Durability and degradation of natural stone in Syracusan façades: materials and techniques compatible for recovery interventions

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Abstract

The building heritage on the island of Ortigia, the historical center of Syracuse, is characterized by the texture and color of the local calcareous stone. Natural decay and alterations, due to human action, constantly modify the image of the city perceived by the users. In fact, the chemical and physical characteristics of the stone typical of eastern Sicily allows a quick and intense degradation of the façades due to various environmental factors. These effects are stronger in buildings with defects resulting from design flaws, from construction techniques or from ineffective recovery interventions. The aim of the study is to deepen the knowledge of the natural stone of Syracuse, used both as a structural component and in decoration of the façades, in order to identify methods of intervention and design solutions that are compatible with this particular kind of stone. The analysis of the chemical and physical characteristics, in relation with the surfaces’ treatment, will be compared with the intensity and the rapidity of degradation evolution. In addition, a survey of the alterations due to recurring defects of the construction will be performed, verifying the success of restoration interventions carried out on the façades in Ortigia through the study of the employed techniques and the results obtained. The research will define guidelines for the strategy of recovery interventions, in order to improve the performances of Sicilian stone and to increase its durability.

Keywords: durability, degradation, decay evolution, natural stone, recovery.
1 Introduction

The urban image is constituted by the whole and the composition of elements characterized by the historical and actual social organization. This image is extremely fickle because of the continuous process of transformation of the city, to which also share limited maintenance and recovery interventions [1,2].

Therefore, the comprehensive urban image is given by the whole of the buildings. These are concerned by a continuous process of evolution and degeneration, that has repercussion on the city appearance. The first one produces contamination as a result of the superposition of components with time; this aspect, nowadays, is accepted by the community and considered as the evidence of the urban history and culture. On the contrary, recent contaminations are often due to obsolescence of buildings, requiring the introduction of new technological components and equipment, in accordance with the logic of adjustment, rather than a strategy of re-qualification. These interventions confuse and make fragmentary the image of the façades.

The second kind of process can be defined as degradation of materials: the physiological decay is merged with the wear of the building elements. Degradation depends upon materials and shapes of the element and can go faster, reducing its foreseen life cycle, that can be related with aggressive environmental factors, congenital pathologies or wrong design solutions. Local conditions of subduing can be applied to the action of these factors, through design solutions aimed at decelerating the degradation evolution and protection of the surfaces.

The object of the present study is the island of Ortigia, the historical center of the Sicilian city of Syracuse and location of the first Greek installation. This installation today is partially recognizable in a city center characterized by adaptations, superposition, and baroque architectures, that are the results of a relevant building activity consequent to the earthquake occurred in 1693. The stone of the façades gives to the center strong continuity.

The constant use of this stone suggests a millenary history. Its reaction to the environmental agents gets different and produces effects that multiply the degradation, on the basis of wrong interventions and treatments, such as removal of material, substitution and integration with different materials or stones deriving from different quarries. These interventions, performed in different ages, are the result of a weak knowledge.

The forms for the analysis and preliminary design requires many and heterogeneous information, deriving from specialist studies. They should allow to relate data through grids specific for the examined case, in order to test the methodology purposed. The informative system, founded on the analysis of the technological elements of the construction and of the kind of stone-working most affected by decay, allows a quick localization, surveying and diagnosis of degradation and alteration [3].

2 Characteristics and degradation of the Syracusan stone

Many studies [4] on the stone used in the building of Syracuse and its province prove that this material is composed by yellowish calcareous sandstone miocene
and pliocenic, porous and with fossils, of the formation of Palazzolo. Different colors and morphological characteristics of the stone surveyed in the Syracusan façades are due to different location of the quarry or to different layers of quarrying.

![Figure 1: The degradation of the Syracusan stone.](image)

This stone has been used since XVII century in the buildings of Ortigia, in particular during the baroque age. Less frequently we find lighter and more compact calcareous sandstones, that are better resistant to the effects of time and to environmental agents. We can find this kind of stone in buildings of XII, XIII, and XIV century (or in parts of these buildings), that did not proof against the earthquakes of the last centuries and were transformed in time.

