MONUMENTAL MASONRY BUILDINGS IN SEISMIC ZONES
CONSERVATION, RESTORATION, RETROFITTING

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ABSTRACT

The question is discussed of how to deal with monumental buildings, in particular in seismic zones, in order to solve problems related to advanced decay, presence of damages due to recent earthquakes, new uses of the construction, which imply modifications and new loads, in presence of official codes which assign, generally for ordinary buildings, safety levels to be guaranteed with the support of numerical evidence.

Such items have been discussed recently in Italy and, following two previous documents [01,02], a text of "Guidelines for interventions on monuments in seismic zones" [03] have been issued by an official body, the National Committee for the Seismic Protection of Monumental Buildings and Italian Cultural Heritage.

INTRODUCTION

Today the engineers are used to operate on new constructions, that they themselves design, verify and construct according to principles and technical codes aiming to assure, first of all, the security. But when the engineers are called to deal with a monumental building they must confront two specific circumstances that should modify completely the approach to the problem:

a) the monument is an existing building;
b) the monument is a building with an "identity" and a "value" that should be conserved.

The architects that deal with the monuments are well acquainted with such circumstances: the science of restoration, in fact, has to do with the relevant problems; but when the security is in question, the different exigencies often come into conflict that can be substantial and not likely to be resolved. Such conflicts can also depend on the fact that the above principles and technical codes, thought as they are in view of the new constructions, do not consider the specific problems relevant to the existing buildings in general and the monumental buildings in particular. That is why it is necessary that the interventions on monuments, whenever they imply problems of security, will be confronted with specific principles and regulations, studied and defined on purpose.
SPECIFIC INTERVENTIONS ON MONUMENTS

The fact that a monument is an existing building is enough to make it necessary to have a specific approach; many choices relevant to new constructions are free and therefore it can be easy and quite economic to reach many results, whereas the interventions on the existing buildings are for various reasons conditioned. These conditions depend on the present situation which can make certain interventions impossible, difficult or, at least, compelling and expensive; moreover the same principles of security must be seen from a different point of view in a situation in which some of the given risk factors have become known and the use has determined some forms of tests.

Furthermore one has to take in consideration the above-mentioned "value", for which one requires that the monument should be "conserved" in time, maintaining its "identity".

Altogether, among the most important factors that make specific the problems relevant to monumental buildings, we can mention:

- the nature and the quality of materials used originally, often very different from the materials diffused nowadays such as steel and reinforced concrete;
- the decay, connected with the time passed in the presence of various kinds of aggressive agents, chemical and physic;
- the constructive elements and the structural typology, characteristic for the period in which the monument was built;
- the age, in general elevated, and consequently the possibility that the monument has undergone significant "tests";
- still the age, that often determines a series of modifications in the construction, due to the above-mentioned seismic tests and the consequent need of repair; moreover the evolutions in the utilization of the construction cause remakings, enlargements, raisings, tamperings;
- the possible state of carelessness, or otherwise an improper use;
- the already mentioned "value", that surely isn't the same for all the monuments and, in any case, is difficult to define and almost impossible to quantify;
- the type of the present use, in many cases public, often with characteristics of crowding.

Each intervention plan, independently of the original reason for it, should be devised as follows:
- a close research into the present situation, constituted of two phases: the survey and the assessment;
- a preliminary evaluation of the consequences of the possible alterations in the utilization;
- designing of the intervention.
The first point requires contributions from various sciences as to the survey and a collegial approach in the assessment. For the reasons explained later on, in general this point should be completed with the research of the seismicity of the area in question. The second point is essential in order to avoid that hasty choices should lead to undesired consequences. The third point comports still a plurality of contributions, which should be well coordinated so that the "weight" of the intervention on the monument were minimized.

LOCAL SEISMICITY

The official seismic zoning of the single towns is often characterized by approximations that influence only little, when the new constructions are in question, but that can assume a greater importance as to the existing buildings. That is why it is necessary, in many cases, to carry out close surveys into the seismicity and also to get acquainted with the local seismic response, which is linked up with the geologic-morphological conditions of the area, that is to say the microzonation.

SURVEY OF THE PRESENT SITUATION

GEOMETRIC SURVEY

This operation is necessary in order to supply for an exact graphic representation of the building as a whole, an indispensable element for the phase of the preliminary evaluation as well as for the subsequent phase of the planning of the intervention.

The geometric survey must be made together with the survey of the presence of the cracks, indicating their direction and width.

