THE DETERIORATION OF STONE MATERIALS: A TOOL FOR ITS IDENTIFICATION AND CHARACTERIZATION

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ABSTRACT
The main goal of the current research is the drawing up of an 'Atlas of alteration and deterioration forms of stone materials' which focuses on lime mortars for external plasters and plasterworks. Buildings are composed of different materials characterised by particular properties that are modified, once these materials are in use, changing their former aspect under the effect of complex chemical and physical transformations. Many of them show their first manifestations on the visible surface of building elements and this research assumes as starting hypothesis the possibility of identifying with adequate certainty most of the alteration and decay phenomena that affect stone materials, starting from the observation of their macroscopic effects. The final goal of this search is the drafting of a 'pre-diagnosis' tool.

KEY WORDS
Atlas, Decay, Stone materials, lime mortar, Plaster

INTRODUCTION

Over recent years the decay of edifices and building components made using traditional materials and techniques has rapidly increased, above all due to atmospheric pollution. The understanding of the nature of alteration and decay phenomena which affect building materials, and the correct evaluation of their effects in order to set up an effective conservation programme has thus become a fundamental issue for all those involved in the conservation and management of ancient buildings.
The reorganization, classification and systematic documentation of degradation phenomena affecting ancient buildings does not exist in the framework of conservation. The sectoral contributions that exist are, in general, restricted to natural stones[1] and clay materials [2].
The study of material decay phenomena has so far involved above all specialist technical and scientific skills, confining the architect to the interpretation of experimental research results developed by chemists, biologists, geologists, petrographers, etc.
Against this background, the goal of this research is to draw up an initial, pre-diagnostic model denominated "*Atlas of commonly recurring forms of alteration of lime mortars for external plasters and plasterworks"*. With the help of a high number of images, coming from real case studies and from technical bibliographic references that can be used as comparison samples, this atlas will allow for the correct recognition of a particular decay phenomenon among many possible others. This will provide the basis for decisions as to the laboratory analyses required to obtain more precise data.
Through the identification of signs and the measurement of parameters, which can be considered the visible manifestation of the altered state of a certain material, it is possible to recognise with sufficient reliability a decay phenomenon, and afterwards to assess its impact on the conservation of the affected artefact, if necessary with additional analyses and instrumental measurements.
This research has been directed towards the identification and classification of the signs characterising the various alteration phenomena whose manifestations can be perceived through the senses. Recurring in similar situations, these signs can be considered as key elements for the recognition of a particular decay phenomenon.

EXPERIMENTAL PROCEDURE AND RESULTS

EXPOSURE SITES

Each building is composed by materials transformed by man's work and characterised by particular properties and features that, once these materials are in place, are modified and transformed by complex chemical and physical transformations. Many of these transformations show their effects first on the visible surfaces of the building components and materials. Their surface is therefore a text where one can read the signs of the material alteration state and to evaluate the necessary parameters for the recognition of decay phenomena. The initial hypothesis is based upon a semiotic approach applied to the study of the deterioration that is by now shared by the majority of the specialists in this field, as testified by several experimental studies[3] which, though referring to other materials and aiming at different goals than those of the present research, gave rise to possible interpretation and evaluation models for decay phenomena, starting from their visible effect.
The present research enters the framework of the above described studies and assumes similar starting hypotheses but differs from them because it does not limit its focus only to the morphological classification and interpretation of decay phenomena but widens it to the evaluation of other classes of signs[4].

