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Experimental and numerical investigation of the effects of wind exposure on historical towns

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Abstract

The Italian territory has a particularly rich cultural landscape, being composed of about 20.000 historic towns and villages, identified as "minor" only because of their relatively small dimension in comparison with the large cities. Many of these urban centers, especially in the southern Lazio, have not undergone the dynamic housing transformation, typical of other old towns, such as abandonment, replacement of the inhabitants with the inclusion of new social classes, or reuse of all or part for tourist-commercial purpose. It would seem that they have retained a "modus vivendi" antinomical of the non-places of contemporary cities, preserving a high social quality of aggregative life within urban arrangements characterized by a strong aesthetic identity. However, most of them are suffering significant degradation due to intrinsic reasons, such as the characteristics of the materials and the quality of construction, or external anthropogenic or environmental factors, such as, respectively, the lack of maintenance, humidity, solar irradiation and wind exposure. Often, the impact of these factors is compounded by the geographical position where these urban centers are located. In fact, many settlements arose and flourished in the Middle Ages, as result of the aggregation of minor architecture grown spontaneously. While, on one hand their original urban composition and the strong empathetic relationship with the natural environment represent an indubitable aesthetic value, they also are among the factors of major vulnerability. Frequently, the degradation of buildings facades has to be sought in the planimetric morphology of roads, forming street canyons where powerful wind channels are conveyed. Alveolization of natural stones or detachment of plaster are triggered by the erosive capacity of the wind enhanced by the development of mold and plants induced by the detainment of water and the low solar irradiation. The analysis of the environmental context is a fundamental step for the preservation of the historic buildings and for the whole project of restoration. In the present research this study is performed on a village (Borgo San Rocco) located in the southern Lazio. In particular, in the present paper the authors present the results of a wider research activity aimed at

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experimentally and numerically investigate historic buildings degradation due to wind exposure. The air velocity field and the viscous stresses in correspondence of the building walls of the Borgo San Rocco village have been numerically investigated by means of modern Computational Fluid Dynamics (CFD) techniques. Validation of the numerical results is obviously crucial. Velocity field, Reynolds stresses and wall viscous stresses significantly depend on the basic assumptions employed and on the turbulence mathematical modelling approach adopted. In order to validate the employed numerical tool a scaled model of part of the Borgo San Rocco Village has been realized with a 3D printer and the air velocity field about the model has been experimentally investigated in the wind tunnel available at the Laboratory of Industrial Measurements (LaMI) of the University of Cassino employing the Particle Image Velocimetry (PIV). A proper uncertainty analysis has been conducted to evaluate the measurement uncertainty affecting experiments. Measurements conducted at the LaMI have been numerically reproduced in order to validate the adopted CFD tool. The validated model will be applied to the simulation of the full-size Borgo San Rocco village in order to analytically correlate buildings degradation to local wind velocity and wall viscous stresses.

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Keywords: historical town; degradation; wind exposure; Particle Image Velocimetry (PIV); experimental; wind tunnel.

1. Introduction

In recent years, the preservation of the historic buildings heritage faces increasingly with the concept of environmental sustainability, intended as the process of social, architectural and urban renovation of villages or small and medium historical towns. The interest on these villages stems from the awareness of their modernity, given by the high quality of social life and by their aesthetic value.

Italy includes about twenty thousand small historic towns that, as for instance happens in Southern Lazio, have not lived the abandonment, replacement of inhabitants with new social classes, or the re-adaptation for touristic and commercial purposes typical of other situations. It would seem, in fact, that they represent antinomic symbols with respect to the modus vivendi of commercial centers or places lacking cultural and historical identity, i.e. the "non-places" of contemporary cities defined by Augee (Aguè, Marc, 1992).

The aesthetic value of these towns often comes from the strong empathetic relationship with the surrounding natural environment, that contributes to define their morphology and position and more often determines the use of specific and constructive techniques.

Grown in the Middle Ages as assemblies of poor houses, the beauty of these places is now given firstly by their urban composition that, following the topography of the area, complies tightly with the surrounding environment and then by the requirements for the environmental sustainability: their specificities for instance, are the use of masonry walls made of local stones enables to control the internal microclimatic factors such as temperature and humidity; the close conformation of the urban plant and the optimal sun orientation serves also to protect the towns from very heat and cold climate, exploiting as much as possible the benefits of passive heating; the orientation with regard to the prevailing wind direction, the color of the external facades and floor, are often designed to reduce the solar heat accumulation and enhance the light reflection; these are just few of the many possible environmental factors connected with the location of historic centers (Pelliccio, 2016).

With these specificities, the small historic towns respond well to social and environmental quality requirements, increasingly demanded by the contemporary society and are thus increasingly attractive from the viewpoint of the urban settlement. However, many of these towns presently live a significant degradation of their condition because of intrinsic phenomena, such as those connected with the degradation of the characteristics of materials, sometimes amplified by poor quality of construction, or external causes such as the lack of maintenance, humidity, solar radiation and wind exposure (Compagnon, 2004; Massimo et al., 2014). A semi-confined environment not prudently designed, with unsuitable microclimatic conditions (values of relative humidity near to saturation), can favor the generation of decay phenomena (Carcangiu et al., 2015) like salt crystallization, exfoliation or alveolization of natural stones or the detachment of plaster on the buildings facades of the stone with devastating effect for porous structures triggered by the erosive capacity of wind.