The results of the analysis performed in laboratory (Table 2) show that the calcareous sandstone of Syracuse seems to be very bio-receptive and often allows the growth of micro-flora. In particular, it results most degraded in the footings of the buildings (Fig. 1), where we can find strong alveolisation and erosion, with consistent loss of material (some centimeters). The stones placed in higher locations (two or three meters high) are usually better conserved, except for those façades that are opposite the sea, thus affected by the action of sea aerosol. In these buildings we noticed a deep erosion diffused on the whole façade, in particular on the balconies, affected by a consistent loss of material.

The upper part of the façades is usually affected by black crusts and surface deposits, that provoke loss of material and damaging the decorations of cornices and overhanging elements. These phenomena are due to a combination of dampness, fluctuations in temperature, and presence of particles (carbonious and contained in the sea aerosol), more than the presence of corrosive gases.
However, in Ortigia atmospheric pollution - due to dioxide of sulphur and dioxide of azote - has been surveyed. The first one is produced by industrial settlements (located in the nearby areas of Priolo and Targia) or by fossil fuels (used for heating or due to traffic).

Table 1: The stone of Syracuse (or Palazzolo).

<table>
<thead>
<tr>
<th>The material</th>
<th>In the buildings of Syracuse are used:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure:</td>
<td>dense, without micro-fractures</td>
</tr>
<tr>
<td>Grain:</td>
<td>fine and homogeneous</td>
</tr>
<tr>
<td>Porosity:</td>
<td>medium</td>
</tr>
<tr>
<td>Bioclasts:</td>
<td>very rare</td>
</tr>
<tr>
<td>Colour:</td>
<td>beige, light ochre yellow or white; homogeneous</td>
</tr>
<tr>
<td>Composition:</td>
<td>limestone 97% (carbonate of calcium) and trails of quartz</td>
</tr>
</tbody>
</table>

The stone: faded yellow miocenic calcareous sandstones, porous and with fossils, of the formation of Palazzolo;

- pliocenic calcareous sandstone, very porous, used only for decorations. These stones are the same type of material, with different chromatic and morphological characteristics, due to the different place and layer of quarrying.

These stones were used since XVII century in Ortigia, mainly in the baroque buildings.

Less frequently we find lighter and denser calcareous sandstones, that are best proof against the degradation. Rarely we find oolitic calcareous sandstone, with massive or stratified structure.

- Characteristics of the stone: in Ortigia we find different types of the same stone;
- Maintenance interventions: e.g. the replacement of finishing and plasters.
- Environmental agents: e.g. exposure to wind.

Stone-working: The quarrying, before the use of the circular saw, was performed in horizontal layers towards the lower part. Picks were used for the cut, in order to dig triangular horizontal and vertical furrows. Into these furrows, wedges were thrust by sledge-hammers, until the stone was broken. The stones were transported in the yard and cut by hand using serrated saws along pencil marks. The pieces was smoothed by “rospi” and squared by iron squares.
Table 2: The degradation of the Syracusan stone.

<table>
<thead>
<tr>
<th>Degradation phenomena</th>
<th>Localization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alveolisation</td>
<td>On footing, maximum height 1.60 m</td>
</tr>
<tr>
<td>Erosion</td>
<td>On brackets, balconies and overhangs</td>
</tr>
<tr>
<td>Surface deposit</td>
<td>Cornices and overhanging elements</td>
</tr>
<tr>
<td>Black crust</td>
<td>Cornices e overhanging elements</td>
</tr>
<tr>
<td>Change of the original color</td>
<td>In washed away areas</td>
</tr>
<tr>
<td>Pitting</td>
<td>On the facing</td>
</tr>
<tr>
<td>Breakage</td>
<td>On jambs and architrave</td>
</tr>
</tbody>
</table>

**Environmental factors**

**Black crust**
- Deposit of dusts due to the air stagnation allowed by an high value of ratio buildings height– street breadth, even if the traffic is limited
- Presence of deposit of dusts on the surfaces exposed to the wind is limited or lacking, even if the traffic is considerable

**Alveolisation**
- Presence of degradation on the surfaces exposed to the wind, mainly on the surfaces exposed to east
- Presence of degradation in streets perpendicular to the surfaces directly exposed to the wind, due to the acceleration of the wind

