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PCM-enhanced lime plasters for vernacular and contemporary architecture

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Abstract

Phase Change Materials (PCMs) have the ability to absorb and release thermal energy, in the form of latent heat, during the melting or solidifying processes respectively. Thus, they may be used as additives in the production of thermally efficient composite building materials, such as plasters. This paper focuses on the design and production of PCM-enhanced lime plasters with significantly low thermal conductivity and increased specific heat capacity. The aforementioned plasters are appropriate for application in southern European climatic conditions. Due to their compatibility with traditional substrate materials, they may also be used for the renovation and retrofitting of existing structures.

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Keywords: lime; plasters; PCMs; energy efficiency; compatibility

1. Introduction

High energy consumption, due to population growth and much needed interior comfort conditions, has led to large emissions of CO_2 in the past few years. Great efforts to reduce CO_2 emissions have been made since 1997, when the European Union (EU) promised to reduce the amount of greenhouse gas emissions by 8% below the levels of 1990 emissions between 2008 and 2012, and by 20% by the end of 2020 [1].

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The building industry is one of the main consumers of energy; its contribution to global energy consumption reaches up to 40% [2]. While traditional buildings were usually constructed considering the immediate environmental climatic conditions and aiming to keep the interior spaces cool in the summer and warm in the winter, these aspects have been forgotten in modern architecture, which is mostly based on mechanical methods for heating and cooling. The latter have led to huge increases in energy demand and have resulted in an annual growth rate of energy use estimated around 2.3% [3]. As a result, EU Member States today are obliged to take measures to encourage building owners to renovate their properties by upgrading the thermal performance of existing building shells.

Traditional building insulation materials are normally used in thick or multiple layers in order to achieve higher thermal resistances. This results in complex building details, an adverse net-to-gross floor area and possibly heavier load-bearing structures [1]. At the same time, conventional insulation materials are not usually appropriate for traditional building facades. Advanced, sustainable and better performing building insulation materials are therefore needed.

Phase Change Materials (PCMs) are currently used in many different applications, due to their ability to absorb or release energy, in the form of latent heat, during the melting or solidifying process, respectively. The principle of latent heat storage can be applied to any porous building material; nevertheless, current research primarily concerns gypsum wallboards and cementitious composites [e.g. 3].

A PCM-enhanced plaster is a heat storage medium combining an appropriate PCM with a cementitious or non-cementitious matrix to produce a low-cost thermal storage material. Most of the relevant published research work refers to the use of PCMs in composites of cementitious origin, such as concrete and cement mortars [e.g. 4, 5, 6, 7, 8, 9, 10]. Nonetheless, research has also been carried out on composites with traditional binders, such as hydrated or hydraulic lime [e.g. 11].

The present research focuses on the design and production of novel cementless PCM-enhanced lime plasters with improved properties. These plasters have been designed for application in southern European climatic conditions, aiming to meet EU strategic policy targets of reduction in primary energy use in the building sector. The composite materials under study can be used not only in new structures, but also for the renovation and retrofitting of existing buildings. The lime-based nature of their matrix and their properties further extend their applicability to listed and monumental buildings.

2. Materials and Methods

Lime-based composite mixtures with constant workability (170 ± 5 mm) were designed and produced in the laboratory (Table 1). In all mixtures, the binder/aggregate ratio was 1:3 w/w, since this has been found to be the prevalent ratio in ancient and traditional lime composites, both in Cyprus and in other areas of the world [e.g. 12, 13]. The aggregate fraction used in the mixtures consisted entirely of local 0-2 mm crushed calcarenite sand. Semi-quantitative XRD analysis of this sand indicated calcite as the predominant mineral, with concentrations reaching up to 60%; albite (25%), quartz (15%) and chlorite (traces) were also present in the sample tested [14].

Table 1. Mix design of laboratory composites. All quantities are measured by mass.

Mixture	Binder (B)		Aggregates (A)	Workability (mm)	Water/ Binder	PCM Additive
	Hydrated Lime	Hydraulic Lime				(% B+A)
AREF	1	-	3	175	0.88	-
HREF	-	1	3	175	0.86	-
APCM	1	-	3	171	0.90	5
HPCM	-	1	3	173	0.92	5