Construction and Building Materials 79 (2015) 115–128

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Cellulosic fiber reinforced cement-based composites: A review of recent research

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HIGHLIGHTS

- Summarizing the latest research on vegetable fiber cement-based composites.
- Reviewing the fibers used, procedures, mechanical performance and durability.
- Durable cement composites with optimized fiber–matrix adhesion have been developed.
- Best performance with vegetable fiber textile reinforcements.

ARTICLE INFO

Article history:
Received 16 July 2014
Received in revised form 12 December 2014
Accepted 4 January 2015
Available online 22 January 2015

Keywords:
Cellulosic fibers
Cement-based composites
Composite processing
Mechanical properties
Durability

ABSTRACT

In the last few years, an increase in interest has been given to the use of cellulose fibers as alternatives for conventional reinforcements in composites. The development of commercially viable environmentally friendly and healthy materials based on natural resources is on the rise. In this sense, cellulosic fibers as reinforcements for cement mortar composites constitute a very interesting option for the construction industry.

This paper presents a review of the research done during the last years in the area of the cement-based composites reinforced with cellulose fibers. The fibers used, processing methods, mechanical behavior and durability are presented. The main achievements found have been the development of durable cement composites with optimized fiber–matrix adhesion. Moreover, the recently developed textile composites will allow obtaining high performance materials reinforced with vegetable fibers.

Contents

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http://dx.doi.org/10.1016/j.conbuildmat.2015.01.035
0950-0618/

1. Introduction: the role of cellulosic fibers as reinforcement in cement matrices

Over the last few years, problems related to environmental issues have motivated extensive research on environmentally friendly materials. Particular interest has been given to the use of fibers obtained from renewable vegetable sources in composite materials [1–4]. A combination of interesting mechanical and physical properties and their environmental benefits has been the main driver for their use as alternatives for conventional reinforcements.

Vegetable or cellulose fibers (VF) exhibit a set of important advantages, such as wide availability at relatively low cost, biorenewability, ability to be recycled, biodegradability, non-hazardous nature, zero carbon footprint, and interesting physical and mechanical properties (low density and well-balanced stiffness, toughness and strength) [5,6]. Vegetable fibers can be found in a wide variety of morphologies – diameter, aspect ratio, length, and surface roughness – and form – mainly strands, pulp or staple (see Fig. 1). Moreover, their surface can be easily modified in order to have a more hydrophilic or hydrophobic character or to attach functional groups [4].

Although brittle building materials have been reinforced with vegetable fibers since ancient times, the concept of VF reinforcement in cement-based materials was developed in 1940s, when these fibers were evaluated as potential substitutes for asbestos fibers [7]. Since then, considerable effort has been made toward the application of VF as a reinforcing material for the production of building components at low cost. Nowadays, the need for sustainable, energy efficient construction materials has oriented extensive research on alternative materials to produce environmentally friendly construction products. Applications of VF cement composites are basically addressed to the non-structural building of thin walled materials, mainly thin-sheet products for partitions, building envelope or ceilings flat sheets, roofing tiles and pre-manufactured components in general [8].

VF cement composites exhibit improved toughness, ductility, flexural capacity and crack resistance compared with non-fiber-reinforced cement-based materials. The major advantage of fiber reinforcement is the behavior of the composite after cracking has started, as the fibers bridge the matrix cracks and transfer the loads. The post cracking toughness may allow more intensive use of such composites in building. Cellulosic fibers provide adequate stiffness, strength and bonding capacity to cement-based matrices for substantial enhancement of their flexural strength, toughness and impact resistance [9–11]. Moreover, these fibers can reduce the free plastic shrinkage [12]; decrease the thermal conductivity [13] and improve the acoustic performance increasing the sound absorption and the specific damping and the density of the composite [14].

Despite all the aforementioned advantages, the industrial production of cement-based composites reinforced with VF is currently limited by the long-term durability of these materials. The durability problem is associated with an increase in fiber fracture and a decrease in fiber pull-out due to a combination of the weakening of the fibers by alkali attack, fiber mineralization due to the migration of hydration products to lumens, and space and volume variation due to their high water absorption [15–18]. This causes the material to have a reduction in post-cracking strength and toughness.

The role of cellulosic fibers as reinforcement lies in combining in an adequate manner the proper interfacial bond between the fiber and the matrix as well as to ensure the durability of the material.

In this paper we present a review of the research done during the last years (2000–2013) in the area of the cement-based composites reinforced with cellulose fibers. The fibers used, processing methods, mechanical behavior and durability are presented.

2. Cellulose fibers used as reinforcement in cement-based composites

Vegetable or cellulose fibers are mainly composed of cellulose, with varying amounts of lignin and hemicelluloses and other minority components, such as water, proteins, peptides and inorganic compounds. All vascular plants which can be found in nature can be used as sources of cellulosic fibers. However, the use of a particular plant as a source of fiber for a given application will depend on their availability and cost of extraction [19].

According to their origin and composition, cellulosic fibers are classified as non-wood and wood fibers. Wood fibers are also known as lignocellulosic fibers because they have a higher lignin content than non-wood fibers. The non-wood fibers can be

Fig. 1. Images of vegetable fibers in different forms: (a) strands, (b) staple, and (c) pulp.