**Erosion**
- We can not define clear relations between erosion and environmental factors. This phenomenon produce an uniform degradation of the stone, modifying shape, dimension, color (lighter).
- Presence of degradation on the surfaces exposed to the wind, mainly on the yellow calcareous sandstone with smooth grain, used since 1800

**Factors that accelerate degradation**
- Wrong design
- Inadequate choice of the stone, mistakes in the quarrying, carriage and storing up
- Inadequate methods of stone-working in the quarry and in the yard
- Wrong installation
- Inadequate use
- Changes of use of the building

3 Degradation causes and evolution process

The degradation of stone is a progressive process. The persistent presence of degradation causes and their interaction with additional causes produce significant increase of the decay on the façades.

In building recovery, data collection on the characteristic of stones and mortar used for their connections, of building components (shapes, dimensions,
materials, construction techniques), of environmental factors, of anthropic actions and on their interactions is necessary both to understand the evolution of the degradation process, and to achieve quality results in interventions. In fact, failure of the recovery intervention often depends on inadequate methods applied for the diagnosis of the causes of degradation. The alterations are frequently examined separately, disregarded from the study of their interactions.

The information surveyed have to be significant and representative of the whole actions that affect on the degradation process in progress. Each degradation phenomenon should be considered as a part of a complex system of related phenomena, in continuous transformation as a result of actions deriving from causes that are internal and external to the building. The understanding of the relationships between the degradation phenomena and the evolution process guarantees a correct diagnosis and definition of choices for the recovery intervention.

The singling out of the causes should start from the systematization of data collected through the analysis of the degraded surface in relation with the context in which it is located, performing the following analyses:

- Architectonic: the building that it is part of;
- Constructive: the wall and the related building elements;
- Environmental: the environmental factors that affect it;
- Anthropic: the human actions and the factors related to the use.

The survey of the degradation phenomena should be considered such as an image of a specific moment of the evolution and the phenomena singled out should not be regarded as the result of a simple process of cause/effect.

However the need to define the degradation causes requires a preliminary study of each single phenomenon, on the basis of its location and intensity. The phenomenon is considered as an evidence of the related causes. These can be classified as follows [5]:

- Direct causes: they act on the buildings following a process of cause/effect or producing chain-reactions, in which each phenomenon can be an intermediate step or the final result.
- Predisposing causes: they affect the phenomenon, but are not indispensable for its presence and grown (e.g. construction techniques of the wall, shape of the façade, etc.).
- Aggravating causes: they affect the extension and intensity of the phenomenon (e.g. long duration and strong intensity of atmospheric factors).

Such as the causes, the degradation phenomena affect each other. Rarely a phenomenon is produced by a single cause, and each cause produce several phenomena and contributes to the evolution of the whole process. The analysis on degradation evolution can give evidence to the hypothesized causes (Fig. 2).

In fact, the building façades are systems in continuous evolution [6], in which the degradation phenomena can intensify with time, for both the permanence of their causes, and the arising of new causes. These new causes are usually produced by the getting worse of the decay and produce other decreasing of the building performances.
In a degraded wall, we can hypothesize the process that produced some phenomena, in order to understand the causes and to foresee the future evolution. An analysis at sight can be associated with instrumental non-destructive analysis \textit{in situ} and chemical-physical analysis performed in laboratory, in order to survey latent degradation and data on the material composition. The comparison between these parameters and data surveyed on not degraded stone can verify the diagnostic hypothesis on the causes of the alterations.

4 Guidelines for the intervention

The interventions realized in Ortigia, to recover the stones of the façades, have been aimed, until today, only to cleaning the surface of the stone. This process
has been usually performed by abrasion, with loss of the original material and shape and damages to the finishing and decoration. In particular, the tools used for the cleaning are generally not adequate to preserve the stone and are often employed (in the yard) for other functions.

Brutal interventions performed on the Syracusan stone are due to poor information and lack of attention to the conservation of the natural local material; they fade colors, shape, dimensions, grain and strength of the stone (Table 3).

