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Improving the energy-efficiency of historic masonry buildings. A case study: A minor centre in the Abruzzo region, Italy

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ABSTRACT

The high cost of energy, along with an urgent need to reduce global worming causing emissions, has contributed to the rethinking of contemporary design and building techniques. It also brought to the forefront the need to increase the energy performance of heritage buildings. Italy's Abruzzo region has many small towns with old structures. The earthquake that struck the area in 2009 caused significant destruction to many communities and buildings. The need to rebuild led to a series of interventions aiming not only at reconstructing, but also at increasing the structure's energy performance. This paper describes a study of Abruzzo's historic buildings and proposes interventions to improve their energy-efficiency. The authors developed a methodology based on an on-site investigation and the study of compatible possible solutions. The first phase includes a series of thermal measurements, using both indirect and qualitative methods such as thermography and direct and quantitative methods. With the information gathered, it was possible to verify the energy performance of each solution based on the level of invasiveness of the proposed intervention. The proposed methodology serves as a guide to recovery design, using a "case by case" approach to identify the method of intervention in each value context.

1. Introduction

The energy crisis, together with the urgent need to reduce pollution emissions, has contributed to the launch of a survey process of design and building techniques; attention is also turning increasingly towards a need to upgrade the energy-efficiency of existing buildings. In fact, the question of sustainability related to the rehabilitation of cultural heritage is today a very relevant issue in the international community, particularly in Italy where 40% of world artistic heritage is concentrated according to estimates by UNESCO [1].

In the Italian context, therefore, the rehabilitation process offers an opportunity to reduce the negative environmental effects. It also needs to be done while respecting the buildings' architectural heritage [2].

The last few decades have witnessed renewed interest in the historic centres due to multiple factors: first, there are plenty of old villages in our territory; second their historical, architectural and environmental values are significant as well as their importance to local economies [3].

This is the case of the small towns of Abruzzo region, in the centre of Italy, hit by earthquake of April 6, 2009. The context of study is the "seismic crater", whose area was defined according to ministerial decrees following the earthquake, and that includes a territory extending over three provinces, L'Aquila, Teramo and Pescara, for a total of 73 municipalities distributed differently among them. This urban settlement are different for morphological and climate aspects, constructive techniques, typological structures and abandonment state [4]. The municipalities most affected by the earthquake were those in the province of L'Aquila, where was the epicentre, and today many of the smaller towns present, characterized by residential buildings, are partially or completely abandoned.

The need to rebuild the buildings damaged by the earthquake provided an opportunity to support the reconstruction of building structures through the introduction of innovative technologies to ensure environmental comfort to contemporary users.

Among all the factors that contribute to determine these conditions, one of the most interesting is the need to reach hygrothermal comfort [5]. This research focuses primarily on this aspect and it is

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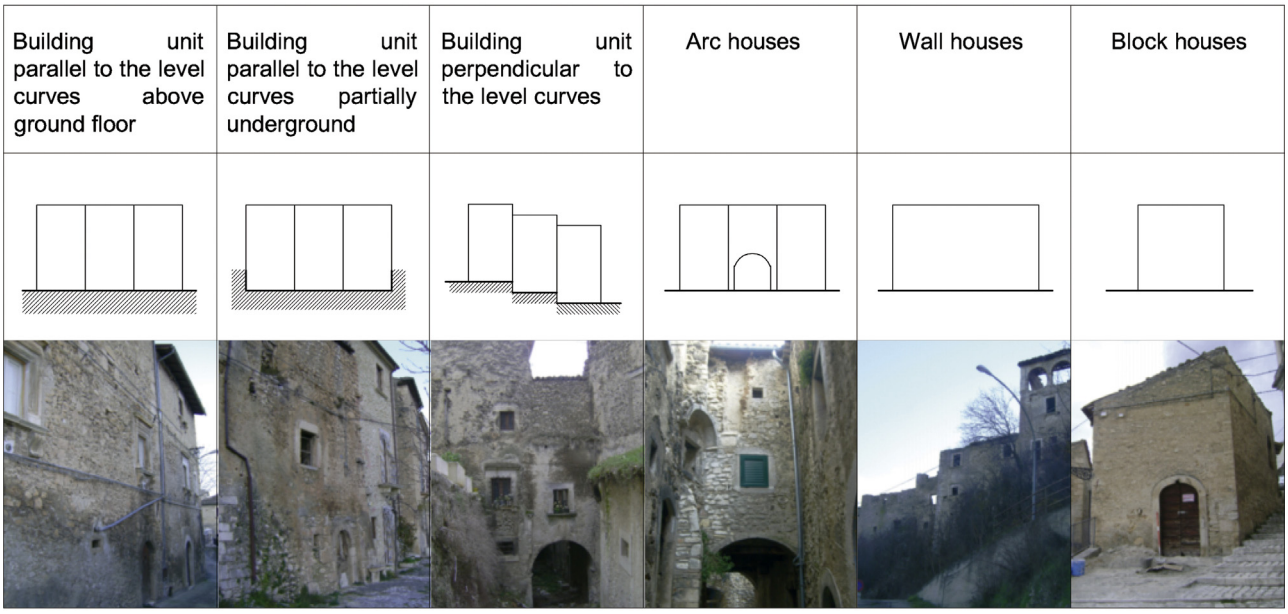

