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Comparative Life Cycle Assessment of gypsum plasterboard and a new kind of bio-based epoxy composite containing different natural fibers

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ABSTRACT

A comparative LCA from cradle to grave between traditional plasterboard, for drywall applications, and different composite boards, made by natural fiber and a bio-based epoxy resin (Supersap CLR), was carried out. The goal of the study was to determine whether the composites based on such a resin combined with natural fibers could be an eco-friendly alternative to plasterboard in the building sector. Moreover, the impacts related to each of the fibers used are also assessed separately from cradle to gate in order to get a better understanding of its influence. Both the results obtained through the IPC.GWP 100a method and the recipe endpoint show a remarkable difference between the plasterboard and all the different composites, the composites offering a 50% reduction in the CO_2 emissions. The calculations performed regarding the impacts related to the different fibers showed only small differences between them.

1. Introduction

Nowadays, there is evidence that supports the existence of global warming (Cox et al., 2000) (Le Quéré et al., 2015) (Parmesan and Yohe, 2003). This situation is making society become increasingly aware of the imminent danger that global warming may cause (Thomas et al., 2004). This change in attitude can not only be observed in the general population but also in new international and even regional laws, norms and regulations. All of them reflect this change in mentality with a common main objective: to avoid the occurrence of global warming or if not possible, to reduce drastically its effects.

Every industry field is undergoing deep change in their production process in order to succeed in making the least damaging products they can. We can consider the construction industry to be especially sensitive in this matter due to the enormous amounts of raw materials required to perform any activity in such a field (González-Vallejo et al., 2015). The search for ecological materials becomes crucial in meeting this necessity (Cabeza et al., 2014). Natural fibers are on the spotlight of many companies and scientific studies (Alves et al., 2010) (John and Thomas, 2008), with the common idea that its use as a raw material results in low environmental impacting products. But are the natural fiber made materials really less detrimental to the environment? In order to answer this question, it is necessary to analyze all the processes involved in the life cycle of each particular material from the moment the manufacturing is started until the end of life of the resulting product. This methodology is known as the Life Cycle Assessment (LCA) defined in the international ISO 14040, 2006 norm (International Organization for Standardization, 2006).

Until now, several studies have been carried out demonstrating that the use of natural fibers in relation with traditional materials, implies a reduction in the impacts associated with the automobile industry (Pegoretti et al., 2014) (La Rosa et al., 2013) (Cicala et al., 2016), the electronics industry (Deng et al., 2016) and in other areas as well. However, only a few studies have been performed concerning a product or a material with direct application to the building sector (Asdrubali et al., 2012).

1.1. Context of the case study

The case study presented in this paper was conducted within a larger project, based on the research of new materials and products applicable to the building industry with a low environmental impact and the study of its acoustic and thermal properties as well.

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The project is developed in Spain by the Polytechnic University of Valencia (UPV), so all the estimated consumption of energy related to transportation and electricity mix were made considering the necessary steps to manufacture the materials in such a country. Despite this fact, the study is easily applicable anywhere else as seen in the subsequent sections.

The building sector in Spain is based on materials extracted from quarries such as clay for bricks or tiles, plaster for drywalls, concrete for the structure or even stone for products like mineral wool. The vast majority of construction projects use these kinds of materials whose extraction from the land implies a huge environmental impact on the ecosystems (Rodríguez et al., 2015). The quest for alternatives to brick and plaster is key to assure a sustainable development and evolution in such a market anchored to the traditional products which sees any use of new materials with skepticism.

In order to counter this skepticism, it is necessary to prove to companies, without any doubt, that the alternatives offered guarantee not only equivalent mechanical, acoustic and thermal properties, but also that they bring noticeable improvement for the environment, therefore adding value to their products. The use of these alternatives opens a whole new market of eco-friendly consumers for the company. Currently the most highly trusted certificates for green construction such as BREAM and LEED reward the use of those kinds of materials.