The research investigated the main modifications that traditional artificial stone materials (mortars for plaster and plasterworks) underwent over time. The analysis has been carried out through the empiric observation, identification and recording of sensorial signs (based upon the five senses) and/or the macroscopic measurable parameters which are their visible manifestation. Before carrying out of the empirical analysis, it was necessary to identify, classify and describe the signs in an objective way.
This goal, however, runs up against an immediate difficulty: the absence of codified methods of analysis based upon perception and learning through the use of the senses, which, at the same time, are required in order to produce objective and understandable descriptions of the observed phenomena.
A specific analytical method and a standardized or shared vocabulary for understandable definitions were required so as to identify, classify and describe the macroscopic decay effects.
In accordance with the goals, analytical method and vocabulary were developed through:
The examination of the definitions provided by the NorMal 1/88 document (containing some short descriptions of some words used to define some decay phenomena), widely adopted within the field of conservation, and the review of all the other NorMal documents to find descriptions, definitions and qualitative parameters useful within this research;
The survey of other studies on decay of building materials, carried out with similar objectives to those of this research[5];
The collection of theoretical, methodological and operational contributions belonging to other fields and considered significant for the present research for their approach;
The collection of data and images from the specific technical literature;
The collection of images and data of altered surfaces, through a field survey within the Ligurian territory.

THE RESEARCH PATH

During the first phase of this research, a state-of-the art overview was realised through the collection of images and data from the available technical literature regarding stone material decay. On the basis of a survey of the bibliographical sources, we were able to develop an initial organised framework for the whole matter.
In brief, in this part of the research the most significant data available in the literature and considered useful for the goals of the research itself were collected and recorded in a specifically created database. This was also used in order to carry out a first selection and classification of the decay phenomena, in addition to the choice and classification of definitions and lexis usually adopted by the specialists, and the elements characterizing the various decay phenomena. The database was also used to identify the more useful classes of information for data collection. In this phase of the research a comprehensive framework of the various decay phenomena was developed as a base for the subsequent steps of the work.
In the second phase, the field of investigation was limited to lime mortars. Case studies were selected within the historic centre of Genoa, where many different examples of lime mortars and of decay phenomena can be found. Experimental data were then collected. The case studies were chosen amongst buildings that provided ample evidence of the macroscopic effects of decay and which, therefore, represented an effective point of departure for this research. The selected buildings were located in various positions at varying distances from the sea and main roads, with differing degrees of exposure to meteorological agents. Ideally, the buildings were also subject to restoration work with access to the façade made easier by on site scaffolding.
The direct survey was implemented following a protocol for the collection of data which was refined during the course of the research. During this stage, a first draft for the technical vocabulary to be employed for the description of the phenomena was carried out along with the drawing up of a database framework for information retrieval. The structure of the database should allow for a comparison between field survey data and those found in the literature.
In this database, each card is organised into four sections which correspond to increasingly detailed levels of phenomena analysis and layouts for consultation.
This work has been paralleled by the ongoing collection of information from technical literature and other research fields. The adopted sensorial-based methodology of observation has been seldom applied systematically [6] (or has been carried out for different purposes than those of this work) to architectural surfaces, so making it necessary to refer to different branches of the research.
The contributions coming from other disciplines investigated as useful reference sectors, were:

a) Semiological analyses;

This discipline provided a theoretical and methodological contribution because its specific field of investigation is the nature of signs and their interpretation.

b) Medical semeiotics and dermatology;

Both disciplines provided a contribution from a theoretical point of view and for the elaboration of the vocabulary, thanks to the chance of partially borrowing research and practical procedures and the vocabulary used in clinical analysis. In particular, dermatology provided terms used to describe superficial skin lesions that proved extremely very useful for the purpose of this research.

c) Analyses based on direct visual comparison employed within industrial production;

In this sector it is usual to resort to comparison procedures referring to visual and tactile sensation to evaluate occuring alterations to metal produced by durability proofs. The description of the steps followed and of the parameters used within this procedure represents a useful example for the development of the present research and provides also a good inventory of specific terms.

d) Metallurgy and deterioration of metals;

In this field, interesting procedures for the evaluation of superficial alteration and useful diagrams were developed.

e) Geomorphology;

Geomorphology deals with transformations of terrestrial crust and, for this reason, shows many similarities with the matter of the present research. This branch of science has thus been useful to develop a specific vocabulary for the description of decay phenomena and a source for the understanding of some mechanisms of action of certain phenomena.

