Some data about rising damp from 30 years of analysis in Venetian buildings

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Abstract
Venice, famous for its urban peculiarity, artistic and architectural heritage, is one of the richest cities in marble and stones, which have been used over the centuries both as building materials and as decoration. But this city suffers from a serious flooding problem, called "acqua alta", which has given rise to its fragility since ancient times, causing many damages to buildings and individual constructive materials. The causes of material degradation are various, but the main problem is rising damp.
An analysis of the rising damp behavior in masonry is proposed, basing on previous studies on Venetian buildings, considering both the construction period and the location. Results have been collected from partially destructive and non-destructive tests carried out on the walls of the building to determine the moisture content at different heights and depths. The purpose is to understand whether there is a general behavior of the results obtained in the wall structure of the buildings, correlated by high water, material and/or exposure, or, if these outputs are specific of each individual building. The salt water exfoliates the brick and plaster, and the water rises up until 2.5-3 meters, with serious problems from thermal, mechanical and indoor comfort point of view.
The final goal is to propose targeted remedial action to limit losses from rising damp by supplying a basic knowledge of the moisture process related to external conditions (environment) and intrinsic parameters (materials and their composition).

Keywords: moisture content, rising damp, cultural heritage, flood.

Introduction

Venice is famous for its urbanistic peculiarity, artistic and architectural heritage, but this city is affected by a serious problem about tides and floods, called "acqua alta", that originated its fragility. This problem is well known from ancient times and aggravated in the last century, caused by a water level increase of + 7.00 cm from 2000 to 2020 [1] and a frequency increase of the phenomena, due to natural and human reasons [2], [3].

The soaked masonries of the buildings, built on a porous ground in contact with salty water, become damaged. This is because water penetrates into porous material by many processes (i.e. condensation, atmospheric agents, drying-wetting cycle, capillary rise) and is involved in several mechanisms, from nanometer scale (swelling of clay) to centimeter/meter scale (fracture) [4]. This damage process begins in the mortar joints and then propagates also in the internal layers, disintegrating the entire masonry.

The restoration problem and the conservation of materials is fundamental in this city because materials are subjected to mechanical stress, deposition, surface alteration and fragmentation, internal erosion and dissolution.

Almost all Venetian buildings have foundations made of wooden piling (usually in the perimeter walls in direct contact with the water canals or in the buildings with high dimensions) and a masonry structure made of clay bricks and lime mortar, with visible finishing or cladding with plaster [5]. The rapid use of clay brick was chosen for need of building techniques and required durability for the peculiar environment conditions. One of the systems historically used for limiting the decay of "acqua alta", especially in prestigious buildings, is the Istrian stone, still visible both as a surface element and as a structural one. Finally, other methods used for obstructing the moisture entrance in Venice building, where the masonry weaving does not own an architectural value, consist in the realization of mechanical intervention, with the removal of one masonry wythes and the successive application of lead or bitumen sheets, between two mortar layers. These are all the methods adopted for the singular building, but the MOSE system has been in operation since 2021 [6], to protect the entire city and its ecosystem.

This work about rising damp measures in Venice would continue the work of Falchi et al. [7], to create a trend evaluation in the years, not in a specific case study but with a wide area of analysis.

Diagnosis method

The diagnosis of rising damp can be carried out in a variety of ways, from invasive to noninvasive systems. For the past 30 years, the most popular approach for quantitative measurements of moisture in walls has been the gravimetric method, with the determination of Moisture Content (MC%) [8]. This is a destructive test, which consists in measuring the percentage of direct water in a material by weighing a sample (powder or piece) extracted from the drilling masonry. The weight difference between wet weight (W_w [g]) and dry weight (W_d [g]) of the sample, indicates the MC% (Eq. 1)

$$MC\% = [(W_w - W_d) / W_d] \cdot 100 \tag{1}$$

This procedure can be performed at different heights or sampling depths and is specific to each building. Moreover, it is not always made in historic buildings because of the difficult reproducibility of data measurements and the difficulty of taking a sample in frescoed or decorated walls.

In this work 17 Venetian case studies are analyzed (Fig. 1) [4], [7], [9]–[14], collecting a total of 250 obser-

Fig. 1 Venice case studies of rising damp (Moisture Content [%] in the masonry).

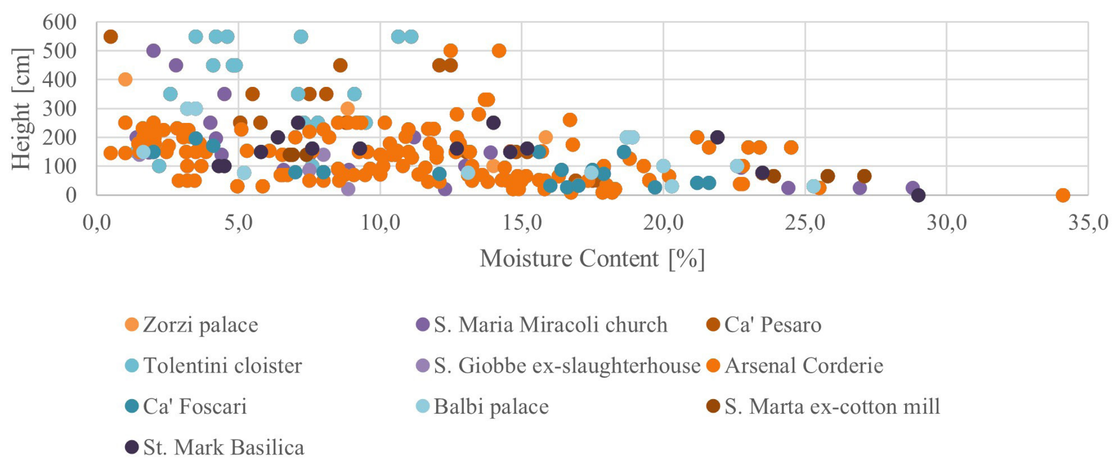

Fig. 2 Relation between MC% and sampling height [cm] in some case studies in Venice.

