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IMPROVEMENT AS A CRITERION FOR THE ANTI-SEISMIC SAFEGUARDING AND STRUCTURAL CONSERVATION OF HISTORICAL SITES: METHODOLOGY AND EXAMPLES

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SUMMARY

The historical centres of cities boast a remarkable architectonic heritage. As a tangible testimony to the numerous civilisations that have come and gone down the centuries, they constitute an archive of historical material which must be preserved intact in both its physical and historical integrity. These sites have always been exposed to periodic episodes of seismic activity, and have survived to communicate across the centuries the admirable construction know-how of the ancients. This culture has only declined definitively during this century, with the modern emphasis on "structure", new materials and advanced technology.
Structural engineering has come up with a series of specific norms for current building practice, concerning anti-seismic measures among other things, which have proved incompatible with the static conservation of historical buildings. The Italian scientific community is convinced that our historical heritage carries within it, in the very conception of building that brought it into being, its own intrinsic resources for withstanding the seismic events that affect the various regions. Increased vulnerability to earthquakes is to be attributed to the profound alterations carried out during restoration work or the natural deterioration of materials as the result of a destabilising environmental impact. Thus norms for conservation in Italy envisage the possibility of *improving* the structural features of historical buildings by repristinating , as far as is possible, the original conformation of the artefact. The most recent anti-seismic legislation in Italy recognises the modalities of improvement, and they also appear in the Euro-code for conservation of the building heritage.

INTRODUCTION

The last fifty years have seen far-reaching transformations in both the social, economic and technological conditions of our planet. One result has been to make people ever more aware of their traditions, and accordingly more determined to safeguard their cultural roots. This phenomenon may indeed be seen as the hallmark of all the recent conflicts in which local tensions have inevitably escalated: war in the Kosovo, guerilla warfare in Kurdistan and Afghanistan, the endemic struggle in the Middle East. One of the most significant points of reference for each individual culture is undoubtedly its heritage of buildings, which represents a record of material history rooted in its territory. Thus the conservation of the material and formal identity of this heritage is always a major cultural priority. However, the conservation of a city's historical centre or an important monument is a complex matter in which technical and administrative decisions requiring economic and political backing have to support the cultural objectives. These decisions are now inevitably conditioned by economical and technological globalisation, and this poses particular threats for the conservation of the identity of material cultures. All too often we have seen standard conservation criteria indiscriminately applied by international consortia in Mexico and Egypt, Italy and Nepal. One of the topics most subject to an exclusively technological approach involving methodologies, norms and techniques which represent so many straitjackets for genuine conservation work is safety: in the interests of "safety", Boards and Institutions lacking any sense of history or sensitivity to conservation issues draw up and enforce the most categorical "standards". A few culturally aware

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interested parties have sought, against the odds, to oppose these measures by formulating a theory of security, which respects the canons of conservation.

In a correct conservation perspective, historic buildings are regarded as archaeological material, and every effort is made to ensure that their structural and material identity [Bellomo M., D'Agostino S. 1997] is left intact. The problem of anti-seismic safeguarding has become a topical issue in recent years, and had some catastrophic consequences in terms of structural conservation. Down through the centuries a succession of building types have enabled the ancient constructions, which comprise our architectural heritage worldwide to survive to the present. Italy is undoubtedly the country with the largest share of this heritage, and has always been in the forefront of conservation culture. At the same time, the Italian peninsula is at high risk from seismic activity. Interested parties in Italy have recognised the importance of viewing material heritage as a "monument-document" [Le Goff, J.1978, Foucault M. 1969]. They have shown, using the concepts of "improvement" and programmed maintenance, how to carry out sensitive conservation work while ensuring adequate anti-seismic safeguarding.

STRUCTURAL SAFETY AND CONSERVATION

Our building heritage is characterised by a continuity in conception, materials and techniques that held good from ancient times down to the 19th century, whereas modern architecture has been fundamentally innovative in terms of design, technology, materials and the techniques associated with industrialisation. It is now recognised that applying such innovations to pre-existing realities constitutes a serious methodological error [Benvenuto E., D'Agostino S., Grimoldi A. 1986]. The ancient buildings still with us today have come through cycles of both natural and man-made challenges including earthquakes and other catastrophes, war damage and periods of neglect and decay. They thus possess much greater safety coefficients than are required for normal use. The conception, scale and geometry of the original building responded to a complex range of functions, and structural safety was just one of its qualities. It is important to realise that modern architecture relies on structural engineering, with its emphasis on precise loads and corresponding safety coefficients. Ancient buildings were homogeneous entities conceived globally to fulfil a series of functions and constructed to resist over the centuries in the face of the most severe challenges. A correct strategy of prevention and conservation, based on a building's historical profile, requires the systematic reduction of all forms of degeneration, accurate documentation, and thirdly appropriate use of the building. These are the premises for the "improvement" of a building's structural dynamics by means of programmed maintenance. It is a strategy with a well-defined methodology and range of suitable interventions [D'Agostino S., Frunzio G. 1995]. It is well suited to monuments, for these buildings, such as churches and sanctuaries of other religions, have maintained their function through the centuries. It is even easier to apply to archaeological remains in the strict sense of the term, whose value as records of material history is immediately apparent. A more problematic case is that of the historical centres of towns and cities. Here we are dealing with a conurbation which has been constantly evolving since ancient times on the basis of socio-economic and cultural stimuli which have transformed the size of the buildings and their structural and decorative features while the building materials and techniques used remained largely constant. Technological progress caused a sharp rise in standards of accommodation and urban life that required an increasingly complex provision of services. Finally historical centres tend to be either prime sites for aggressive property speculation, as is the case of many famous cities, or else left almost entirely in a state of neglect and decadence.

