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Eco-Efficient False Ceiling Plates Made from Plaster with Wood and Plastic Residues

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Abstract. Large amounts of different types of waste are generated each day in the world. Most of them do not receive proper management at the end of its useful life. In that sense, and trying to apply eco-efficiency criteria, the construction sector has recently been working on the design of new building materials that incorporate some types of residues. Those new construction materials improve some of the properties given by traditional options, such as thermal conductivity or lightness. However, many types of research in which new building products are generated do not exist. Subsequently, this paper aims at generating new gypsum plaster false ceiling plates by incorporating two different types of residues: wood waste from the demolition of traditional wooden slabs and polycarbonate (plastic) waste from crushed rejected CDs and DVDs. The flexural strength of the developed plates is tested using the procedure described by UNE-EN 14246. Furthermore, the thermal conductivity of the new pieces is obtained following the method defined by ASTM D5930-09. The results show that for all the scenarios under study when wood and plastic waste is added to the plates, the lightness and the thermal conductivity of the pieces improved. In addition, in some scenarios, the incorporation of polycarbonate waste is linked to an improvement in the mechanical behaviour of the pieces compared to the reference plate. On the other hand, when wood waste is added to the mixtures, the flexural behaviour of the plates decreases, but always achieving the minimum requirements made by the standards. Finally, it must be said that adding waste to the plasters, the amount of gypsum powder used to generate the plates decreases considerably, which represents a significant improvement in the eco-efficiency of new products.

1. Introduction

During the last years, many researchers in the building sector have tried to give a solution to the large amounts of waste that are generated each day on our planet [1, 2]. In that sense, most of them developed new construction materials that included different types of waste as aggregates. Thus, new eco-efficient materials with enhanced properties have been generated [3, 4].

On the one hand, some investigations have just analysed the influence of wood waste in the generation of new sustainable building materials. Mohammed et al. evaluated the partial replacement of fine aggregate by wood chips in the generation of new concretes [5]. Later, the behaviour of wood-sand concrete under humid and dry environments was also tested by Coatanlem et al. [6]. Other research used wood-ash as a partial substitute of cement in the generation of new concretes and mortars [7, 8].

Recently, Corinaldesi et al. analysed the effects of adding wood waste as a sand replacement in the design of new cement mortars composites with enhanced thermal properties [9].

On the other hand, previous researches have just studied the usage of different types of plastic waste as aggregate in a gypsum plaster matrix. Most of them showed that, when the amount of residue added to the mixture increased, the lightness and the thermal behaviour of the new materials improved, as it was certified by San Antonio-Gonzalez et al. when they used EPS and XPS residues [10, 11]. PET and PUR wastes were also studied by other researches, obtaining a similar tendency [12, 13]. Recently, the effects of adding wire pellets to a gypsum matrix were evaluated by Vidales-Barriguete et al. [14].

On a previous stage of this research, the authors have just studied the influence of adding wood [15] and polycarbonate (PC) waste [16] to a gypsum composite. The mechanical properties of those new plasters have already been tested. Thus, this paper aims at generating new eco-efficient false ceiling plates using the wood-gypsum and PC-gypsum plasters that had already been characterised on the first stage. Apart from the mechanical properties of the plates, their thermal conductivity has also been measured.

2. Materials and methods

2.1. Materials
All the materials needed to generate the new gypsum plates are listed below:
- Commercial gypsum for construction B1 according to UNE-EN 13279-1 standard [17].
- Water.
- Wood Shavings (WS) that was obtained from demolished wooden slabs (beams and joists) in rehabilitation works. The WS were particles from 1 to 10 mm as it can be appreciated in figure 1a.
- Polycarbonate (PC) waste from rejected CDs and DVDs collected in different recycling points of our university. The discs were crushed obtaining pieces up to 4 mm (figure 1b)

(a)  (b) 

Figure 1. Wood shavings (a) and polycarbonate waste (b) used as aggregate in the development of the new gypsum plates

