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Thermal insulating plaster as a solution for refurbishing historic building envelopes: First experimental results

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ABSTRACT

In Italy, historic buildings constitute 20% of the built environment. Although historic buildings are usually excluded from the obligation of adopting specific energy standard, energy related aspects should be nevertheless faced and managed in order to exploit the building "usability" potential, to attain indoor environmental quality and energy efficiency conditions. The energy refurbishment of this kind of building is, however, a very complex matter that leads to a number of question concerning buildings conservation and valorisation aspects. A non-invasive technique, that is, the application of thermal plaster to the internal side of a building envelope, has been investigated in this paper. Thanks to its relatively easy installation and reversibility, thermal insulating plaster seems to represent a very interesting solution as it is able to offer a good compromise between energy and conservation aspects.

The aim of this work is to present a thermal, vegetal based, insulating plaster, which has recently been developed within a research project, and to investigate its potential to reduce the heat flux exchanged through the vertical envelope of historic buildings, by means of measurements carried out in both the laboratory and in the field, for a real case application.

1. Introduction

The refurbishment of existing buildings is a crucial point for the achievement of the energy and climate objectives of the European Union (EU) for 2020 and 2050. The energy performance of existing buildings is still very poor, and the construction sector is responsible, on average, for 35% of the energy consumption in Europe and in Italy [1]. The problem is made even more complex in Italy, by the remarked presence of historic buildings, which constitute 20% of the existing building stock (2 out of 10 buildings were built before 1919) [2].

Passing from energy related aspects to the cultural ones, according to the Italian Constitution (art.9), historic buildings should be preserved and protected because they constitute a source of knowledge of the architectural history of the country. Consequently, the strategy concerning the protection of historic buildings must be enhanced, and it could be more easily implemented if buildings continue to have a function and a role, as theorised by Annoni [3]. Specific maintenance interventions are therefore needed to refurbish the buildings from the energy point of view. Although historic buildings are usually excluded from the obligation of adopting specific energy standards, energy related aspects should be faced and managed in order to exploit the building "usability" potential, so as to create acceptable indoor environmental quality and energy efficiency conditions.

The energy refurbishment of this kind of building is a very complex matter that leads to a number of question concerning conservation and valorisation of the building aspects and which require "one case at a time" approach [3], when deciding how and where to intervene on a building.

A literature review has shown that a qualitative and quantitative approach to the energy and sustainability of heritage buildings needs to be applied [4]. Furthermore, the lack of a methodology, technologies and knowledge on historic building retrofitting has been observed. Till now only a few experimental and modelling activity researches have been conducted on this topic [5,6]. One study has recently presented a methodology, based on MCDM analysis (multiple-criteria decision-making), to select the best solution for the internal insulation of a brick wall in a historic building [5].

Thanks to the relatively easy installation and reversibility, thermal insulating plaster seems to represent a very interesting solution, as it is able to offer a good compromise between energy and conservation aspects for those buildings where it can be applied

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Nomenclature

e_{24}	daily energy (Wh/m^2)
λ_{eq}	equivalent thermal conductivity (W/mK)
λ	thermal conductivity (W/mK)
$\dot{q}$	specific heat flux (W/m^2)
$\dot{Q}$	heat flux (W)
s	thickness (m)
Δt_s	surface temperature difference (K)
U^*	equivalent thermal transmittance (W/m^2 K)

(i.e. no frescoed walls). The first results of a research project, aimed at developing new kinds of plaster and insulation materials with low embodied energy, are presented. In this work, the analysis has focused on a new thermal, vegetal based plaster, developed specifically for internal insulation. In particular, the study here presented deals with its applicability to the internal side of an existing historical building envelope under refurbishment, and assesses the impact on the thermal flux reduction.

The thermal insulating plaster has been tested in the laboratory to assess its thermal properties and in a real historic building, to investigate its potential to reduce the heat flux exchanged through the vertical envelope on which it has been applied.

2. Thermal insulating plaster

Plaster has been used for thousands of years as constructive element in buildings, especially in Europe. The versatility of this material allows it to be both used internally and externally, with the possibility of applying rendering or plastering mortar to different substrates, constructions and compositions. Thermal insulating plaster represents one of the possible solutions that can be adopted to face energy related problems in existing and historic buildings. The workability of thermal plaster is very similar to that of traditional plaster, as it can be used on non-aligned, out of square, or even on curved supports. Thermal insulating plaster is in fact flexible and can be suitable for any architectural or design solution. Moreover, thermal insulating plaster is characterised by a high water vapour diffusion coefficient, with a water vapour resistance factor (μ value) of between 5 and 15. For this reason, the application of this technology to existing walls is possible for envelopes affected by capillary rising damp, a problem which is very often present in historic buildings. Thermal insulating plaster has been studied not only to be a finishing or a protection layer of the walls, but also to improve their thermal resistance. These special kinds of plaster are characterised by thermal conductivity values that are more than ten times lower than traditional plaster (standard lime plaster 0.7 W/(mK)) and they are divided into two categories: plaster with natural binders (natural hydraulic lime) and plaster with cement or artificial binders. These types of plaster are usually pre-mixed and ready to use and are made with light weight aggregates (LWA), such as cork, clay, perlite, pearls of expanded polystyrene, expanded glass, etc. LWA are able to significantly improve the thermal and acoustical insulation performances of the component. Additionally, the weight of the component is noticeably reduced, compared to traditional ones [7].

