Construction and Building Materials 114 (2016) 6–14

Contents lists available at ScienceDirect

Construction and Building Materials

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

Physical and mechanical properties of wood-gypsum composites from demolition material in rehabilitation works

M.J. Morales-Conde [a,*], C. Rodríguez-Liñán [b], M.A. Pedreño-Rojas [b]

[a] Instituto Universitario de Arquitectura y Ciencias de la Construcción, Escuela Técnica Superior de Arquitectura, Universidad de Sevilla, Avenida Reina Mercedes, n 2, 41012 Sevilla, Spain

[b] Departamento de Construcciones Arquitectónicas 1, Escuela Técnica Superior de Arquitectura, Universidad de Sevilla, Avenida Reina Mercedes, n 2, 41012 Sevilla, Spain

HIGHLIGHTS

- An experimental characterization of the physical and mechanical properties of wood-gypsum composites is shown.
- The additives used consisted of wood shavings and sawdust from wood waste mixed in various proportions.
- The results showed that increasing the amount of wood waste reduced density, Shore C hardness and thermal conductivity.
- In addition, the mechanical properties of the composite material were, in general, lower than in the reference samples.

ARTICLE INFO

Article history:
Received 17 December 2015
Received in revised form 11 March 2016
Accepted 23 March 2016
Available online 29 March 2016

Keywords:
Wood waste
Gypsum
Composite
Thermal behaviour
Shore C hardness
Physical and mechanical properties

ABSTRACT

This paper presents the results of an experimental characterization of the physical and mechanical properties of wood-gypsum composites. The additives used consisted of wood shavings and sawdust from wood waste mixed in various proportions. The results showed that increasing the amount of wood waste reduced density and Shore C hardness. It was also observed that a rise in the percentage of wood waste slightly lowered thermal conductivity. This fall was more pronounced in the compounds containing wood shavings than in those with sawdust in the same proportion. In addition, the mechanical properties of the composite material were lower than in the reference samples. A 40% addition yielded a decrease in flexural strength of 61% for samples with sawdust (S40) and 65% for samples with wood shavings (WS40). Regarding mechanical resistance to compression, the compound with sawdust waste at 40% (S40) saw a reduction of 71% and 78% for the compound with wood shavings at 40% (WS40).

1. Introduction

Today's construction sector faces an environmental crisis of various dimensions particularly since buildings are a direct cause of pollution, producing waste and consuming large quantities of energy. The growing interest in sustainable development and the efficient use of energy is reflected in a series of legal measures arising from the transposition of EU Directive 2002/91/EC [1] on Energy Efficiency in Buildings into Spanish law. The need to adapt existing housing to the new regulations on the reduction of energy consumption and CO_2 emissions means that a considerable proportion of the housing stock will undergo rehabilitation and/or renovation in the future.

Experts attending the National Environment Congress (CONAMA 10) estimated that over 400,000 homes per year should be rehabilitated [2], an increase in renovation works that would generate large amounts of construction and demolition waste (CDW) that need to be properly managed. In 2008, Spain produced 47 million tonnes of CDW while recycling only 13.60%, which meant that the targets set by the National Plan for Construction and Demolition Waste for that year were not reached [3]. In addition, the European Environment Agency has stated that recycling levels in Spain were well below the average for the European Union.

This led to the approval of the European Directive 2008/98 [4] and the Spanish Royal Decree 105/2008 [3] on CDW, with a new approach that considers not only the waste phase but the whole lifecycle of the products and materials involved in construction, so that the impact of waste generation on the environment is reduced and waste management is better regulated. In particular, the Directive requires the adoption by Member States of measures necessary to ensure an increase to a minimum of 70% in terms of weight, treatment, recycling and other recovery operations of non-hazardous CDW by 2020.

* Corresponding author.
E-mail address: mjesus.moralesconde@gmail.com (M.J. Morales-Conde).

http://dx.doi.org/10.1016/j.conbuildmat.2016.03.137
0950-0618/

Despite the high upside potential of CDW from building works, the legislation allowing the use of CDW in the production of new materials and components for construction is limited and restrictive. The legislation does not provide recommendations on the valuation of other categories of CDW such as feedstock in the manufacture of recycled materials. For this reason, one of the main problems concerning recycled materials is the lack of interest shown by manufacturers, who do not consider reuseage as an alternative raw material, as well as the ignorance of those charged with executing building works of the possibilities and benefits of CDW.

The existing legislation on recycled materials is primarily focused on standardizing the recycling of materials in structural concrete [5]; these materials can include aggregates and water as well as ferrous steel from recycled waste. Apart from research into materials covered by these regulations investigators, mainly in Portugal and Spain, have focused on the behaviour of concrete when mixed with different proportions of recycled aggregate CDW [6–10], or of wood ash or ceramic waste when deployed as cement replacement, thanks to their pozzolanic properties [11,12]. Researchers have also studied the application of these new materials in construction products like concrete building blocks or paving blocks [13–15].

