OPPORTUNITIES FOR RECYCLING CONSTRUCTION AND DEMOLITION WASTE (C&DW) INTO WPCs

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ABSTRACT

Huge quantities of C&D waste like plastics, mineral wool or gypsum plaster board end at landfill because recyclers don't know what to do with it due to its nature and volume. Though the fraction of these wastes is usually below 10% by weight in a C&D site, thousands of tonnes are accumulated year by year in Europe, and even more by volume. Thus, it was studied the possibility of recycling C&D waste into polymer composites. Moreover, not only plastic and wood could be recycled for traditional WPCs but also other wastes such as wool insulation and gypsum plaster board.

Several formulations varying component ratios were premixed in a preheated internal mixer and then extruded into profiles for testing. It was found out that filler contents of 60% including wood, gypsum plaster board and mineral wool could be processed using standard equipment. Moreover, a strong positive effect was observed in the properties after the addition of the C&D waste.

Thus, addition of C&D waste such as gypsum plaster board and mineral wool to WPCs suppose not only a recycling way to a problematic waste fraction, but also the possibility of obtaining WPCs at lower cost and with improved performance, mainly for outdoor applications such as decking, fencing or railing.

INTRODUCTION

Construction and demolition (C&D) waste represents one of the European Union's largest waste streams by weight and volume, accounting 25% of the waste generated yearly in Europe.

The stony fraction represents the most representative part of C&D waste, typically accounting up to 75% of the total amount of C&D waste. However, the increasing use of plastics and other materials in construction is yielding to the obtaining of different types of wastes. In fact, the wide use of plastics in construction is highlighted by their high consumption (second consumption sector after packaging), what represents almost 20% of total plastic consumption in West Europe. Plastics are used in pipes, isolation, frames, indoor design, etc. Furthermore, the newer the building the higher its plastic content and thus, plastic residues increase in demolition wastes. Plastic wastes in demolition are generated from floor and wall coverings, pipes, isolators, profiles, windows and garnishes. When it comes to construction wastes, most of the plastic residues are constituted of packaging products, despite some other plastic wastes are formed by damaged products like pipes, windows, etc. In construction sites plastics from packaging are already recovered and recycled in plastic recycling facilities. However, plastics from demolition sites are miscellaneous and dirty, so it cannot be separated by usual plastic separation techniques and thus, they usually go to landfill or are incinerated. However, if proper sorting systems and processes are applied we could find that the main plastics found in C&D waste are polyolefins, both polypropylene and polyethylene.

Wooden waste materials account for between 11% and almost 40% of the C&D waste depending on the European country. This material comes from clean lumber, plywood, painted and/or treated wood, pallets, furniture and cabinetry. One of the problems associated to recycling of wood is that it is usually painted or treated; thus, its reuse must be carefully controlled. Nowadays, incineration for energy recovery is considered as the only recycling way for this waste fraction.

On the other hand, the Directive 2002/91/EC on the energy performance of buildings shifts towards the direction of improving the buildings´ overall energy efficiency. It points out that buildings should be designed and built in such a way that the amount of primary energy required to operate them will below. In order to minimise the building's energy consumption by means of thermal protection of its envelope (walls and roofs), insulating materials with low conductivity values are used. The European market of insulating materials is characterised by the presence of two families of products: inorganic fibrous materials like mineral wool which account for 60% of the market and foamy polymers accounting for 27% of the market. However, due to the nature of these materials and the difficulties for recycling, they are usually landfilled or incinerated.

Other waste streams in C&D accounts for rubber, paper/cardboard, glass, metals or plaster/gypsum board. One of the most problematic waste fraction is plaster/gypsum board. It accounts for high amounts but usually goes to landfill.

Wood-plastic composites (WPC) are widely used; especially, for decking, cladding, fencing and ornaments. WPCs provide the advantageous performance of both raw materials with an appearance similar to wood but with the processing capacity and design flexibility of plastics. WPCs allow the introduction of high contents of wood and can be manufactured by typical plastic techniques. Among their advantages lower price compared to both plastics and wood, lightness in hollow and/or foamed structures, design flexibility, environmental performance, less water absorbance than wood and mechanical performance comparable to reinforced plastics can be mentioned. But could WPC be made of C&D waste, not only using plastic and wood but also recycling other potentially usable waste fractions?

WPC made of waste can find several applications in the construction industries. The wood-like appearance, easiness to assembly and low cost make the composite profiles suitable to manufacture animal shelters and storages in forestry and rural areas with minimum visual impact. Among its benefits it can be mentioned that plastic composites are easy to keep clean and animals do not eat/bite them as they do with wood. Likewise, assembly/disassembly, durability and simplicity make it ideal for removable offices for C&D sites or other industries.