Fig. 1. Construction types in the minor centres.

the result of a complex work on the minor historical centres of the inner territory of Abruzzo and their energy-efficiency[1] and of desire to introduce innovative and high performaning products even in historic and valuable contexts.

For this purpose the chosen village of Sant'Eusanio Forconese exemplify a set of common characteristics of the villages situated in the province of L'Aquila, to illustrate the experimental tests described in the following paragraphs.

2. Methods of intervention

2.1. Typology of Abruzzo's historic buildings

The basic construction of Abruzzo's minor centres is characterized by a spontaneous "architecture without architects" style [6]. It is the result of experience gained by traditional builders, who were able to develop building methods that took into account the local topography and climate. The study of vernacular construction techniques, building types, together with their historical analysis, is therefore a critical step to understand the evolution of the towns building and to make future improvements.

The construction types found in those villages are determined by the type of soil, the building morphology and local climatic conditions [7]. These climatic conditions are very different in the studied region. The area affected by the earthquake of 2009 and object of this study has a very cold climate in winter with rainfall also of snowy nature, and the snow can persist in the soil for several weeks (usually during the December, January and February). The summer is instead characterized by significant temperature range between day and night, which can vary also by 20 degrees.

Identification of construction types is important because involves the acknowledgement of the technological traditions that, together with the figurative and spatial ones and the historical aspects too, determine the typology where to include the different townhouses: arc houses, wall houses, block houses, etc. . . . as shown in Fig. 1.

The centres, most of which have medieval origin, are characterized by dwellings of modest size, generally two-storey tall, in which the housing units are not well defined and includes other living cells. The masonry techniques change from one urban area to another, but they use similar local materials and identical masonry laying [8].

The earthquake that took place in the region during past centuries have determined the evolution of construction techniques, the implementation of seismic defences, and the reuse of recovered material; the traces of the different layers can be seen in buildings where the masonry is exposed. The facade generally constituted by blocks of medium size, is laid on horizontal and continuous shelves, and characterized by a homogeneous weaving. Instead, independent intervention can be seen on the upper floors, where irregular stone, laid on discontinuous shelves, is often used [9]. The windows are generally made in wood with a single glass poorly performing. Finally, from a heating system point of view stoves and fireplaces are widespread.

2.2. Historical masonry and their current energy performance

The research focused on the building envelope that is the main responsible for the unit's energy performance. In particular, the

[1] The study is a section of a more large research project PRIN 2009:"Mortarless building technologies for recovery and improved energy efficiency in the context of the reconstruction of buildings, inhabited areas, and towns in earthquake-prone areas of Abruzzo". This research is developing in the DICEAA Department, University of Studies of L'Aquila, School of Engineering, with unit responsible Prof. Eng. Renato Morganti. Team working: Prof. Eng. P.De Berardinis, Prof. Eng. G. Di Giovanni, Prof. Eng. A. Bellicoso, Prof. Eng. A. Tosone, Prof. Eng. F. Marcotullio. Collaboraters: Eng. M. Rotilio, Eng. D. Di Donato, Eng. O. Boccia, Eng. L. Ciammitti, Eng. D. Franchi, Eng. C. Marchionni.
The research program mentioned was divided into two main areas, which are closely related to each other: the search for new housing and typological models and the individuation of tools and methods for improving the energy efficiency of historic buildings. The rehabilitation and energy-efficiency improvement of this type of built heritage, damaged by the earthquake, cannot be considered as the simple action of transferring the technologically-advanced rules, processes, and materials used in new construction into the existing built context. On the contrary, it must be seen through the use of an action of transformation whose main goal is to preserve the historic values and ensure the development of a sustainable process. For this reason, it needs to integrate new functional and safety conditions and, at the same time, to ensure a life lasting energy efficiency and self-sufficiency of the single building and the entire built context [4]. In relation to this last topic has been developed the research shows in this paper that, starting from the study of the behaviour of vertical closures, will also extend to the other elements of the building.