vations to create a dataset of the past 30 years. The analysis is not constant over these years, but is concentrated between 1980-1990 and 1995-2000, mainly when conferences on the topic were organized or funding regarding Venetian land conservation were published. This survey highlights the lack of data for long time periods

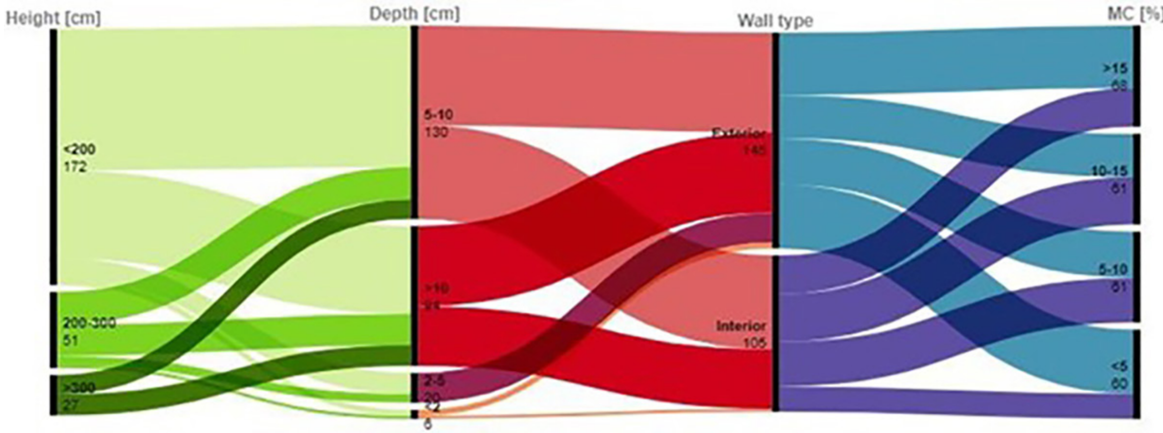

Fig. 3 Feature selection of rising damp in Venice; the variables considered are sampling height [cm], sampling depth [cm], wall type and moisture content [%].

because testing requires many years of investigation, and difficulties in data processing and high expenses incurred from time to time.

The parameters used in this evaluation are (i) wall type – interior (105 data) or exterior (145 data), (ii) sampling height [cm], (iii) sampling depth [cm] and (iv) building floor height with reference to the location of "Punta della Salute" ZMPS [cm] [15]. A correlation can be found between MC% and height of sampling (Fig. 2): the higher the masonry drilling height, the lower the water content recorded. Therefore, 3 areas in the walls can be observed: (1) at the base a wet area (below 200 cm) with a higher MC%; (2) the intermediate region as a transition phase (between 200 cm and 300 cm); (3) the dry area on the top of the masonry (over 300 cm) [7].

Conclusions

Regarding the study of rising damp in cultural heritage, it is clear how many variables participate in the phenomenon, intrinsic and extrinsic, and in different quantities.

The movement of water within the masonry has shown a trend somewhat related to the tidal level. Samples taken at 1978 to 1987 recorded an increase in moisture content (+14.5%, mean value recorded on 107 data), and an increase in tidal level of +4.00 cm (maximum recorded level)[1]; from 1987 to 1997 there was a 15.6% decrease in moisture content (55 data) and -13.00 cm on tidal level; finally, since 1997 there has been a slight increase of +7 MC% (88 data) and +15.00 cm on tidal level (excluding the exceptional flood of 2019).

By means of feature selection analysis, it is possible to identify in a small database with multiple attributes, such as the one adopted here (of 250 observation MC% in Venice) those features that are more significant than others. The most important evaluated variables are sampling height (ii) by 50%, sampling depth (iii) by 16% and wall type (i) by 8%. The remaining 26% are related to the analysis building, a variable of little significance in this case since each building is stand-alone.

After identifying the most important attributes, the distribution of the data can be seen from Fig. 3. Sampling was done at different heights, with a dissimilar distribution; 69% on masonry at height < 200 cm, a zone classified as wet area. Here, the MC% is evenly distributed between 1 to 15%. Depth sampling is concentrated above 5 cm, to investigate the core of the masonry without the influence of the surrounding environment. Finally, tests were carried out on 145 samples of masonry exposed to the outside and 105 samples to the inside. However, from the samples taken on the different types of walls, the moisture content is distributed in the same percentage among them (24-27%), so it is significant that the water content in the walls is independent of the interior or exterior location.

The identification of buildings to be analyzed begins with a visual survey of the level of capillary rise front, brick erosion or salt band, and then a decision can be made to investigate deeper the internal MC% distributions, thus integrating qualitative and quantitative approaches. This monitoring, if planned properly, will provide knowledge both on the specific building and at the urban level, and of the relationship with the MOSE system.

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