MATERIALS AND METHODOLOGIES

- Raw materials

Recycled polymers were taken from a recycling facility due to availability but always assuring the presence of the type of plastics obtained as C&DW.

Wood was also taken as a waste from a manufacturing company in order to assure 100% free of metals which could damage extrusion machinery during transformation.

Gypsum plaster board and mineral wool were taken from a C&D site as waste.

- Formulation

Several formulations were prepared through combination of different polymer/wood/wool/gypsum ratios. Recycled polypropylene (PP) and polyethylene (PE) was used. Plastic content was maintained at the minimum to increase as much as possible other waste content. Compatibilizer and lubricant were also added.

Mixture code	**Plastic**	**Wood**	**Gypsum**	**Wool**	**Comment**
PE 50	HDPE 47.5%	47.5%	-	-	
PE 60	HDPE 39%	59%	-	-	
PE 42/10/10	HDPE 30%	42%	10%	10%	
PE 31/0/31	HDPE 30%	31%	-	31%	
PE 20/21/21 3.5	HDPE 30%	20%	21%	21%	Lubricant 3.5%
PE 20/21/21 4.0	HDPE 30%	20%	21%	21%	Lubricant 4.0%
PE 20/21/21 5.0	HDPE 30%	20%	21%	21%	Lubricant 5.0%
PE 20/42/0	HDPE 30%	20%	42%	-	
PP 42/10/10*	PP 30%	42%	10%	10%	
PP 22/20/20*	PP 30%	22%	20%	20%	
PP 32/0/30	PP 30%	32%	0%	30%	

*: They were obtained as trials because industrial manufacturing didn’t succeed.

- Processing

In order to make mixtures processable by extrusion, it was necessary to mix the raw materials in a preheated high intensity mixer to form some kind of aggregates able to be processable. These mixtures were directly fed to the extrusion machine (CONEX CWE 380-1) and were run as usual for WPCs. Hollow profiles of 60x40x8mm were obtained. Test samples were obtained by mechanizing the profiles.

Initially some trials were carried out for processability study, after fine-tune of processing parameters test samples were obtained.

Figure 1. Mechanized test samples and extruded profiles

PP was found to be very difficult to get into molten stage in the mixer because it captured dust from gypsum boards and mineral wool.

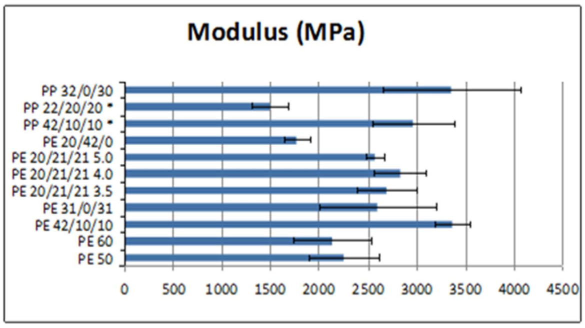
- Testing

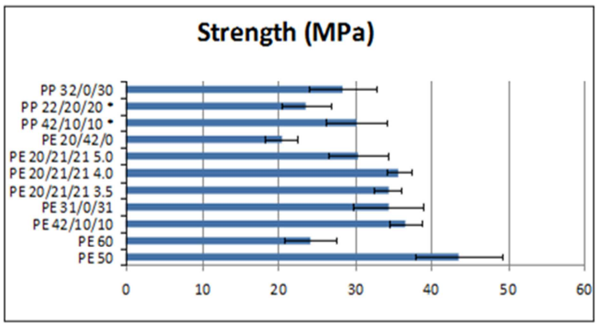
Different formulations were tested according to physical and mechanical properties in order to evaluate their suitability for further products:

- ✓ Flexural modulus and strength (ISO 178)
- ✓ Notched and unnotched Charpy impact strength (ISO 179)
- ✓ Density
- ✓ Heat distorsion temperature (HDT) (ISO 75)
- ✓ Water absorption
- ✓ Reaction to fire-single flame source test (ISO 11925-2)
- ✓ Brinell hardness

RESULTS

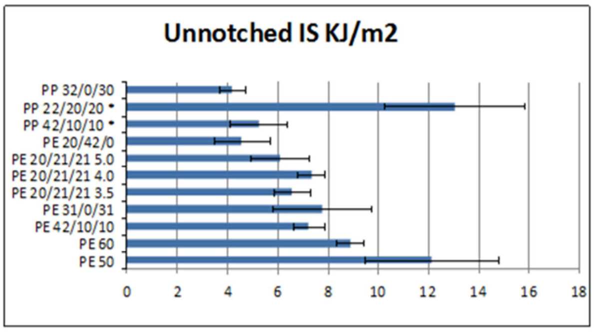
<u>Flexural modulus and strength</u>

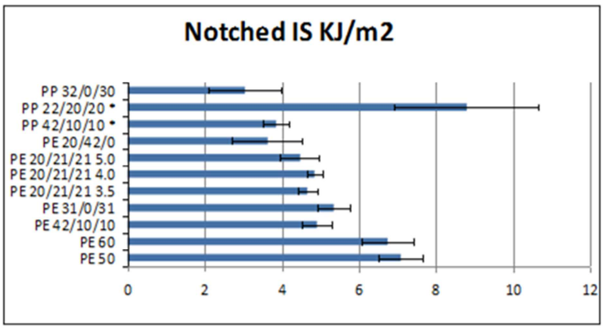




Attention must be paid to the gypsum content because a high content of gypsum decreased flexural properties. However, the combination of C&DW with wood provided very good flexural results. The addition of different lubricant contents did not affect flexural results.

