STATIC REQUIREMENT AND TYPE’S COMPLEXITY IN THE DIAGNOSTICS PHASE

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ABSTRACT

The preservation of an historical building, whatever its architectural and/or artistic value, is more appropriate as it is deeper the building knowledge, its development, its materials and constructive techniques. So the preliminary phase of a restoration intervention is the data acquisition, the direct characteristics and conditions recognition of the building and the survey of significant alterations. The reasons that cause these modifications, in great number of cases, are not respectful of the building static efficiency, so its static requirement could be weakened. In fact, a very high percentage of building damages is attributable to these modifications are not always sufficiently respectful of a structural balances consolidated over time. The study focuses on the analysis of the restoration intervention on two trilobate pillars that separate the central space from the presbytery in the Cathedral of Matera, a little city in the southern part of Italy. Through the use of sonic tests - carried out despite the complexity of the shape of a building structural and constructive elements that characterizes these pillars – it was possible to show the effectiveness of the implemented intervention, highlighting its critical points and its weaknesses. The research aims to show how - despite the type complexity of some structural elements of a building - becomes essential an appropriate building knowledge to realize interventions that are able to operate a correct restoration interventions of a building and, at the same time, that it is respectful of its type and material peculiarities.

INTRODUCTION

The preservation of an historical building, whatever its architectural and/or artistic value, is more appropriate as it is deeper the building knowledge, its development, its materials and constructive techniques. In fact, the protection and conservation of monumental heritage represent varied and sometimes even alarming aspects; however, they help us to identify the commonly called “architectural emergency”. This is essentially related to the size and the great number of cases to resolve and – together - to the limited availability of usable resources and experiences. So, it’s necessary to optimize in a better way the just limited financial and temporal resources, giving to our monuments the respect that compete themself. Faced with a degraded monument, the renovation designer can meet three main questions: “if” to perform a restoration, “where” to perform a restoration and “how” to perform a restoration. To these questions it is possible to add another one that regarding the economic aspect: “when” to perform a restoration intervention. In order to respond adequately to these questions, it is necessary to advance “step by step”, through easily defined procedures, as the degradation identification, the causes determination, the
assessment of residual safety and, finally, through the suitable intervention choice and the definition of its executive method.
So the preliminary action is the research of all information about the monuments; these informations are required to describe the structure and all the transformations that it has suffered; in this situation, it becomes essential the history knowledge of the building, from its construction until the last modification that it has undergone.
In the first phase of data acquisition, the direct recognition of the building characteristics and the survey of the checked alteration, should be complemented by research of design documentation and of events that have affected the structure during all its life cycle.

SHAPE’S COMPLEXITY AND STATIC BALANCE

The structural and static complexity of the historical building represent the more important characteristics of each monuments.
In fact, in the last years, the necessity to operate interventions of masonry structural reinforcement has become increasingly urgent, stimulating both by the objective requirements related to increased degradation of the monumental buildings and by a greater interest towards conservation theory.
The restoration criteria, in fact, impose severe restrictions on the possibility to realize a different intervention types but - at the same time - stimulate the choice of the suitable solutions.
Naturally, these solutions will sought in changes to realize to the main parameters that constitute the mechanical part of the structure (i.e. the geometry, material and loads).
In fact, changes, modifications, partial demolition and reconstruction are quite frequent in a building history, especially in a monumental building. A lot of monuments, in fact, have modified its shape and its structural and functional organization in its life cycle, realizing - for example – of superelevation or addition part of construction, modifying the static distribution of the force, etc.; a very high percentage of building damages is attributable to these modifications are not always sufficiently respectful of a structural balances consolidated over the time.
These changes led new structural stresses - not always proportionately allocated over the building structure – and very often they led a new shape and aesthetical characteristics.
Thus, the geometry changes are surely the most effective (i.e. the increase of stiffness obtained with the increase of resistant section or by adding a constraint).
The criterion for an intervention on the geometry was almost abandoned, although structurally good; the practice of complete replacement of degraded elements with other more or less “similar” to the original is realized very often, while frequently are offered - in parallel to existing structures - structures that are able to bear the load of the structure, in case of triggering the collapse.
It is considered, therefore, that the elaboration of a proposed consolidation intervention is essential to achieve different objectives that ensure the maximization of the monument respect.
These objectives are:
1. to allow maximum persistence of the original material, limiting at minimum the transformations (demolition, replacement, etc.);
2. to recognize the variable “time” as a positive sign that are able to add value to the building, which must be understood as a “palimpsest” on which are layered different elements;
3. to use objective knowledge that are closely related to the building or specific pathological situation;
4. to make decisions on the basis of technical assessments, supported by an in-depth knowledge and never based on historical, critical or aesthetic judgments;
5. to realize recognizable and reversible interventions, in order to make possible in the time control, monitoring, additional maintenance (i.e. the introduction of new technologies or systems more effectively);
6. to establish a correct maintenance program over time, not aimed at any replacements intervention at predetermined intervals, but based on observation of the phenomena, in order to prevent possible dangerous situations and slow down the aging process of the building.

