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Development of vegetal based thermal plasters with low environmental impact: optimization process through an integrated approach

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Abstract

The use of thermal insulating plasters represents an effective solution in energy retrofit of existing buildings. Thermal properties are usually improved through the addition on the plaster formulation of Light Weight Aggregates, as expanded polystyrene and perlite. The drawback of these thermal plasters is the higher environmental impact, especially when added to natural binders, as natural hydraulic lime.
Within a research activity a process of optimization was followed in order to get the most effective blend, applying iteratively the LCA methodology, measuring the thermal conductivity and testing the environmental impact in terms of Volatile Organic Compounds and formaldehyde emission rates.

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Keywords: Thermal insulating plasters; Energy Retrofit; Embodied Energy; VOC emissions,

1. Introduction

Energy retrofit of existing buildings is nowadays a priority. The use of thermal insulating plasters represents an

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3.2. The LCA analysis

The environmental impacts have been evaluated with the Life Cycle Assessment methodology defined by the UNI EN ISO 14040/44 [9]. The LCA method is been applied as a tool for integrating environmental criteria into the company strategic plans. In particularly, the analysis aims to develop and improve a range of experimental prototypes of thermal plaster using natural matter as a primary source including minerals and plants, often derived from agriculture by-products or scraps. The LCA study has been developed by three progressive steps: the first one is the analysis of raw materials in order to support the formulation phase, the second one is the comparison between the prototypes and the benchmark, and the third one is the evaluation of all embodied energy of thermal plasters considering also the effect of the installation phase. The Functional Unit for the former two steps is the kWh/kg, while the functional unit of last analysis is kWh/m^2 related to a 4 cm of thermal plaster thickness.

The system boundary, covering cradle-to-gate, include all the processes from the extraction of raw materials, transports, up to the plant processes of manufacturing and packaging. The Life Cycle Inventory is based on two kinds of data: indirect and direct data. The former belongs to the database Eco-Invent v.2.0 (raw materials: lime, perlite, zeolite, vermiculite, cements, EPS). The latter have been gathered directly from companies involved in the research project. It includes processes related to: raw materials such as corncob tillage and recycled cork, transport route, the transformation of wheat straw granulated, corncob granulated, cork granulated, and the plant's processes related to experimental thermal plasters manufacturing.

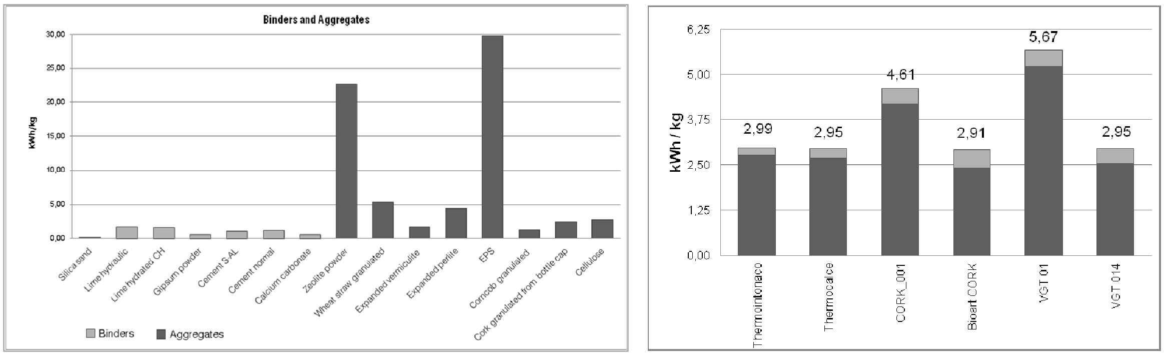

Fig. 2. (a) Embodied energy of raw materials; (b) Embodied energy of 1 kg of thermal plasters.

The comparison between binders and aggregates based on the adaptation of data from Ecoinvent (excluding wheat straw and granular corn cob, whose are direct data), underlines the need to maximize the use of vegetal materials waste, trying to contain mainly the amount of zeolites. However, EPS, despite its low ecological features, gives excellent performance in thermal resistance in relation to the minimum amount by weight in the mixture (Fig.2). The environmental and energy analysis of materials were fundamental in a blend formulations for a thermal plaster prototypes. The usefulness of the raw materials analysis is demonstrated in the comparison study of mixtures: the VGT 001 is in fact much more impactful of VGT 014, since, in the last formula the zeolite was removed (Fig.2b). Results of the LCA analysis are shown in Fig. 3 and in table 3, where: NRE is the content of non-renewable energy, RE is the renewable energy, evaluated with the CED method v. 1.06; GWP is the global warming potential expressed in carbon dioxide equivalent, constancy with IPCC emission factors. The analysis highlights a correspondence between the GWP and the energy analysis for each product. table 3 show that the emissions related to thermointonaco (EPS), thermocalce (PRL), bioart cork and VGT_014 are comparable. The last step of the environmental impact assessment is represented by the evaluation of technological characteristics in the installation phase. Different quantities needed of each plaster, in relation to the thickness and the surface, affect the total amount of powder used: the quantity of mixture used for the Thermointonaco is 8,6 kg, about half of that of the other plasters. The fig. 3 points out that the relationship between the embodied energy of the six plasters change again, and Thermointonaco reveals to have the lower impact especially by virtue of the very low weight of the aggregate in EPS.