The aim of any recovery intervention on the natural stone is to avoid the loss of material, removing the degradation phenomena [7]: the loss of the superficial layer, already hardened, consolidated and acclimatized in its location, deprives the material of an effective protection by other degradation agents. In fact, the removing of the superficial layer deprives the stone of a protective coat, grown with time, that is resistant to chemical attacks due to environmental factors combined with the chemical characteristics of the stone. In particular, the crystallization of the salts, that produce alveolisation and erosion, is slowed if the stone is seasoned outdoor, in similar environmental conditions.

The intervention suggested in the present study is aimed both to remove the degraded material preserving the surface of the stone, and to choose techniques that limit the evolution of degradation process. In order to restore the Syracusan stone, the technique employed must refrain from using water, that is the main cause of alteration and degradation.

Therefore, we need to remove the degradation phenomena, in particular black crusts and surface deposits, taking into account the following variables:

- chemical and physical characteristics of the stone, in relation with their resistance to the action due to particular environmental conditions
- environmental conditions of the location

The intervention chosen should limit the loss of material and avoid the use of water.

5 Conclusion

The historical analysis of the buildings (e.g. age of construction, chronological analysis of the transformation) can give information about particular or unique characteristics. These have to affect design solutions aimed to make the most of the urban identity.

Identity is an abstract value, due to many heterogeneous factors, and is related to the “sense” of the city. In maintenance actions, identity should be brought into effect singling out bonds and requirements for the project. These are the information indispensable to choose interventions that are able to guarantee the conservation of materials and performances, together with the control of transformations.

The analysis of a building should be performed by surveying its physical characteristics, expounding the signs of natural and anthropic causes of alteration and degradation. This analysis is aimed at a diagnosis, that allows an optimization of the interventions. It should be adequate to the building characteristics and should allow to drawing up an informed preliminary project.
Table 3: Ineffective interventions for the recovery.

<table>
<thead>
<tr>
<th>Degradation:</th>
<th>Intervention</th>
<th>Description</th>
<th>Object</th>
<th>Cause of ineffectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface deposit</td>
<td>Cleaning with atomized water</td>
<td>Use of a spray of water that removes the dust with the pressure of the water and its action of washing away. Common water is used, in long time.</td>
<td>Corbels, corner-cupboards, cornices, jambs, wall covering.</td>
<td>Process of alveolisation and/or erosion of the stone, due to a long exposure of the stone to the water.</td>
</tr>
<tr>
<td>Spots, crusts</td>
<td>Cleaning with micro-sand-blasting</td>
<td>Mechanical action that removes the dust with a jet of abrasive sand, with low pressure.</td>
<td>All the components of the building.</td>
<td>Loss of material, alteration of the decorations. It requires previous consolidation.</td>
</tr>
<tr>
<td>Surface deposit, spots, black crusts</td>
<td>Cleaning by brushing</td>
<td>Mechanical manual action that removes the dust using brush with stiff bristles. This action is performed under a water jet.</td>
<td>All the components of the building.</td>
<td>Loss of material, with visible signs of the abrasion, and a process of alveolisation and/or erosion of the stone, due to a long exposure of the stone to the water.</td>
</tr>
<tr>
<td>Surface deposit, black crusts</td>
<td>Cleaning by abrasion, using mechanical tools</td>
<td>Mechanical manual action removes dust and crusts, using mills or little grinding wheels.</td>
<td>All the components of the building.</td>
<td>The intervention produce a relevant loss of material, removing degradations together with large quantities of stone, alteration of the decorations and reduction of dimension of the wall.</td>
</tr>
<tr>
<td>Spots</td>
<td>Removal of spots of paint or enamel by chemical removers</td>
<td>Chemical action: spread of the remover on the spotted surface and successive removal by spatula. Usually the intervention is followed by washing with water.</td>
<td>Footing, jambs, architrave</td>
<td>The intervention produce processes that change the natural color of the stone and its chemical characteristics.</td>
</tr>
</tbody>
</table>
The recovery of the image of historical façades requires a project based on Maintainability, Durability and Reliability criteria, in order to define effective design requirements. The Aspect is the class of needs which describes the factors that characterize the building condition, giving prominence to the perceptive characters, that is the singling out of those signs that show the building status. The perceptive “uneasiness” (damage and degradation signs) should be analyzed for the diagnosis, in order to single out their evolution in time and their causes.

References