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Effects of corn stalk fiber content on properties of biomass brick

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HIGHLIGHTS

- Piling density is increasing with the increasing corn stalk fiber content.
- Elastic recovery and drying shrinkage and permanent deformation rates in thickness are the greatest.
- Compression strength is changing from low to high similar to a concave parabola.

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ABSTRACT

In order to explore the effects of corn stalk fiber content on properties of biomass brick, compression strength and deformation rate are studied. Compression strength ranges similar to a concave parabola with the increasing corn stalk fiber content. Deformation rates in thickness are greater than ones in length and width. Drying shrinkage and permanent deformation rates of brick are greater than elastic recovery one in length and width. Elastic recovery deformation rate is greater than drying shrinkage and permanent ones in thickness. The results provide a basic theory for manufacturing biomass brick.

1. Introduction

There are about 1.0 billion tons corn stalk in the world, and 0.25 billion tons corn stalk in China [1,2], which can be used as raw material [3,4]. Industrialization utilization of stalk is a fundamental policy for solving the problems about the stalk waste and burning [5,6]. Corn stalk fiber and particle can be manufactured into straw-cement composite material, straw-plastic composite material, straw-wood composite material [5], and biomass building material [7–11]. Lightweight building materials can be made from corn cob and cement [12–14], and corn cob ash can be used as raw material to manufacture the mixed cement mortar [15,16], cement concrete [17], and coating [18].

Based on the principles similar to poplar wood fiber being molded into fiberboard and wood-plastic material and calcium hydroxide slurry [19] as an adhesive with the flame retardant property, corn stalk fiber can be molded into light biomass brick for indoor partition wall, which provides an effective way to add its value. New brick is similar to the properties of the light wood, which is good sense in touch and warmth and decoration surface. It can balance the relative humidity of indoor air, improve the indoor environmental quality and increase the housing habitability with the characters of moisture desorption and absorption. Biomass brick is molded from the loose accumulation body to dense entity [8]. The mixture is squeezed and moved and bonded, the inter space between fibers shortens, and the contact area increases, so that fibers can be connected each other, air and liquid water can be squeezed out. There are hydrogen bond, Van der Waals' force, pastern nail, interwoven friction, and chemical bond in the brick, which are contributed to the compression strength [20]. When brick is dried, the moisture is disappeared continually with the volume shrinkage. At the same time, carbon dioxide reacts with calcium hydroxide to produce calcium carbonate.

Corn stalk fiber is an important ingredient for biomass brick, which content can affect the properties of brick. Effects of corn stalk fiber content on its properties including density and compression ratio and dimensional deformation and compression strength, are studied in the article, which provide a basic theory for manufacture and application of biomass brick.

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2. Materials and methods

2.1. Materials

Properties about corn stalk and poplar wood fibers and calcium hydroxide are shown in Tables 1–3. They are bought in the market.

2.2. Methods

2.2.1. Material formulations

Biomass brick is made from corn stalk and poplar wood fibers and calcium hydroxide, its formulations are shown in Table 4. Ratio of total mass of poplar wood and corn stalk fibers to the one of calcium hydroxide is fixed, which is equal to 1:4. Each experiment is repeated for 20 times.

2.2.2. Molding Process

The process of biomass brick is shown in Fig. 1.

Mass of corn stalk and poplar wood fibers and calcium hydroxide are balanced using an electrical balance (Model JA21002, Shanghai Jingtian Electrical Instrument Co., Shanghai, China) with a precision of 0.01 g. Moisture content is tested using a halogen moisture detector (Model JT-K6, Jingtai Co., Taizhou, China). They are mixed enough with the mixing machine (Model JJ-5, Shandong Luda Test Measurement Machine Co., Taian, China) and put into the squeeze die (Fig. 2).

The squeeze die is customized (Model custom, Shandong Luda Test Measurement Machine Co., Taian, China). There are three parts consisted of squeeze head and bucket and backing board (Fig. 2). The head is the loading body. The bucket is the square shape, which is 235 mm inside length and 110 mm inside width and 100 mm inside thickness. The backing board is the loaded body. They are molded in the press machine (Model MY 50B,Qingdao Jilongchang Equipment Machine Co., Qingdao, China), in which the press is equal to the greatest load when the head is pressed into the bucket completely, the keeping press time is equal to 1 min, and the temperature is equal to room temperature.

Table 4
Mass ratio of corn stalk and poplar wood fibers and calcium hydroxide.

Scheme number	Mass ratio		
	Poplar wood fiber	Corn stalk fiber	Calcium hydroxide
1	1	1	8
2	1	2	12
3	1	3	16
4	1	4	20
5	1	5	24
6	1	6	28
7	1	7	32
8	1	8	36
9	1	9	40
10	1	10	44

Dimensions of wet brick (shown in Fig. 3) in length and width and thickness are measured with the plastic ruler (Model 30 CM, Deli Group Co., Zhejiang, China). It is dried for 48 h in the hot air drying house (Model 4.5 m × 2.8 m × 3.0 m (length and width and height), Jinan Longxiang Painting Equipment Co., Jinan, China), where it is 50 °C in air temperature and 32.2% in relative humidity of air and 0.12 m/s in air velocity. The heating rate is 1.2 °C/min and the precision is 0.1 °C. The relative humidity and temperature of air are measured using a temperature humidification electrical meter (Model 310 RS-232, Center Technology Co., Taiwan, China), and the velocity is measured using a Thermo Ball electrical wind velocity meter (Model QDF-3, Inspection Equipment Co., Beijing, China).

Dimensions of dried brick (shown in Fig. 4) in length and width and thickness are measured, and the compression strength is tested with the electrical strength test machine (Model QJ-211, Shanghai Qingji Instrument and Meter Co., Shanghai, China). The brick is loaded vertically in the thickness direction by the movement velocity in 1.0 mm/min. It is the compression strength when the deformation reaches 2.5 mm in thickness direction, shown in Fig. 5. The brick can recovery its dimension as same as before when it is unloaded.

Table 1
Moisture content and density of raw materials.

Raw materials	Corn stalk fiber		Poplar wood fiber		Calcium hydroxide	
	Range	Mean	Range	Mean	Range	Mean
Moisture content (%)	9.15–11.34	9.95	7.13–8.16	7.64	57.61–60.72	59.10
Density (g/cm^3)	0.083–0.094	0.089	0.046–0.051	0.049	1.275–1.296	1.285

Table 2
Mesh ratio of corn stalk and poplar wood fibers.

Mesh (number)	Mass percent (%)										
	10	20	30	40	50	60	70	80	90	100	⩾100
Corn stalk fiber	3.18	6.99	6.35	14.24	13.93	2.94	5.42	4.26	4.49	5.17	33.02
Poplar wood fiber	0.63	26.23	20.08	13.88	11.32	5.56	3.54	4.07	1.66	2.38	10.65

Table 3
Constituents of corn stalk and poplar wood fibers [21,22].

Constituents	Content (%)					
	Ash	Hot water extract	1%NaOH extract	Cellulose	Lignin	Pentosan
Corn stalk fiber	4.66	20.4	45.62	18.38	18.38	24.58
Poplar wood fiber	0.32	3.46	15.61	43.24	17.10	22.61