Sample name	NRE (kWh/kg)	RE (kWh/kg)	GWP ($kgCO_2eq/kg$)
Thermointonaco	2.75	0.23	0.854
Thermocalce	2.68	0.27	0.928
Cork_001	4.20	0.41	1.180
Bioart Cork	2.42	0.49	0.889
VGT_001	5,21	0.46	1.371
VGT_014	2.52	0.43	0.881

Table 3. LCA results CED and GWP100 IPCC

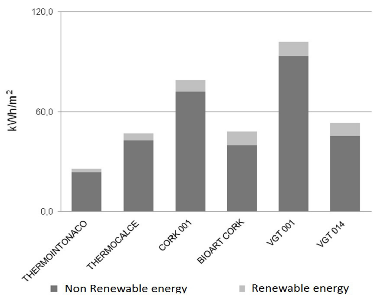

Fig 3. Embodied Energy for 1 m^2 with 4 cm of thickness

3.3. Laboratory measurement of (VOCs) and formaldehyde emission

Interior building materials can be significant pollutant emission sources and therefore can definitely affect the indoor air quality. A number of investigations on the emission from indoor sources have shown that interior architectural coatings, such as paint and varnishes, contribute to indoor air pollution, in particular during the installation process [10]. However in the literature does not appear sufficiently investigated the contribution of some products commonly used for the substrate, such as plaster, which although appear to be an integral part of the final solution. Few studies are therefore available, such as Kwok et al. (2003) [11], showing the influence of substrate on VOCs emissions from paint and varnishes and founding that VOCs emission closely related to the substrate type.

Laboratory measurements have been performed to assess the release of Volatile Organic Compounds (VOCs) and formaldehyde of some types of thermal plaster, VGT014 and BIOART CORK, in order to optimize their formulation, to assess their Indoor Air Quality (IAQ) performance, to compare different blends. Emission tests of (VOCs) were made at the Istituto Giordano (RN, Italy), accredited technical institution for the product testing and certification.

The test was carried out using testing chamber method according to standard UNI EN ISO 16000-9:2006 [12]. The products were applied on a substrate of glass, with a test specimen surface of 0,06 m^2 (Fig. 1c). The weight amount was respectively 240 g (VGT014) and 136 g (BIOART CORK). The test specimens were positioned in a chamber of 0,06 m^3 (loading factor 1 m^2/m^3).

Air sampling has been done after 8 and 28 days after introduction of the test specimen in the emission test chamber (Fig. 1d), using markes sorbent tubes (carbopack C 60/80, Carbopack B 60/80, Carbosieve SIII 60/80) for VOC analysis by GC-MS and using tubes containing silica gel coated with 2,4-dinitrophenylhydrazine (DNPH) formaldehyde analysis by HPLC-UV.

Results are reported in table 4 and compared to the French classification [13], based on emission after 28 days. French regulation foresees that since 2012, any covered product placed on the market has to be labelled with emission classes based on their emissions, as tested with ISO 16000 and calculated for European reference room, needed for comparing test result with air concentration limit values. The same reference room is used in EU Countries with advanced IAQ standard and rules, as Germany and Belgium.

The comparison shows that the tested products have extremely high performances, coming in emission class A + for the French market for all parameters analyzed. The main differences are found in the emission of (TVOCs) on the third day: VGT_thermal plaster is more performant, with values more than halved compared to Cork_thermal plaster. The larger particle size of the latter, and therefore the greater surface area exposed to the air, contributes to increasing emissions in the short-term measurements (C6-C16 expressed in toluene equivalent, according to ISO 16000-6:2011).

Table 4. Test results and comparison with French classification.

Testing parameters	VGT014 Results [µg/m³]			Bioart cork Results [µg/m³]		
	8 days	28 days	Emission class	8 days	28 days	Emission class
Formaldehyde	<3	<3	A+ (<10)	<3	<3	A+ (<10)
Acetaldehyde	<3	<3	A+ (<200)	<3	<3	A+ (<200)
Toluene	<2	<2	A+ (<300)	3	<2	A+ (<300)
Tetrachloroethylene	<2	<2	A+ (<250)	<2	<2	A+ (<250)
Xylene isomers	<2	<2	A+ (<200)	4	<2	A+ (<200)
1,2,4 Trimethylbenzene	<2	<2	A+ (<1000)	<2	<2	A+ (<1000)
1,4 Dichlorobenzene	<2	<2	A+ (<60)	<2	<2	A+ (<60)
Ethylbenzene	<2	<2	A+ (<750)	<2	<2	A+ (<750)
2-Butoxyethanol	<2	<2	A+ (<1000)	<2	<2	A+ (<1000)
Styrene	<2	<2	A+ (<250)	<2	<2	A+ (<250)
TVOCs	107	<5	A+ (<1000)	258	<5	A+(<1000)

4. Conclusions

The development of new ecological thermal plasters to be used in refurbishment or in new buildings aimed at realizing high energy efficiency and high indoor air quality environments has to face different aspects. The thermal conductivity, which in the past represented the key factor in the selection of Light Weigh Aggregates, reveals to be no more the driving property when the whole energy related issues are considered and indicators concerning the environmental scale are duly taken into account. Circular economy, Embodied Energy, Global Warming Potential, along with VOC and formaldehyde emissions shall form an integral part of the development process.

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