2. Methodology

2.1. Goal and scope definition of the study

The main goal of this study is to perform a comparative Life Cycle Assessment between two construction oriented materials. One of them is the traditional gypsum plasterboard, widely used all over the world as a drywall component, and a new kind of epoxy composite, produced in the UPV laboratory, thought to be an alternative to the previous one.

The epoxy composites produced have an epoxy-made matrix with ecological content known commercially as Supersap ("Entropy Resins delivers sustainable composites," 2011) and natural fibers of different kinds (flax, hemp, coir, jute and shredded cotton fibers) as the solid filling. The objective pursued is to determine, with a quantitative analysis, if the use of these composites may suppose an ecological alternative to traditional plasterboard.

The motivation for this study comes from a recent industrial production innovation made a few years ago by the company Entropy Resins in creating the epoxy resin Supersap, which is partially made out of ecological materials. The company claims to reduce CO_2 emissions to around a 50% with respect to regular epoxy resins ("Entropy Resins delivers sustainable composites," 2011). An LCA of the environmental impacts generated by composites made using Supersap and natural fibers compared to those generated by epoxy with glass fiber has already been performed (Angela Daniela La Rosa et al., 2014a, b) . The study included a comparison between the impacts generated by Supersap epoxy resin and Petroleum based epoxy resin (depicted in Table 1). That comparison shows that the impacts generated by Supersap are significantly lower in most categories. In addition, a comparative LCA using Supersap in building envelope solutions was carried out with special attention to thermal conductivity (A. D. La Rosa et al., 2014a, b). However, composites made using Supersap have not been compared to gypsum plasterboard, yet.

This comparative LCA is performed from cradle to grave, meaning that the processes considered are the ones from the beginning of the production of every material used, going through each process of manufacturing until the end of life of the final product, in this case its landfilling. As it is explained in the following sections, the use phase in the studied materials won't produce any impact over the environment.

2.2. Functional unit

The functional unit considered in this study is 1 m^2 of material, each material having a slightly different thickness. This difference in volume between them is not considered to be relevant because they accomplish the same task as a part of a drywall system regardless of their thickness.

2.3. Inventory analysis

An Inventory analysis based on the model described in the subsequent sections has been performed following the framework provided by the ISO 14040 (International Organization for Standardization, 2006). The objective of an inventory analysis is to account for every activity, raw material and process that can

Table 2
Transportation processes.

Raw material	Means of transportation	Distance (Km)
Flax fiber	Lorry 16 metric tons	250
Jute Fiber	Transoceanic ship	6711
	Lorry 16 metric tons	100
Coir	Transoceanic ship	3584
	Lorry 16 metric tons	350
Hemp Fiber	Lorry 16 metric tons	450
Recycled shredded cotton fiber	Lorry 16 metric tons	50
Epoxy resin	Transoceanic ship	6000
	Lorry 16 metric tons	250

Table 1
Potential environmental impacts associated to 1 tonne of petroleum-based epoxy resin and 1 tonne of plant-derived Supersap Entropy resin.

Impact category	Units	Petroleum-based epoxy resin[a]	SuperSap Entropy[b]
Abiotic depletion (ADP)	kg Sb eq	59,4	0,01
Acidification Potential (AP)	kg SO2 eq	40,3	25,44
Eutrophication Potential (EP)	kg PO4— eq	6,6	6,9
Global warming (GWP100a)	kg CO2 eq	6663	4079
Ozone layer depletion Potential (ODP)	kg CFC-11 eq	1,26E-06	0
Human toxicity Potential (HTP)	kg 1,4-DB eq	490,44	545,17
Fresh water aquatic ecotoxicity Potential (FAETP)	kg 1,4-DB eq	246,5	66,39
Terrestrial ecotoxicity Potential(TETP)	kg 1,4-DB eq	29,1	228,63
Cumulative Energy Demand (CED)	MJ eq	2,16	1,9

[a,b]Values published by (Angela Daniela La Rosa et al., 2014a, b).