THE CASE STUDY

This research focus upon the Cathedral of Matera - a little city in the southern part of Italy (Fig. 1), a massive architectural structure, built at the end of the XIII century.

![Figure 1: The Matera Cathedral](image)

In Apulian Romanesque style, it keeps its formal and architectonic connotations almost unchanged outside, even though some interventions have substantially changed the inside style. It does not show any plain deterioration signs of its static structure, but it is plain a pathology outside. The study focuses on the analysis of the restoration intervention on two trilobate pillars (Fig. 2) that separate the central space from the presbytery.

Through the use of sonic tests - carried out despite the complexity of the shape of a building structural and constructive elements that characterizes these pillars - it is possible to show the effectiveness of the implemented intervention, highlighting its critical points and its weaknesses.

![Figure 2: The trilobate pillars](image)

In fact, with the sonic tests are measured and analyzed the characteristics of propagation of elastic waves inside the walls with the aim to understand the homogeneity of the structure, the changes of material properties caused by degradation, the structural defects - such as cavities or cracks - and the magnitude of the resistance of materials.
This test is carried out by measuring the time and speed of the wave that passes through the wall, a mechanical impulse generated by a transmitter and picked up by a receiver. The speed of an elastic waves in a homogeneous, isotropic and perfectly elastic, is linked to the dynamic elastic modulus $E_d$, by the following relation:

$$ E_d = v^2 \cdot d \cdot \frac{(1+v)(1-2v)}{(1-v)} $$

in which:

- $E_d =$ dynamic modulus in Pa
- $v =$ speed of the wave in ms$^{-1}$
- $\nu =$ Poisson modulus
- $d =$ density of the elements in kgm$^{-3}$

The elastic wave loses energy in his propagate, and this is due to a decrease in the intensity related to the propagation law of the spherical type, while another decrease is the interface between the gap, where the energy is partly reflected and partly refracted.

High speed - closely proportional to the elasticity modulus and to the strength of the element - and short term indicate a compact structure (i.e. single body masonry or multiple body well connected), while discontinuities, fractures, porous materials are considerably lower speed and consequently increases time.

Figure 3: Sonic directions of investigations carried out on the left trilobate pillar

The test was performed on the above said columns, identifying different directions (Fig. 3 and Fig. 4) - at different heights - in order to cover the largest part of the surface; these directions would also consider the different materials connections, related to the particular shape of the pillars. Certainly this complexity became an important element to evaluate in order to operate a correct and precise evaluation of the investigations project.
Figure 4: Sonic directions of investigations carried out on the right trilobate pillar

Table 1: Sonic tests results on the left trilobate pillar

The sonic test carried out on the left pillar (Tab. 1) highlight the values between 1400 m/s and 1800 m/s at different levels and in the range 1.50-2.73, which usually characterize those walls not strongly degraded and presence of voids.
Table 2: Sonic tests results on the right trilobate pillar

From the observation of results, it is possible to note that lower values are not recorded along the longest paths - such as those linking the two semi-columns or the semi-column with the pilaster - but along the shortest paths within the elliptical shape. This leads us to assume a more widespread damage, also visible on the surface of the pillars.

Figure 5: Damage visible on the surface of the pillars

While, the investigations on the right pillar (Tab. 2) highlight of values between 1450 m/s and 1850 m/s at different levels and in the range 1.50-2.73, which usually characterize those walls not strongly degraded and presence of voids.

Even the pillar right, by the observation of partial results show that higher values are recorded along the longer trajectories (as above said), the lowest (about 1400 m/s) along the shortest paths within the elliptical shape. This leads us to do the same considerations of the left pillar.

Sonic tests were carried out also on the stone base of the pillars using the same investigation test. The measured values are greater than 2000 m/s that indicates a good state of preservation.

The research - applied on the above described pillars - is on going also for the other structural
elements of the Matera Cathedral in order to provide a complete knowledge of the monument and to develop a suitable restoration intervention.

CONCLUSIONS

The research aims to show how - despite the type complexity of some structural elements of a building - becomes essential an appropriate building knowledge to realize interventions that are able to operate a correct restoration interventions of a building and, at the same time, that it is respectful of its type and material peculiarities.

The study aims to realize an applicative methodology more respectful of the monumental heritage, in order to avoid a simple acritical transposition of the calculation models in the recovery interventions.

This research can also contribute to increment the typology of the tests to carry out on the masonry; in fact, in relation to all the problems of tests and investigations (first of all the geometrical complexity), it is not necessary to have only one kind of survey, but an organic plan that consider in particular way the shape and the morphology of the investigated element, in order to have a more possible complete cognitive frame. Only in this way it is possible to interpret the real phenomena and give the necessary parameters to realize a correct intervention.

REFERENCES