Apart from structural concrete and new products with their various applications, research has also centred on the use of mortars and recycled aggregates. Researchers have so far investigated ceramic waste as a recycled aggregate in the production of mortar or concrete, or as a cement substitute. The reused ceramic waste [16] mainly comes from manufactured tiles, sanitary pieces or bricks [17,18], which is ground into cement [19] as a form of cement substitute in the production of mortar [20,21] or as an addition. As for their use as aggregate in the form of a natural aggregate replacement, thicker fractions have been used as aggregates in concrete production [22] and the finer pieces as recycled aggregate in mortar [17,18]. Recent studies have also applied recycled plastics to the production of mortars [23–25].

Research into composite materials based on a plaster matrix includes works by del Rio Merino [27–29], while other investigators have studied gypsum composites to which glass fiber was added to the gypsum [26] and to plaster, although in these cases other additives such as mica or vermiculite were also used [30]. The fibers, whether natural or artificial, that have been mixed with gypsum to improve its properties include those from shredded tyres [31,32], polypropylene fibers [33], short pita fibers [34] or mineral wool fibers from recycled CDW [35].

On the other hand, research aimed at creating a lighter composite than gypsum has experimented with a broad mixture of materials to achieve a significant reduction in material weight and improve certain properties of the gypsum itself, such as in thermal and/or acoustic behaviour, thereby obtaining a material that can be used for partition panels or suspended ceilings, for instance. This group of so-called granular-light materials includes expanded polystyrene [EPS], which is one of the most widely used materials for such panels and ceilings [36,37]. Other investigations have employed cork to reduce weight [38], while lightweight aggregates used in studies include compounds like expanded clay, perlite and vermiculite [39]. Recent research has focused on adding agricultural waste such as rice husks and crushed shells to gypsum [40].

This paper proposes the use of wood waste from the rehabilitation of houses with a horizontal wooden structure [41,42] as a component to be mixed with gypsum in order to generate a compound that is both lighter and superior in terms of its thermal properties. Furthermore, both natural and artificial fibers are added to increase the resistance of the new compounds in order to obtain a composite of recycled material for a wide range of construction applications. In this regard, the research focuses on the characterization of the physical and mechanical properties of the material composed of gypsum and wood waste according to dosage and additives. The ultimate aim is to obtain the best proportion and mixes to suit as wide a range of applications as possible.

2. Materials

The experimental specimens consisted of plaster as base material and wood waste as main additive (in the form of wood shavings and/or sawdust), with natural fibers (straw) and artificial fibers (fiberglass) added to improve the properties of the new compound obtained.

2.1. Base material

A controlled B1 gypsum cast (gypsum for construction) was used, in accordance with UNE-EN 13279-1 [43], also known as YG/L (its traditional name), whose characteristics are shown in Table 1.

2.2. Recycled materials

The main additives were wood shavings and sawdust from wood recycled from various rehabilitation works on houses in the historic centre of Seville. Traditionally, the structure of these buildings is made of pine wood, mainly of scots or black pine. In this case, the wood was obtained from the wooden beams and joists of floor slabs in buildings whose design is known as domestic architecture [42] (Fig. 1). Since no previous rehabilitation works had been carried out in these buildings, it could be assumed that no treatment had been applied on the wooden structures (i.e. wood preservative, insecticide or fungicide).

To obtain the sawdust and wood shavings, the wood waste was crushed and sieve-screened, and then classified as wood shavings if measuring between 1 and 8 mm, and as sawdust if less than 1 mm.

2.3. Fibers

The two types of fiber used as additives were:

- Natural Fiber: straw,[1] as we believed it could improve the characteristics of the new compound.
- Artificial Fiber: glass fiber extracted from manufactured mesh by manual dismembering.

The materials used are shown in Fig. 2.

3. Test specimens

The test specimens were composed of varied mixtures of additives, the proportions of which are specified in Fig. 3. The aim was to find the replacement ratio getting the largest amount of waste reused with an optimal workability and a suitable resistance without incorporating additives for the preparation of the mixtures.

The optimum mixing ratio of water was determined according to the procedure described in standard EN 13279-2 [44] for the different proportions of waste to be added, depending on the workability of the sample obtained. The most favourable water/gypsum ratios are: 0.55 in those mixtures whose proportion of added waste does not exceed 10% (i.e., 2.5, 5 and 10), 0.80 for mixtures with 20% of added waste, and 1.25 for mixtures to which 40% of waste is added.

In total, 50 different mixtures (divided according to the compounds used and the percentage of waste in the mixture) as well as the reference sample (R) were produced. From each mixture, two specimen types were prepared for characterization. The average size of the specimen used in the first round of testing was $160 \times 40 \times 40\ mm^3$. These were classified as Samples A. Density tests were carried out on these samples, which were later tested in the laboratory for flexural strength. Six specimens measuring $160 \times 40 \times 40\ mm^3$ were produced for each sample. The number of samples was determined according to the standard EN 13279-

[1] Straw is an abundant low-cost material found in agricultural waste in the region of Andalusia.