in the hydration system and influence further hydration process of Portland cement, achieving a certain anticoagulation effect.

- (3) The compatibility of Portland cement and bamboo is relatively poor. When bamboo Portland cement particle boards are prepared by utilizing Portland cement and bamboo as raw materials, certain modification measurements are required to be taken so as to control or weaken the anticoagulation effect of anticoagulation ingredients in bamboo on Portland cement.
- (4) The physical and mechanical properties of the bamboo Portland cement particle board prepared by combining the bamboo shavings with Portland cement directly cannot meet the national standard requirements for cement particle boards.
- (5) In order to prepare a bamboo Portland cement particle board with bamboo and Portland cement, the bamboo particle board must be pretreated with alkali, by carbonization, or hydrothermally, so as to reduce or remove the water-soluble sugar and carboxylic acid in bamboo, which have the retarding effect on Portland cement.

4. EXPERIMENTAL SECTION

4.1. Experimental Materials. Bamboo shavings were purchased from Hunan Taohua River Industrial Limited Company (water content: 10%, length: 10–30 mm, width: 1–6 mm, and thickness: 0.5–0.8 mm). The moso bamboo powder (30 meshes) was processed by using a pulverizer, which was then transferred to a drying oven to completely dry at a temperature of 103 ± 2 °C and then hermetically preserved for high-performance liquid chromatography. Portland cement, R52.2, was purchased from Yangchun Cement Limited Company, Zhucheng.

4.2. Experimental Equipment and Instruments. The following equipment and instruments were used in this study: a Waters 244-type high-performance liquid chromatograph (American Waters Company) equipped with a chromatographic column (Diamonsil C18; 250×4.6 mm), a Waters 486 differential detector, an MS10 pump, a six-way valve sample injector, a Zhejiang University 2000 chromatographic work station, and a mobile phone: experimental parameters—0.05 mol/L H_2SO_4 (v/v); temperature, 55 °C; and flow velocity, 0.01 mL/min; solvents—redistilled water filtered through a $0.45 \mu\text{m}$ filtration membrane was used, acetonitrile employed was chromatographically pure, methyl alcohol filtered through a $0.51 \mu\text{m}$ filtration membrane was a guaranteed reagent, and phosphoric acid used was a guaranteed reagent; an IR-Prestige-21-type FTIR spectrometer (Shimadzu Corporation); an XRD6000-powder-X-ray diffractometer (Shimadzu Corporation); a probe-type thermometer (accuracy: 0.1 °C; Shenzhen Youkong Electric Limited Company); artificial board single-layer hot press (Y33-50; Pingxiang Jiuzhou Precise Press Limited Company); an all-purpose mechanical tester (DCS-R-100; Shimadzu Corporation); and an MIRA3LMH-type scanning electron microscope (TESCAN China, Ltd.): experimental parameters—test pressure, 0.8 MPa and test voltage, 15 KV.

4.3. Experimental Design. **4.3.1. Measurement of the Hydration Heat of Portland Cement.** The experimental scheme was implemented according to the design in Table 4.

Table 4. Hydration Heat Measurement Scheme

test no.	material	mass/g	remarks
1	Portland cement	200	
	tap water	110	
	Portland cement	200	
2	bamboo powder	62.5	30 meshes
	tap water	110	

Experiment 1: 200 g of Portland cement and 110 g of tap water were taken in a beaker and stirred thoroughly in order to mix the Portland cement with tap water uniformly and then the mixture was transferred rapidly into a self-produced Portland cement hydration heat-measuring device (Figure 6).

Experiment 2: 62.5 g of dried bamboo powder and 110 g of tap water were taken in a beaker and stirred thoroughly so as to soak the bamboo powder uniformly. Then, 200 g of Portland cement was added and stirred thoroughly so as to mix the bamboo powder uniformly. Following that, Portland cement and water were added and then the mixture was rapidly transferred to a self-produced plastic temperature-measuring device expanded to a certain thickness.