New kinds of thermal insulating plaster are still being studied to reduce their thickness and to improve their thermal conductivity. Research is moving towards new aggregates, that is, innovative or natural materials. High-tech solutions, such as aerogel or phase change material (PCM) based plaster, are also being investigated.

In this paper the results related to traditional and advanced materials for thermal plaster are presented, with particular focus on the thermal properties of a vegetal based plaster. Vegetal aggregate materials, derived from corncobs, were added to a natural Wasselonne hydraulic lime and expanded silica (perlite), and the resulting plaster was tested through a laboratory analysis and in field measurements. The particle size distribution of the ingredients was studied in the laboratory to obtain the best combination from the physical, mechanical and thermal points of view. Wasselonne lime is a Natural Hydraulic Lime (NHL 2, according to the EN 459-1:2010 standard [8]) that has been extracted since 1932 in the Alsace region, France, and it constitutes a significant percentage of the final product. The natural aggregate in these prototypes was 43% (33% corncobs and 10% of dried expanded silica) and it played a double role: firstly, it contributed to an improvement in the insulation of the plaster by exploiting a waste material (i.e. the corncobs) and, secondly, the mechanical properties of the plaster were improved and the risk of cracking was hence reduced. Furthermore, the natural binder gave a high water vapour diffusion coefficient to the plaster (that is, higher than cement binders). Application tests were carried out by spraying the thermal insulating plaster onto a test wall using a plastering machine (Fig. 1a and b).

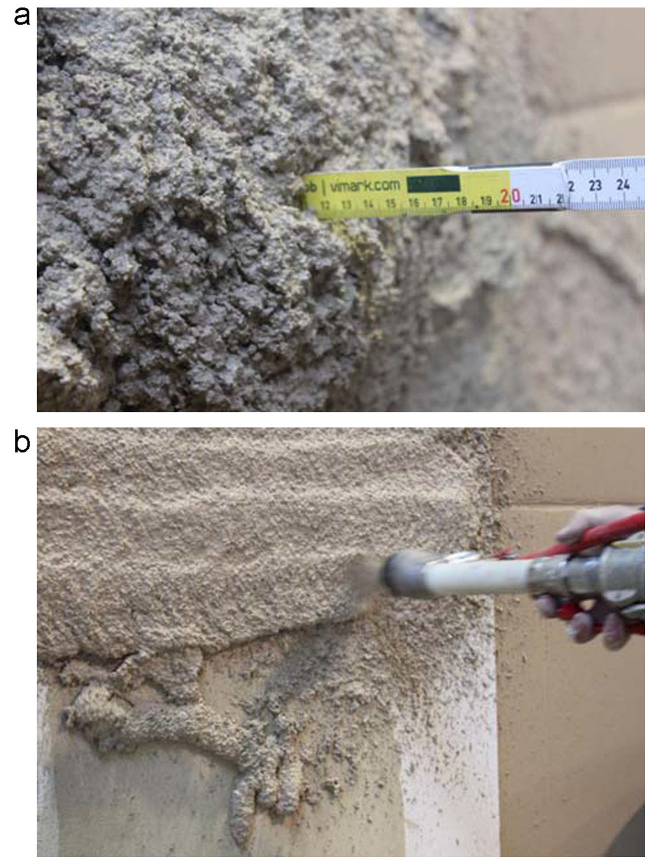

Fig. 1. (a) Evaluation of the possible thickness for thermal insulating plaster applications. (b) Mechanical application of the thermal insulating plaster.

The results have showed that this technology is capable of supporting greater thicknesses of thermal insulating plaster (above 10 cm) than traditional insulating plaster. The same result could only be achieved using a traditional plaster through the repeated application of thin plaster layers onto its support with the consequent risk of cracking. The sample that passed the first mechanical test and presented the best performance was named VGT_04, and the results related to this sample are hereafter presented. The results concerning long-term decay and the marcescence and oxidation processes are not yet available, but these important aspects are currently under investigation. Furthermore, on the basis of the