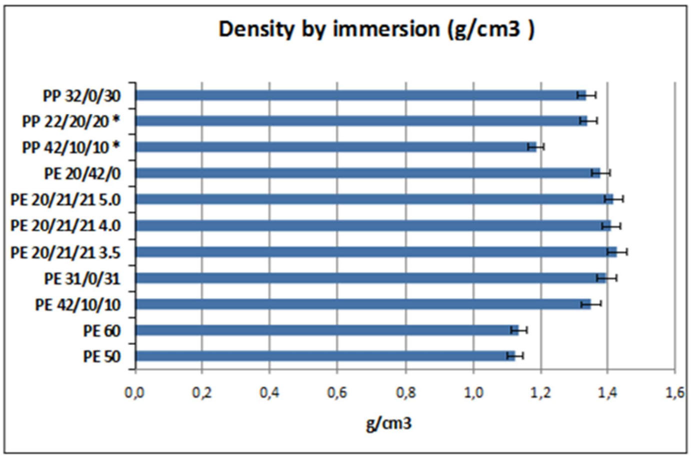
<u>Notched and unnotched Charpy impact strength</u>





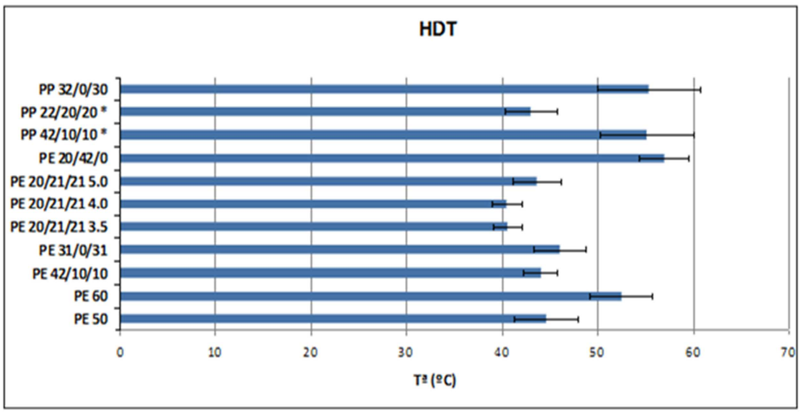
Addition of C&DW decreased impact strength and the lowest values were influenced by the highest gypsum content. Similar values were obtained for the rest of the composites.

Density



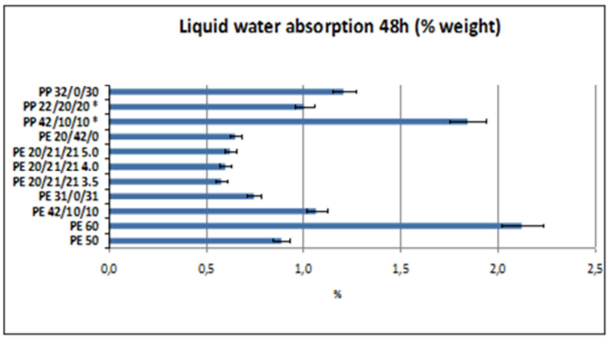
Addition of C&DW provides an increase in density of 25% with PE and 20% with PP. However this increase give rise to values still lower than values presented by polyvinyl chloride (PVC) profiles (around 1.5 g/cc).

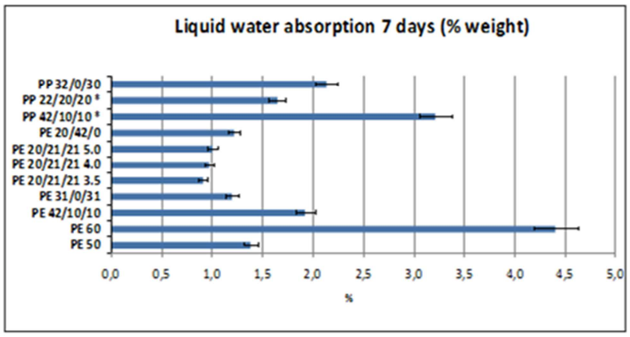
Heat distorsion temperature (HDT)



