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Review

Treatments of plant biomass for cementitious building materials – A review

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HIGHLIGHTS

- Review uses of biomass-based cement and concrete composites.
- Describe difficulties arising when using biomass in cement and concrete composites.
- Describe solutions like coating, impregnation, chemical and physical treatments.

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ABSTRACT

The use of plant biomass for developing energy efficient and low cost construction materials is an emerging field in building construction and civil engineering. Although the biomass-based cement and concrete composites have several advantages, such as low densities, low amount of CO_2 gas emission, good thermal and acoustic insulation, there are also disadvantages or open questions like the durability of biomass in alkaline cement matrix, the high absorption of water and the cement-biomass compatibility, all deteriorating concrete mechanical properties, which are already intrinsically low due to the low mechanical properties of biomass-based fillers. This review gives the necessary basis in plant structure and composition for understanding how and why many treatments tested on biomass for overcoming the above-mentioned difficulties are acting. This paper reviews research papers and patents on the treatments tested to improve the mechanical properties, durability and compatibility of biomass for its use as concrete fillers for building materials.

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1. Introduction

Cement concrete is the most widely used engineering material because of three primary reasons: (1) excellent resistance to water, (2) the ease to form structural concrete elements into a large variety of shapes and sizes, and (3) usually being the most readily available material [1]. Low maintenance, good fire resistance and cyclic loading resistance are some of other considerations that favour the use of conventional concrete structures. However, the fact that concrete is brittle, its cracking and shrinkage tendencies (both drying and thermal shrinkages), and its low tensile strength are serious disadvantages in structures built with concrete. When strength of concrete is increased, its brittleness is also increased [2] and cracking is induced, which could lead to serious damages to the concrete [3]. To overcome this problem, the combination of regular concrete with reinforced steel bars is a common strategy designed so that the two materials act together to resist tensile forces. Unluckily, the high permeability of reinforced concrete, that allows water and other aggressive elements such as chloride to penetrate, or slow carbonation, is responsible for the corrosion of steel bars [4–6]. It leads to the infrastructure deterioration and to severe industrial and natural environment drawbacks.

Concrete consists of a binding medium, which is usually cement, water, aggregates, and reinforced steel bars. The productions of these construction materials are expensive and consume an enormous amount of thermal and electrical energy as well as non-renewable resources. Thus, it is not possible to use them in very low cost housing, especially in developing and under-developed countries.

Another crucial aspect when using concrete-based structures is their thermal properties. At least in Europe, there is a strong move towards having better thermally insulated housings to reduce energy consumption while keeping good comfort conditions in buildings, with EC and EU National directives and regulations forcing builders to improve their construction methods. The design of energy-efficient buildings requires to mastering the control and the understanding of the thermal performances of structures. This is a complicated problem for concrete with different facets like the need to have the lowest thermal conductivity to reduce heat loss and a very high thermal inertia to store heat. All published work concludes that what controls mostly the thermal conductivity of concrete are the type of aggregate (having itself its own thermal conductivity characteristics), the porosity and the moisture content [7]. Classical concrete blocks prepared with mineral aggregates have thermal conductivities λ in the range of 1.5 to 3 W/m K, decreasing down to about 1 W/m K when adding various mineral admixtures [8]. Such values impose to add either very efficient or thick insulating materials to concrete structures.

In the early 1970's, the elimination of a wide range of products based on fibre silicates (asbestos) was initiated due to the cancer health risks [9,10]. Fibre-cement composite was a major user of asbestos but now this reinforcing mineral fibre can be replaced by synthetic fibres such as polypropylene using the air-cured Hatscheck process [11]. However, the production of such polypropylene fibres requires amines (ultraviolet stabilizers) and phenol compounds (anti-oxidant), and high energy consumption [12]. In addition, when concrete is deposited or dumped, polymer fibres are not decomposing, these polymers being not biodegradable [12,13].

With regard to the environmental aspect and economic viability, it is clear that the replacement of reinforced steel bars, mineral aggregates and asbestos or inorganic fillers by biomass-based materials could be an important step to alleviate some of the drawbacks and problems cited above [9,14,15]. Hence, researcher groups have been focusing their investigations on enhancing the engineering properties of cementitious products containing biomass, including preparation procedures, biomass treatments, long term durability, ease of production, mechanical and thermal properties as well as environmental impacts. Numerous articles have been published on the physical, mechanical, structural and functional properties of these biomass-based building materials made of concrete. The use of biomass to replace conventional materials seems to be a feasible solution to solve the problem of pollution, to reduce the amount of CO_2 emission and to develop more energy efficient and cost effective durable construction materials.

2. Composition, properties and availability of biomass

Biomass is the matter based on carbon, hydrogen and oxygen produced by Nature. Chemical compositions and structure of bio-

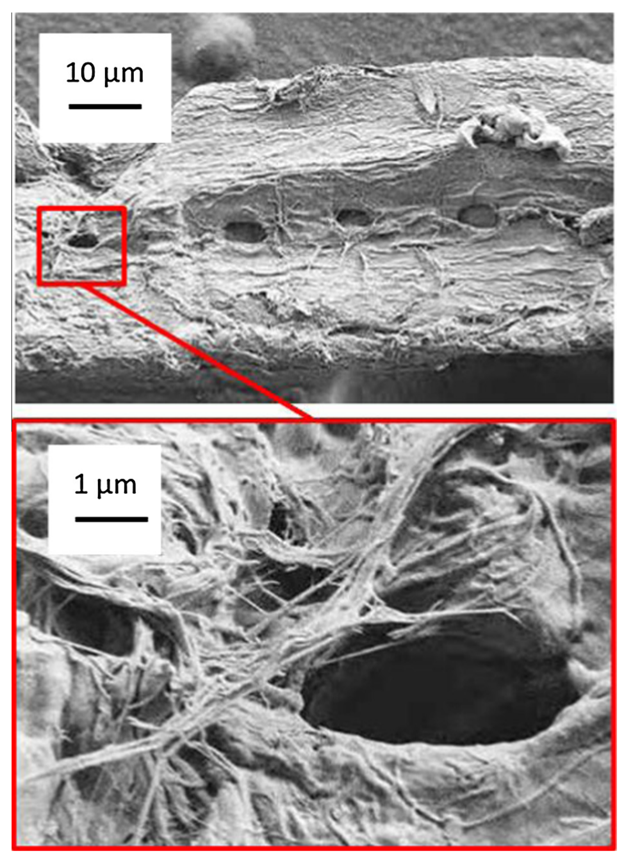

Fig. 1. Spruce bleached sulphite pulp fibre observed by scanning electron microscopy. Top: this fibre is the wall of a single cell, where the nucleus was in the central part. What we see here is the outside part of this fibre. Bottom: the picture is showing the array of microfibrils of less than 100 nm thickness attached to the surface, surrounding a pit opening (Reprinted with permission from the PhD dissertation of Nuno dos Santos [24]).