HISTORICAL SURVEY

The historical survey of the building must be made keeping in consideration at least three aspects relevant to the existence of the building:

- to evaluate the development in time of the building;
- to analyze the different constructive masterships;
- to evaluate the damages caused by the earthquakes occurred and the possible reparations carried out (the seismic history of the monument).

DIAGNOSTICS

The acquirement of detailed information regarding the materials, and in particular their mechanic characteristics, is essential to evaluate the present situation of the monument.
as well as to make decisions relevant to the interventions. In fact if such data are not well known, one could be led to overestimate the necessary strengthening interventions in order to assure the security. So, the interventions not only might be unnecessary and expensive but could also alter inopportune the distribution of the sti.ifnesses; a further consequence might be an irreversible loss of identity.

EVALUATION OF THE PRESENT SITUATION

Once we know the geometric structure of the building, as well as the mechanic characteristics of the materials and of the constructive elements, we can proceed to evaluate the present situation. Such an evaluation, as regards an existing building, cannot be made in a schematic and formal way, as it is possible to do when the new buildings are in question.

PROBLEMS RELEVANT TO FOUNDATIONS

As to the foundations two categories of problems can be considered. They regard, respectively, the cases in which the site and the construction give rise to geotechnic problems, independently from the presence of the earthquake, and the cases in which such problems are not present, or anyhow aren't acute.

In the cases relevant to the first category the problem ought to be resolved from the geotechnic point of view in that it has essentially little to do with the seismic question; in the cases relevant to the second category it seems reasonable to act as the current Italian code provides for: do nothing if the foundations haven't evident problems and, furthermore, changes of the favorable situation are not foreseen.

STRUCTURAL ANALYSIS

The structural analysis requires the singling out of a suitable structural model; such an operation, often easy for a new building (for instance the frame model for an ordinary r.c. building), can become very delicate when an existing building is in question. On the other hand, there are only few accredited structural models of reference.

The computation program called POR uses the best known model for the masonry buildings; one must remember that such a model can be considered valid for buildings which have the ordinary box type structure, which is characterized by the presence of floors sufficiently rigid in their plane, load-bearing wall and interstories not too spaced and number of floors not too elevated.

When the buildings with a special typology are in question the singling out of the model must be affronted with great prudence, avoiding, among other things, to extend the use of the POR method excessively because it could be
mistaken, and could, moreover, lead to suggest erroneous choices of intervention. In such cases it seems not opportune to investigate global models which, in order to be significant, require that one were extremely well acquainted with the particulars of the structures and that one should take in consideration the cracks (due to a natural accommodation of the structure to the external situation, often beneficial); rather it seems more appropriate, in preliminary analyses, to prefer partial verifications, which favour the security (because they omit every collaboration) and require less calculations, in that they are limited only to some portions of the building, or even to single building elements, which have an almost independent behavior.

In addition to the numerical approach, well-known and used in the frame of modern engineering, the analysis of the monuments suggests a completely different point of view, that can be defined "historical-experimental": it occurs to evaluate the seismic history of the monument, considering the seismic events it has suffered as experimental evidence on the field, evaluating the relevant damages, the repairs carried out and the subsequent results, the present situation compared with the above moments of verification.

EVALUATIONS OF THE USE

The intervention on the monument can and must lead to reconsider the use to which the monument is subjected, with a particular reference to the topic of the risk mitigation, both when the risk is seismic and when it is of other nature. That is why the preliminary evaluations must precede the possible modifications, with an approach that must necessarily be global, and resort more to the planning capacity than to the automatic application of regulations. This means, for instance, to move a library to the first floor, reducing the loads in the higher part of the building, with an evident improvement as to the seismic loads, or otherwise to move halls, avoiding to build a fire-escape. Still it can mean that the destination of the building as a whole should be questioned, in particular if one is planning to change the original destination causing greater loads and/or greater occupancy.

CONCEPTION OF THE INTERVENTION ON THE MONUMENTAL BUILDING

A precise point of the current Italian seismic code defines the so called intervention of improvement, that consists in the "execution of one or more works relevant to the single structural elements of the building with the purpose of attaining a higher degree of security without anyhow modifying substantially the global behavior".

On the other hand the "heavier" intervention of seismic retrofitting is required in cases which usually reconcile with difficulty with the exigencies of conservation. In fact, such
an intervention aims to make the building fit to resist the seismic loads foreseen (by the same code) for the new buildings. Such an intervention is required only when one intends (we mention here only 3 points of 5, the most significant):

a) "to raise or to enlarge the building";
b) "to make variations of occupancy causing, in the structures concerned with the intervention, increases of the original loads that are superior to 20%";
c) "to carry out structural interventions aiming to transform the building by means of a series of systematic works that bring forth a building organism different from the previous one".

