Cellulose Fiber

Subjects: Materials Science, Textiles

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Cellulose Fiber (CF) is one of the most abundant natural resources in the world, and it is widely found in agricultural residues, such as rice straw, rice husk, maize straw, bagasse, wood shavings, wood chips, bamboo chips, etc. These agricultural residues are mainly composed of cellulose, hemicellulose, lignin, pectin, wax and some water-soluble materials. Cellulose is the most important component of CF, and its chemical formula is (C6H10O5)n.

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1. Typical Properties of CFs

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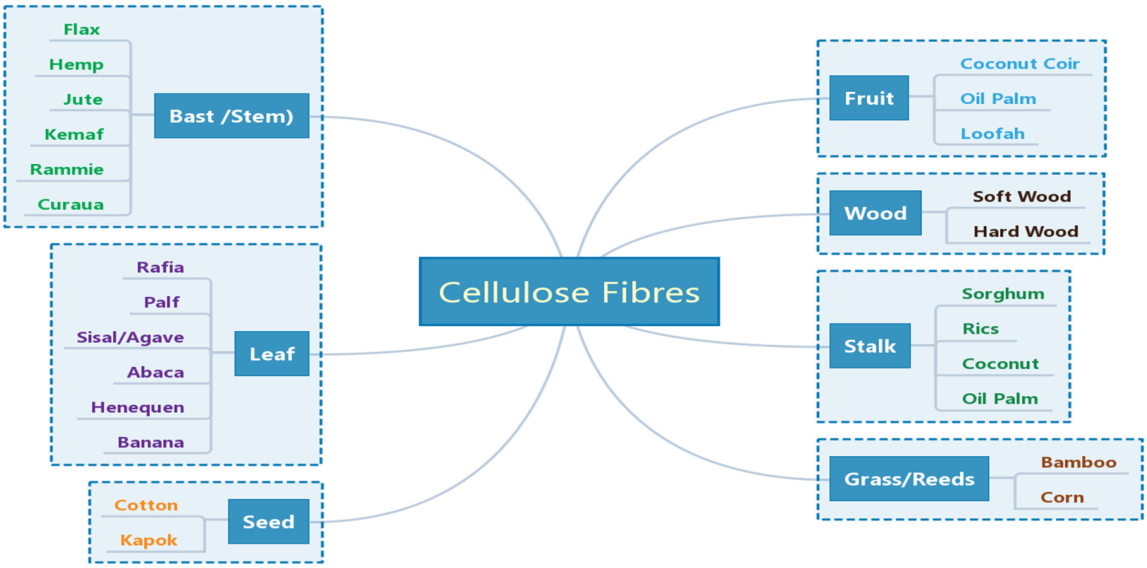

Figure 1. Classification of CFs used for reinforcement the geopolymers. Reprinted with permission from ref. [3]. Copyright 2020 Copyright MDPI.

It can be seen from **Table 1** that the density of CFs is roughly similar, with little difference, between 1.1 and 1.6 g·cm^{-3}. The density of bast fiber is basically about 1.5 g·cm^{-3}, its tensile strength is relatively large, and the tensile strength of fruit coconut husk fiber is relatively small.

Table 1. Mechanical properties of typical fibers.

Fiber Type	Fiber Name	Density/(g cm^{-3})	Tensile Strength/MPa	Specific Strength/(S ρ^{-1})	Tensile Modulus/GPa	Specific Modulus/(E ρ^{-1})	Elongation at Break/%	Ref.
Bast	Flax	1.5	800–1500	535–1000	27.6–80	18.4–53	1.2–3.2	[4]
	Hemp	1.48	550–900	372–608	70	47.3	2–4	[5]
	Jute	1.46	393–800	269–548	10–30	6.85–20.6	1.5–1.8	[6]
	Kenaf	1.45	930	641	53	36.55	1. 6	[7]
	Ramie	1.5	220–938	147–625	44–128	29.3–85	2–3.8	[8]
Leaf	Abaca	1.5	400	267	12	8	3–10	[9]
	Sisal	1.45	530–640	366–441	9.4–22	6.5–15.2	3–7	[8]
	Banana Leaf	1.35	600	444	17.85	13.2	3.36	[8]
	Coconut leaf	1.15	500	435	2. 5	2.17	20	[10]
Seed	cotton	1.6	287–597	179–373	5.5–12.6	3.44–7.9	7–8	[10]
Grass	bamboo	1.1	500	454	35.91	32.6	1.4	[10]
Fruit	Coconut shell	1.2	175	146	4–6	3.3–5	30	[8]
Wood	Soft wood	1.5	1000	667	40	26.67	4.4	[10]

2. Fiber-Reinforced Geopolymer Composites

Geopolymers can be prepared in two ways: alkali excitation and acid excitation. According to the different active raw materials, alkali excitation methods are mainly divided into alkali-silicate glass body cementing materials and alkali-silicate mineral cementing materials. Alkali-silicate glass body cementing materials mainly use amorphous

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silicate glass, basalt, as raw materials, such as slag, fly ash, various metallurgical slags, coal gangue, etc., and the main alkali-silicate mineral, the geopolymer is a crystalline mineral such as in clay, feldspar and other tailings.