The final product of this part of the research was: an ordered inventory of degradation phenomena to be included in the elaborating atlas; an inventory of signs marking the main alteration phenomena that affect lime mortars for plasters and plasterworks; a vocabulary for the description of the signs; an inventory of sample images and a first draft of the Atlas of the most frequently recurring forms of alteration of lime mortars for external plasters and plasterworks.

The Atlas tables contain for each phenomenon the macroscopic characteristics of the material subject to decay classified according to the following terms: geometric (form, state, extent); chromatic (tone, luminosity, saturation); tactile (roughness, adhesion, cohesion). These characteristics may also play an important part in identifying the phenomenon itself.

In order to identify these characteristics, each phenomenon was broken down into items that are perceivable by sight, touch, and hearing. Subsequently, the resulting perception was assigned a terminological definition able to provide an empirical scale of values which is as objective as possible. In this way, the evaluation will be, normalised and reproducible.

The scale utilised derives from the literature on decay, existing and/or adopted UNI regulations, or has been modified by the study disciplines mentioned above.

Non-measurable but qualitatively describable elements have been defined as “signs”, whilst measurable characteristics are defined as “parameters”.

In order to identify the presence of a particular phenomenon with certainty it would be necessary to be able to identify a group of signs that were present in the same phenomenon and which were at the same time absent in all other phenomena. This type of diagnosis in a clinical methodology is termed “logical diagnosis” in the light of its being based on a binary scale in which every sign can be assigned exclusively two possible values: present or absent. In practice, the situation appears more complex as signs are often not only classifiable as present or absent, but possess varying degrees of intensity which can make it difficult for a “sense” analysis to establish a whether a certain sign is in fact present or absent.

The break down of the visible effects of a phenomenon into a high number of signs ascribable to sensorial perceptions (sight, touch, hearing, taste), and to measurable macroscopic parameters tends to rule out possible interpretative ambiguities that may arise.

In some cases, therefore, diagnosis based on the sensorial recognition of a sign will generate only “probable” conclusions which, to be confirmed, will require more substantial instrumental diagnoses.

On the basis also of these considerations, three types of macroscopic signs were identified:

Strong or necessary signs [7]

Signs whose presence (either singly or combined) allows for a high rate of probability in identifying decay phenomena;

Weak signs

Signs that aid phenomena recognition. However, being common to various phenomena, they can generate interpretative ambiguities. Consequently, their presence will add probability to a conclusion..

Indirect signs

Signs that are not connected directly to the phenomenon or which do not appear directly on the altered surface but which are closely connected to it. Indirect signs are, for instance, material present underneath the article stemming from crumbling and/or crushing (debris heaps).

In addition to these three types of signs, macroscopic parameters characterising certain specific decay phenomena have been identified. In general, these parameters allow for a quantitative evaluation of the phenomenon (percentage of area affected, quantity of material lost, etc.); they can also provide backup in recognising the phenomenon itself.

Macroscopic parameters

These parameters are provided by easily-available measuring instruments such as rules, callipers, and Munsell Soil Color Charts that can aid the identification of the phenomenon or its causes in addition to quantifying the impact on the overall evaluation of the phenomenon.

RESULTS

The objective of this research was achieved with the first organized collection of tables with the following descriptive contents (for an example of the tables contained in the Atlas see figure 1 and 2) and a suitable number of images of altered surfaces and building components. Figure have been selected and organised to evidence the different emergence of the same process on different materials and under different environmental conditions;