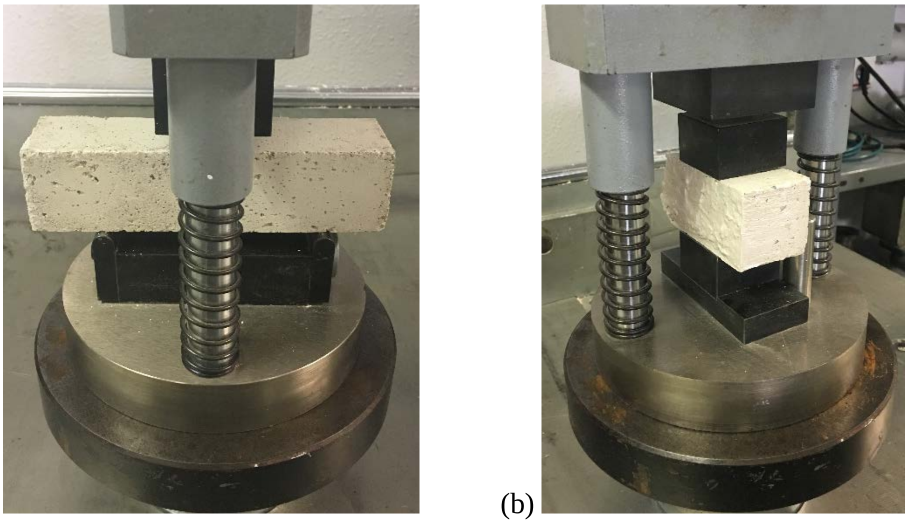
2.2. Gypsum plasters (mixtures) under study
Apart from the reference material (the one without any type of waste), six more mixtures were generated using WS and PC waste as aggregate. The composition of each mixture (materials and amounts used) are defined in table 1.

Table 1. Composition of each gypsum mixture under study

	Gypsum [g]	Water [g] or [ml]	W/G Ratio	Wood Shavings [g]	Polycarbonate [g]
Reference	1000	550	0.55	-	-
WS10	1000	550	0.55	100	-
WS20	1000	800	0.80	200	-
PC10	1000	550	0.55	-	100
PC20	1000	550	0.55	-	200
PC40	1000	550	0.55	-	400
PC60	1000	550	0.55	-	600

2.3. Test methods

As it was mentioned, in the first stage of this research [15, 16], the new gypsum composites were characterised following the procedures defined by UNE-EN 13279-2 [18]. Their dry state density, flexural strength and compressive strength were obtained (figure 2). To test them, three 40x40x160 mm^3 specimens for each mixture were elaborated.

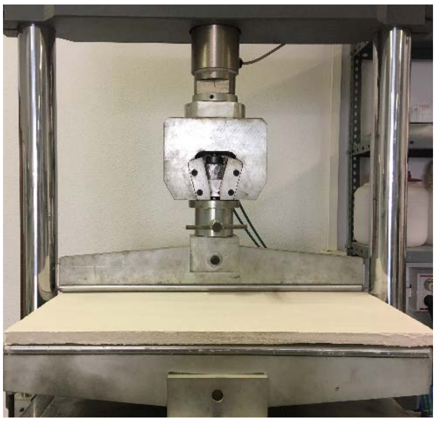


(a) (b)

Figure 2. Flexural strength (a) and compressive strength (b) tests

According to the false ceiling plates, after their preparation, the plates were preserved for seven days in a curing chamber at 23 ± 2 °C and at a relative humidity of 50 ± 5%. After seven days, the specimens were placed in an oven for 24 h at 40 ± 2 °C to constant weight and tested for flexural strength. In this test, each plate had to bear a uniform linear load of 6 kg (0.1 kN/m) on its central fibre (figure 3a). The plates must withstand this stress for 30 min without visible signs of damage [19]. After this test, the plates were tested to breaking point to obtain the breaking load value for each one.

Furthermore, the thermal conductivity of the plates was tested using the ISOMET-2114 device (figure 3b) and following the procedure defined by ASTM D5930 [20].


(a)


(b)

Figure 3. Flexural strength test for the gypsum plates (a) and thermal conductivity test (b).

3. Results and discussions

3.1. Gypsum composites characterisation
The dry state density, the flexural strength and the compressive strength of the new gypsum plasters had already been measured. The results are presented in table 2.