2.1. The Polymerization Mechanism of Geopolymer

Under the condition of strong alkali, the silicon-oxygen bonds and aluminum-oxygen bonds of active materials such as kaolin are broken to form oligomers of polymer monomers, namely oligomeric silicon-oxygen tetrahedra and aluminum-oxygen tetrahedra. Under the same conditions, oligomeric silicon-oxygen tetrahedrons and aluminum-oxygen tetrahedrons are dehydrated and polymerized to form geopolymers with a three-dimensional network structure in space [11]. It is generally believed that the reaction of geopolymers can be divided into four processes: dissolution, diffusion, polymerization and solidification. Using metakaolin as the active material and (NaOH) or (KOH) as the alkali activator, the reaction mechanism of the resulting geopolymer is shown in **Figure 2** [12][13].

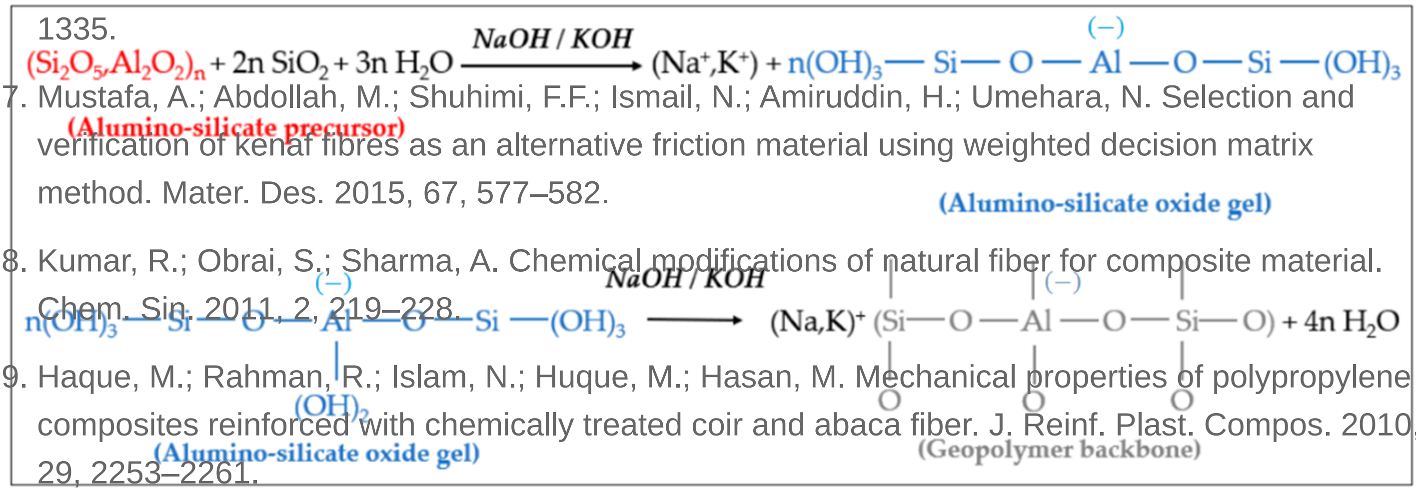

Figure 2. Hydrolysis and polycondensation of aluminum-silicate precursors and formation of geopolymers.

It can be seen from **Figure 2** that the aluminosilicate raw materials (precursors) gradually dissolve in (NaOH) or (KOH) alkali activator, producing a large amount of silicon and aluminum monomers. These monomers gradually diffuse in the solution from the surface to the inside, and quickly undergo a polycondensation reaction to form silico−alumina oligomers. The oligomer gel phase solidifies and hardens to form geopolymers.

2.2. Fiber Matrix Interface Bonding Mechanisms

A geopolymer composite is composed of fiber and a matrix with different properties, and the interface between the fiber and matrix is formed. The interface of the composite includes the geometric surface of the matrix and the fiber in contact with each other and the transition area, which is an extremely complex microstructure. Adjusting the bonding state of the fiber and the matrix interface, and optimizing the characteristics of the interface layer between the fiber and the matrix can make the geopolymer composites achieve the best performance. Improving the interfacial adhesion between the fiber reinforcement and the matrix is the most critical factor in the interface control technology of composites. The bonding forms of the fiber and matrix interface generally include interdiffusion,

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electrostatic adhesion, chemical bonding and mechanical interlocking [13][14]. According to the microscopic morphology of the bonding of fibers and geopolymers, the interface bonding is usually mainly in the form of mechanical interlocking.