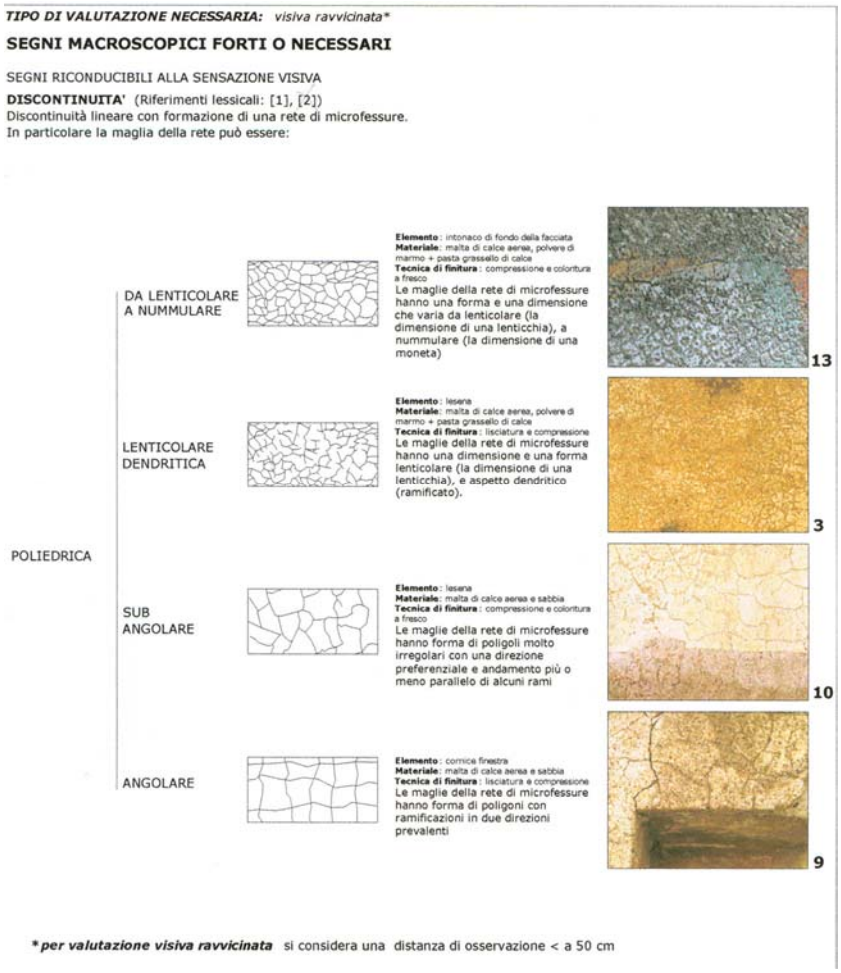
- Verbal description of the phenomena;
- Description of the empirical assessment techniques (visual, acoustic, tactile) and of those auxiliary for the situ analysis (macrophotographs, special photographic shots) and of possible laboratory tests for rigorous evaluations;
- Preparation of abacuses and schemes describing the possible correlation among the different degradation phenomena and the possible basis or co-operating causes;
- Indication about the possible evolution of the catalogued phenomena, derived from the literature and the field researches;
- Indication about the recording and elaboration forms of the acquired data;
- Easy and synthetic reference to the specialised literature to offer a picture equipped to offer an in-depth analysis

FINAL REMARKS

The Atlas can be considered a draft of an easy-to-use operational tool that can guide operators in identifying decay phenomena and elaborating first interpretation hypotheses for the main deterioration processes that affect lime plasters and plasterworks.

The research and its results are part of the framework of those studies which endeavour to make the sensorial analysis of degradtion processes objective, reliable and verifiable. This area of research also includes studies in visual observation automation [8]. in particular to obtain information on the state of conservation of building materials through image processing procedures. The latter represents one of the possible further developments of this research.

Figure 1 – 2 show two tables from the Atlas relating to the phenomenon of "craquelure". Each phenomenon is provided with at least 12 images as examples of the possible presence of the phenomenon on plaster and plastic elements with varying mixture compositions. The table shown at Figure 2 contains those elements required for the recognition of the phenomenon.



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[5] This has also been the subject of research carried out in Europe on brick masonry decay phenomena that has produced a Damage Atlas and a Masonry damage diagnostic system. Cfr. L. FRANKE, I. SCHUMANN, *Damage Atlas. Classification and Analyses of Damage Patterns found in Brick Masonry,* Fraunhofer IRB Verlag, 1998.

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