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Review

Cement-bonded composites from lignocellulosic wastes

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ABSTRACT

A large quantity of lignocellulosic wastes is generated worldwide from various sources such as agriculture, construction, wood and furniture industries leading to environmental concerns. Use of these wastes in making cement-bonded construction materials can reduce the magnitude of the problems. However, in this effort there are various restraints like compatibility of these wastes with cement, their toxicity, and limited composite strength. This paper reviews the results of recent research into the use of these wastes in making cement-bonded composites used as building materials. The approaches like pre-treatments, use of chemical admixtures and modified manufacturing process, adopted to overcome the aforementioned drawbacks are described. The benefits and limitations of the use of such materials in building are also discussed.

Contents

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1. Introduction

Lignocellulosic materials are obtained from wood and natural plants. They are composed of lignin and cellulosic compounds as main chemical constituents. Large amounts of these wastes are generated around the globe from various human activities. In developing countries the growth of industries based on agro-forestry products has accelerated the generation of wastes like rice husk and straw, wheat straw, bagasse, oil palm strands, hazel nuts and saw dust. Whilst in developed countries, besides the agro-forestry wastes, a huge quantity of timber waste is available from the demolition of old structures such as buildings, railways, telephone and fencing poles, and bridges. During the second half of the twentieth century considerable quantity of medium density fibreboard (MDF) was used, which presently needs replacement. At the same time the waste MDF has to be disposed or recycled. Table 1 indicates the quantum of some lignocellulosic wastes generated in different countries [1–9]. Presently these wastes are either burnt or land filled. These approaches cause various environmental problems like air pollution, emission of green house gases and occupation of useful land. The increasing charges of landfill are further aggravating the problem. Moreover, these methods of disposal are certainly wastage of a primary resource. In addition, the biodegradation of lignocellulosic wastes in landfills, emits methane, a green house gas which has 72 times heating effect relative to that of CO_2 [10]. However, composting and burning of certain wastes are not possible due to legislation. For instance, wood structures are subjected to some form of chemical treatments during their service period to protect them against insect and decay. Most of these preservative chemicals are of toxic nature and therefore lead to great health risk if used in recycling. Moreover, some wastes likes cork granules are resistant to biodegradation and do not burn easily without special gasifires [11]. In view of this situation, it is important to find out some alternative methods of disposal of these wastes.

Building construction is a material intensive activity and consumes large amounts of materials. Therefore, the utilisation of lignocellulosic wastes in making cement-bonded construction materials offers an attractive alternative to their disposal. For this purpose, the lignocellulosic wastes have a number of suitable features including low density, low requirements of processing equipment, negligible abrasion to the processing machinery and abundant raw material availability. Furthermore, they can be effectively encapsulated in a cementitious matrix as it is known that wood and plant based fibres have been used with considerable success with inorganic binders like ordinary Portland cement (OPC), gypsum and magnesite since the early part of the twentieth century. However, the production of wood cement composite panels began around 1965, due to the growing public concern about the health hazards associated with the use of asbestos [12,13]. Substantial research has been done in this area and wood is used in various forms for making cement-bonded products [14–16]. The emphasis was upon the use of 'clean' or virgin wood. However, the increased consumption of wood is causing depletion of the forest resources. In view of this environmental concern also, it is necessary to make efforts towards the use of alternative raw materials like lignocellulosic wastes. This paper discusses the properties of the cement-bonded composites made using the lignocellulosic wastes, their advantages, limitations and possible applications in construction.

2. Characteristics of wastes

The physical and chemical properties of the lignocellulosic wastes vary considerably with their source and storage condition as well as time. The main sources of lignocellulosic wastes are agricultural by-products, wood wastes from construction demolition and furniture industry wastes.

2.1. Agro-forestry wastes

From the agriculture farms and forest product based industries a considerable quantity of wastes is generated. The agro wastes mainly contain the stems of the crop plants like wheat, rice, sugarcane and arhar, while forestry wastes include cork granules and bark of the trees.

2.1.1. Wheat straw

Wheat is grown in various part of the earth coming in the temperate climate zone. It is one of the major cereals that have been used in several countries. After harvesting the crop, a large quantity of straw, estimated to be more than the crop itself, is available as waste. The present worldwide generation is about 709 million tons per annum [7]. It has been reported that wheat straw has a more complicated microstructure than that of wood. In addition it has more variability in terms of cell type and size. In comparison to wood it has shorter fibres and thinner cell walls. Wheat straw and wood materials contains almost equivalent amount of cellulose (~45%). However, the hemicellulose content is higher (28%) and the lignin content is lower (18%) when comparing with wood samples (23% and 27%, respectively) [17]. Wheat straw has desirable geometric and mechanical characteristics for making cement-bonded particleboards, but its inhibitory effect on cement hydration is a constraint [18]. The higher hemicellulose content may be responsible for greater inhibitory effect on cement hydration. Nevertheless, using accelerated processing techniques

Table 1
Lignocellulosic wastes generation in different countries.

Country	Source	Type of waste	Quantity per year	Reference
Japan	Construction	Used timber	20 million m^3	[1]
Malaysia	Oil palm industry	Oil palm shells	2.6 million tons	[2]
UK	Construction	Used timber	2.5 million tons	[3]
	Pallets (packaging)	Used timber	1.3 million tons	
USA	Construction	CCA treated	8 million m^3	[4]
	Railway ties	Creosote treated	1.3 million m^3	
	Poles	Creosote and pentachlorophenol treated	2 million m^3	
World (mainly Portugal)	Cork industry	Cork granules	85 thousand tons	[5]
India	Agriculture	Organic waste	350 million tons	[6]
World	Agriculture	Wheat straw	709.2 million tons	[7]
World	Agriculture	Rice straw	673.3 million tons	[7]
World	Agriculture	Coir	0.1 million tons	[8]
World	Agriculture	Bagasse	102 million tons	[7]
World	Agriculture	Cereal straw	2 billion tons	[9]