Table 2. Gypsum composites characterisation tests results

	Density [g/cm^3]	Flexural Strength [MPa]	Compressive Strength [MPa]
Reference	1.336	3.420	6.680
WS10	1.166	2.900	6.530
WS20	0.954	2.680	5.790
PC10	1.242	3.541	8.984
PC20	1.235	3.054	8.036
PC40	1.194	2.617	7.701
PC60	1.138	2.328	5.590

3.2. Flexural strength test results
The flexural strength test results for all the plates are presented in figure 4.

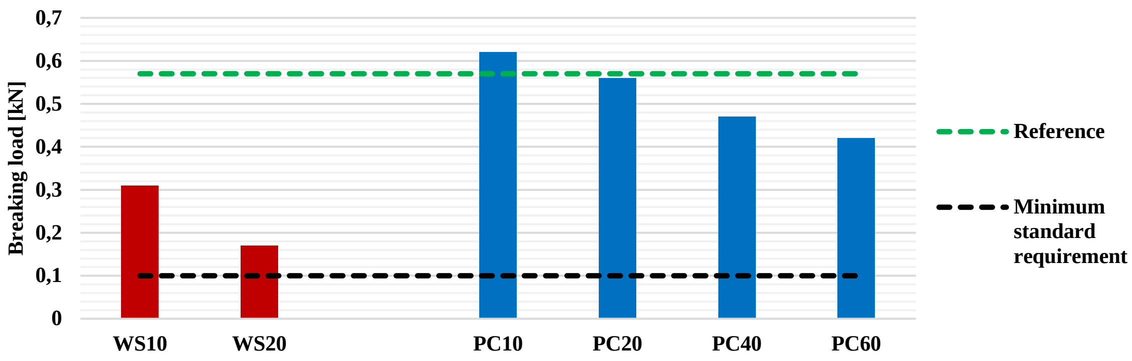


Figure 4. Flexural strength test results for the plates

As can be appreciated, for both types of waste, when the percentage of residue increased the resistance of the plate decreased. That drop was higher for the plates that contained wood waste, being the WS20 the one that achieved the lowest value (0.17 kN). On the other hand, a slight improvement was obtained for the PC10 plates (0.62 kN). Finally, it must be noted that all the plates passed satisfactorily the 0.1 kN minimum value required by the standard [19].

3.3. Thermal conductivity test results
The thermal conductivity test results are presented in figure 5.

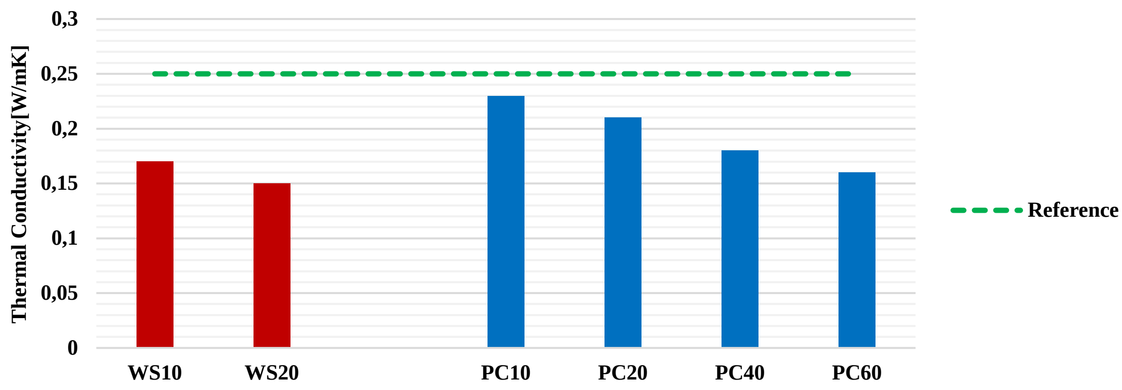


Figure 5. Thermal conductivity test results

As it can be noticed, by adding both types of waste to the plates their thermal behaviour improved substantially. That improvement was higher for those mixtures that contained wood shavings, being the WS20 plates the ones that achieved the lowest conductivity value (0.15 W/mK).

4. Conclusions

In this research, new eco-efficient false ceiling gypsum plates were developed using wood and plastic waste. According to the results, the following conclusions can be drawn:

- In terms of mechanical behaviour, for both types of waste, when the percentage of residue increased the resistance of the plate decreased, passing all of them the minimum 0.1 kN value required by the standards. That drop was higher for the plates that contained wood waste. On the other hand, a slight improvement was obtained for the PC10 plates.
- According to the thermal conductivity results, by adding both types of waste to the plates, their thermal behaviour improved substantially. That improvement was higher for those mixtures that contained wood shavings.
- Adding waste to the plasters, the amount of gypsum powder used to generate the plates decreases considerably, which represents a significant improvement in the eco-efficiency of new products.

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