High gypsum content increased HDT. The rest of the composites showed lower HDT than reference (decreases of 10-20%)

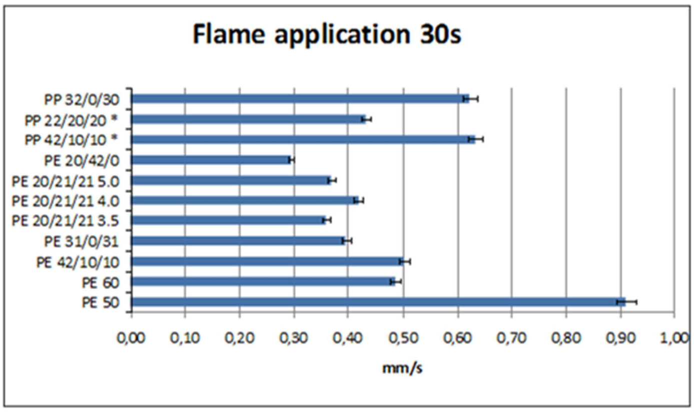
Water absorption





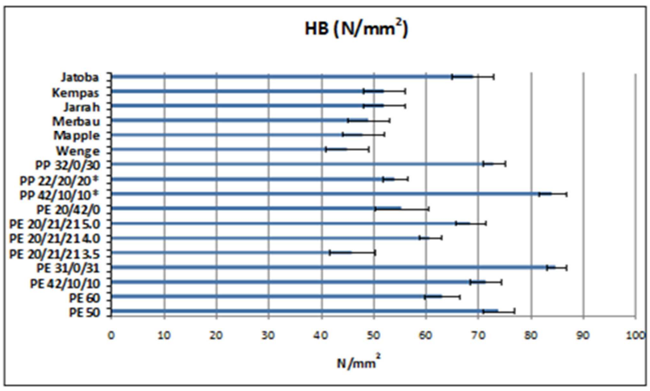
Being hygroscopic, any inclusion of wood wastes gives rise to higher water absorption of the samples than neat plastic. At reducing wood content by substituting it with other inorganic C&D waste, water absorption decreases. It was also stated that PP composites absorb more water than HDPE ones.

<u>Reaction to fire-single flame source test</u>



The reduction of wood content by adding C&DW improved fire results by reducing flame propagation speed, especially when using high gypsum content. In general, similar results were observed for the rest of the composites. In the specific case of PP, this matrix gave rise to worse results than PE based composites.

<u>Brinell hardness</u>



As a reference, the Brinell Hardeness of different tropical woods was included into the study (Jatoba, Kemplas, Jarrah, Merbau, Wenge) and also maple. All these woods have a hardness degree of 4 which corresponds to very hard wood (ash tree, beech, walnut and pine have a value of 3, while larch 2 and spruce 1). Composite samples show even higher values than those shown by very hard tropical woods.

Referring to gypsum contribution, a reduction of hardness is stated while mineral wool increases these values. A higher lubricant content also increase hardness values.

CONCLUSIONS

Huge quantities of C&D waste like plastics, mineral wool or gypsum plaster board end at landfill because recyclers don't know what to do with it due to its nature and volume. Though the fraction of these wastes is usually below 10% by weight in a C&D site, thousands of tonnes are accumulated year by year in Europe, and even more by volume.

Composites based on C&D waste; i.e. polymers, wood, mineral wool and gypsum plaster board were developed and characterized. It was demonstrated that Wood/gypsum plaster board/wool insulation formulations with contents above 60% can be processed in extrusion with recycled polymers. The obtained products can be processed by extrusion like plastics while being wood-like.

As regards performance, better results were obtained with PE than with PP. The best test results were obtained with samples of formulation PE/wood on gypsum and wool basis as well as just wool basis (PE 20/21/21 and 31/0/31). It was demonstrated that they were even more suitable for outdoor applications than traditional WPCs because they led to reduced water absorption. Samples of formulation PE/wood on gypsum basis were discarded due to their low flexural properties and high density.

This table summarizes the performance of the formulations with the best performance (PE/wood/gypsum/wool and PE/wood/wool).

<table>
<tr><th colspan="2">Improved performance</th><th colspan="2">Worsen performance</th></tr>
<tr><td rowspan="2">Increased flexural properties</td><td>20% in modulus</td><td>Reduced Charpy impact strength</td><td>20-25%</td></tr>
<tr><td>40% in strength</td><td>Increased density</td><td>25% (to get a value similar to PVC)</td></tr>
<tr><td>Reduced water absorption</td><td>60%</td><td>Reduction in HDT</td><td>15% (but all above 40ºC)</td></tr>
<tr><td>Reduced flame propagation speed</td><td>20%</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Higher hardness</td><td>>10%</td></tr>
</table>

ACKNOWLEDGEMENT

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