In order to ensure consistency in the research conditions of different experiments, two parts of same materials and devices were prepared in experiments 1 and 2: one part was used for measuring the hydration temperature of the tested cement in the mixture (in this part, a thermocouple was needed to be inserted into a sample) and the other part was used for performing XRD, FTIR spectroscopy, and analysis of hydrates of the cement in the mixture.

4.3.2. Preparation of Bamboo Portland Cement Particle Boards. The mass ratio of Portland cement to bamboo shavings was set as 3:1, and the mass ratio of water to Portland cement was set as 0.5. The density of the bamboo Portland cement particle board was set as 1.2 g/cm^3 . The preparation steps are as follows: bamboo shavings, Portland cement, and water were measured, fed into a stirrer, and stirred for 3 min so as to mix the bamboo shavings with Portland cement uniformly. Then, the uniformly mixed materials were manually paved on a steel base plate to form a $300 \text{ mm} \times 300 \text{ mm} \times 12 \text{ mm}$ plate blank. Following that, the paved plate blank and the base plate were put into the cold press and cold pressing was performed at a pressure of 5.0 MPa. After pressing the plate blank into a thickness gage, steam was fed into the plate blank continuously; the steam flow was regulated to ensure the curing temperature at 60–80 °C, and pressure-maintaining thermal curing was performed for 12 h. After finishing the curing process, the pressure was released and the cold press was opened to obtain bamboo Portland cement particle board semi-finished products; these semi-finished products were stacked and cured for 28 days naturally to obtain the finished products of bamboo Portland cement particle boards. The finished products were transferred to an oven and dried at a temperature of 70–90 °C until the moisture content of the cement particle boards reached about 10%. The dried finished products of cement particle boards were cut into sample slices with same specifications for measurement. The procedure was repeated three times, and the average of the test results was taken.

4.4. Detection and Representation. **4.4.1. Detection of Water-Soluble Saccharides and Organic Acids.** The water-soluble saccharides and organic acids in the bamboo powder were detected by using a high-performance liquid chromatography.

graph; 5 g of bamboo powder samples was weighed and soaked in distilled water at room temperature for 24 h. The soaked bamboo powder samples were centrifuged at 4000 rpm for 25 min. Three parts of 20 μL supernate was taken, high-performance liquid chromatography detection was performed under the abovementioned chromatographic conditions so as to obtain a chromatogram of free saccharides and free organic acids. The sample feeding was repeated three times, the peak areas of the respective peaks were calculated by using an area normalization method, and their contents were calculated by using an external reference method.

4.4.2. Hydration Temperature Measurement. The hydration temperature (room temperature: 15 $^{\circ}\text{C}$) of Portland cement was measured in a sample mixed system within 24 h by using a needle-type thermocouple; the measurement was performed once every 4 h, and the hydration temperature was recorded; a 24 h hydration temperature–time curve of Portland cement was drawn.

4.4.3. XRD and Infrared Spectroscopy. 25 g of sample was taken from the hydration heat measurement device at each time interval of 0, 4, 8, 12, 16, 20, and 24 h, they were then added to anhydrous alcohol and soaked for 2 h until the hydration reaction of the cement in the samples stopped. The deposited cement and hydrates were filtered out by using filter paper and then they were ground into a thin powder by using a triturator. After the anhydrous alcohol was volatilized completely, the sample was transferred to a drying oven and dried completely at a temperature of 103 ± 2 $^{\circ}\text{C}$. Then, XRD and FTIR spectroscopy detection were performed.

4.4.4. Detection of Physical and Mechanical Properties. The physical and mechanical properties of the bamboo Portland cement particle board were detected according to the national standards of cement particle boards (Standards GB/T24312-2009).

4.4.5. Scanning Electron Microscopy. A MIRA3LMH scanning electron microscope was used to observe the cross-sectional morphology of bamboo Portland cement particle boards. The test pressure was 0.8 MPa, and the test voltage was 15 kV.

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Notes

The authors declare no competing financial interest.

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