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Study of innovative solutions of the building envelope for passive houses in Mediterranean areas

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Abstract

In Mediterranean climate, passive houses have to be designed to contrast overheating, considering the dynamic behaviour of the opaque envelope, the effect of shading devices and free-cooling. These aspects prevail on the use of elevated insulation thickness and large windowed surfaces toward South. Innovative technical solutions involving dry assembled opaque walls with natural materials and the role of thermal inertia combined with free-cooling, are investigated. A reference building with thermal energy requirements lower than 15 kWh/m², both in winter and in summer, was identified analysing the thermal bridges in the structural nodes and the rational exploitation of solar heat gains.

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Keywords: dry assembled walls, envelope dynamic behavior, structural nodes, simulations, thermal energy demands

1. Introduction

The theme of sustainability in new buildings has reached considerable importance due to the difficult to attain two apparent conflicting targets: the reduction of the impact on the outdoor environment and the achievement of indoor thermal comfort condition [1]. The environmental impact of a building involves not only its management, but also the construction, the supply of the raw materials, their transportation and the eventual disposal of the same building [2]. The exploitation of particular materials associated to adequate sizing procedures and the employment of renewable

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Nomenclature

f_a	Attenuation factor [-]
$g_\perp$	Normal solar transmittance [-]
g_{gl+sh}	Normal solar transmittance with shading device [-]
κ_M	Thermal capacity per unit area [J· K^{-1}·m^{-2}];
M_S	Surface mass [kg·m^{-2}]
S	Time shift [h]
U	Thermal transmittances of opaque and transparent walls [W·m^{-2}·K^{-1}]
Y_{IE}	Periodic thermal transmittance of opaque walls [W·m^{-2}·K^{-1}]

sources to supply the air-conditioning plants, allow for the achievement of sustainable buildings [3]. Compared to traditional constructions, in continental climatic contexts passive houses are designed to attain limited energy consumption in heating applications, because the latter are predominant on cooling demands [4]. For this reason, building walls are equipped with high insulation thickness, to reduce transmission thermal losses, and large glazed surfaces facing South to maximize solar gains. However, if the same approach in warmer climatic context is used, the energy performances of the building are strongly penalized in summer [5]. In Mediterranean areas, in fact, thermal comfort conditions are compromised by indoor air overheating, also in winter. Therefore, building envelopes have to be equipped with suitable technical solutions to favour the nightly natural ventilation and the control of the solar radiation transmitted through glazed surfaces and opaque walls [6]. In the latter case, reduced value of the periodic thermal transmittance are recommended, because adequate time shifts and attenuation factors of the transmitted thermal wave allow for summer thermal loads removal by exploiting the nocturnal free-cooling. Additionally, the envelope sustainability can be improved by reducing the quantity of materials required for its realization, employing natural resources available in proximity of the construction site with the possibility to recover them during the building disposal [7]. In this paper, feasible building opaque envelopes for passive houses located in Mediterranean area and based on the employment of dry assembled walls, have been investigated. The general aim of the present work is the definition of a new housing model contextualized to the Mediterranean climate, which is more responsive to the current needs of the housing market and, at the same time, which addresses the major challenges imposed by the sustainability themes. Dry assembled walls allow for an easy building assembly, whereas an appropriate arrangement of layers with different properties can provide lightweight and robustness building envelope with high thermal inertia [8]. Dry assembled horizontal and vertical walls, with suitable layering systems, are able to realize flexible envelopes and to reduce the construction time. Moreover, the same walls can be built directly on site according to established sizes, in order to minimize the material wastage, and assembling them on appropriate frames, allow for the respect of the local anti-seismic legislation favouring the attainment of aesthetic and functional requirements. In order to validate the actual performances of the best technical solution individuated among the several examined cases, energy evaluations of a reference passive house optimized for the Mediterranean context, have been carried out by dynamic simulations in DesignBuilder® environment [9].

2. Technological criteria adopted for opaque walls

The proposed technological solutions concern a building structure frame made by steel beams, on which dry assembled walls can be easily mounted. The steel frame is required to respect the current seismic standards without compromising the choice of the internal environment subdivision. Moreover, the same frame structure allows a quick installation of ground and ceiling precast floors. Conversely, a steel frame could highlight the presence of thermal bridges, therefore appropriate correction actions have to be analysed adequately. The investigated wall layering systems consider traditional and innovative components to reduce the delivered thermal fluxes, both in winter and in summer, guaranteeing insulation properties and a suitable thermal inertia; the latter is required to rationalize the role of solar heat gains in the building. In winter, these are stored in the inner side and re-used during the night, whereas