From the above remarks the two documents [01] and [03] draw the conclusion that the intervention of improvement must be regarded as the "natural" approach to be taken in consideration for the monumental buildings in seismic areas, where one is in presence of ordinary pathologies, that is to say modest damages and problems depending on the old age. With all that the conception and the practise of maintenance, both routine and extraordinary, is completely recovered.

The consequences of the choice of the improvement as the practice of intervention, which are discussed in the same documents, together with the modalities of their carrying out, can be summarize as follows:

- one accepts the safety level given to the building by the original constructors, after that the decay has been eliminated;
- while analyzing the present situation a special attention is given to the above-mentioned historical approach;
- the possible calculations are elements of evaluation among others (of qualitative, comparative, heuristic nature) and they do not exclude these latter;
- every intervention must prefer the original materials and masterships; in every case the interventions must be compatible with the existing tissues, with a great suspicion towards the utilization of different materials;
- the use of whatsoever innovating technology, up to now considered as "indispensable" is not excluded a priori, but it must be subjected to the triple verification of the compatibility, of the durability, and of the reversibility. Moreover, one must add still another condition, that of the mechanic efficiency, too often considered to be obvious without a scientific verification;
- all the evaluations and choices must be a result of pluridisciplinary contributions and of collegial decisions.

In terms of intervention technologies the document [03] gives, in the Commentary, quite significant indications, that contest resolutely the modern acritical adoption, often generalized, of certain solutions; for instance, one can read:
As regards the walls:

"Generally one must intervene using materials with physical-chemical characteristics that are homogeneous to those of the original materials.

In every case it is essential that the building tissue of the wall subjected to the intervention will be completely homogeneous again, uniformly resistant and rigid, and that the opportune scarfs will be realized, in case they were lacking.

The intervention with materials different from the masonry, in particular the insertion of concrete elements, can exceptionally be accepted, but one must pay special attention to the above-mentioned aspects while evaluating the consequences of the intervention as regards the structural behavior and consider, obviously, the aspects relevant to the architectonic identity.

In case the walls should have particularly bad mechanic characteristics one can resort to injection of binding mixture, whose feasibility and efficacy must be preventively proved.

Usually it is better to avoid using the reinforced drillings due to their character of irreversibility as well as for the legitimate doubts regarding their durability and for the uncertainty relevant to their efficacy. The use of this technic should be proposed only in really exceptional, localized cases whose necessity must be proved and consequences evaluated.

As to the tie rods:

"The ancient practice of inserting tie rods, used for centuries in masonry buildings, should be reconsidered and adopted systematically, when it is opportune, specially in seismic areas."

As to the floors:

"usually the wooden floors should be conserved;...
- "the insertion of tie beams inside the thickness of the walls, that requires continuous cuts on the masonries, should be avoided, giving the preference to tie rods;...."

Conclusions:

Two points emerge from the above proposed discussion.

First of all it is necessary to give up the useful but not always valid securities given by the formal controls, whose use is reasonable only as to the new buildings and that have, moreover, the great defect of giving the ignorant and
the incompetents the illusion to "know how". Instead it occurs to adapt an approach based:

- on the sure ability of the operators;
- on the interdisciplinary collaboration and on the evaluations and choices made by decision of a team;
- on the close study of the present situation and the history of the building in question;
- on the utmost respect both for the material and for the cultural reality of the building.

In definitive such an approach is much like the one followed in medicine for the problems regarding the persons and it differs quite from the approach characteristic for the engineering of the new constructions.

On the other hand there is a circumstance that is in the same time disappointing and extremely stimulating: one has already realized that many errors have been done working on the monuments, but the right way to intervene is hardly at all known still. That is why there is a great need to carry out scientific research characterized by the close studies in different sectors (chemical-physical aspects regarding the primary and compound materials, their resistance and mechanic behavior, the behavior of constructive elements and of the buildings as a whole, conception of the security, critical survey of the traditional and innovating technics, historical studies, ...) as well as, once more, by opportune interdisciplinary studies with a synthetic character.

REFERENCES

[01] Raccomandazioni relative agli interventi sul patrimonio monumentale a tipologia specialistica in zone sismiche (Document of the National Committee for the Seismic Protection of Monumental Buildings and Italian Cultural Heritage, Rome, June 1986)