If the documentary value of all the historical buildings spread over the territory is recognised, they will be safeguarded as relics, which are too precious and unique to be abandoned. This can be achieved by following two essential orientations:

- promoting a correct conservation culture so that everyone becomes aware of its importance in perpetuating a specific historical and cultural identity;
- operating so as to limit every form of degeneration, from the structural – which is the root cause of all forms of vulnerability – to the environmental, and facilitating an appropriate use of the site which precludes the extremes of speculation and neglect.

SEISMIC SAFEGUARDING AND "IMPROVEMENT"

There are two aspects of the vulnerability of historic buildings to seismic activity [Corsanego A., D'Agostino S. 1992]. The first can be called "intrinsic", for it is linked to the construction concept of the building and the process of its modification over the centuries. The second we can call "induced", because it is a consequence of the state of degeneration of the building. Intrinsic vulnerability depends on the building's type and size and the

materials and techniques used in its construction: all elements, which have a recognised cultural value. Induced vulnerability means the degree to which the quality of the construction has deteriorated in time as a result of ageing and both natural and man-made phenomena; human interference in modern times is recognised as being invariably hostile and harmful.

Interventions designed to remedy the first aspect often involve radical treatment which can alter important features of the building, while it is generally possible to act on the latter by specific restoration of weakened structural elements; such treatment is indispensable to prevent further deterioration. The experience gained from recent earthquakes has shown that it is rare for intrinsic vulnerability to cause significant damage. This is the logical consequence of two factors: in the first place the historical building has endured a succession of seismic phenomena during its lifetime which will have eliminated or reduced to ruins those parts of it which were intrinsically unsound; and in the second place, historical buildings in general, and monuments in particular, were erected according to last for ever, as symbols of a civilisation to be transmitted to future generations.

The intrinsic vulnerability of a building expresses the philosophy of structural safety held by communities in the past, and this determines two extremes between which interventions must be situated. At one end of the range this philosophy is respected for what it is, so that interventions will be limited to restoration that remedies the induced vulnerability by eliminating decay, allowing the building to exploit to the full its original resources. At the other end, safety standards conceived and "calculated" according to the schemes of modern structural engineering will be applied to the building, in a reinterpretation of the ancient dynamics, although these have not been accurately identified. Such interventions tend to "reinforce", and in so doing radically modify the intrinsic vulnerability. It should be obvious how senseless it is to apply theories and models, which were conceived for modern structures to historical manufacts.

Safeguarding against seismic hazards requires different measures according to whether it is human life or the cultural heritage at stake, and this complicates matters further. In the case of human life, the levels of risk held acceptable at this moment in time are strongly influenced by environmental considerations, while for the cultural heritage we still lack a satisfactory classification of risk factors.

The various problems outlined above give rise to two negative tendencies: the intrinsic resources of a historical building are frequently underestimated, and its structure is modified to make it conform to a modern structure susceptible to theoretical modelling. Fortunately the lively debate that has gone on in Italy in the wake of the 1980s earthquakes has come up with the concept of "improvement", based on interventions which do not distort the building's original construction concept, are designed to eliminate the effects of degeneration and do not have to conform to formal coefficients. The most recent anti-seismic legislation in Italy recognises the modalities of improvement, and they also appear in the Euro-code for conservation of the building heritage.

It must however be said that in most cases, both in Italy and internationally, the tendency is still to invest in massive interventions supposedly conforming to "anti-seismic standards" for monuments and historical centres which for centuries have withstood the normal cyclical seismic activity. One particularly interesting case is Rome, with its extraordinary concentration of major monuments. Although the city has undergone significant seismic phenomena over the centuries, it is not reckoned to be at risk according to current norms. Yet all the same, structural restoration projects for its monuments follow the practice of wholescale cementification, which has characterised seismic areas in the last few decades. Thus it is necessary to insist, at the national and international level, on the promotion of a conservation culture based on the following criteria:

- reducing the induced vulnerability of monuments due to degeneration without distorting their original construction concept and using the appropriate traditional materials and techniques;
- avoiding the imposition of formal safety standards drawn up *a priori*, making decisions based on each specific situation;
- If there is conflict between safeguarding the cultural heritage and human lives, taking action which reduces the hazards by ensuring appropriate use of the monument.

THE METHODOLOGIES, MATERIALS AND TECHNIQUES OF IMPROVEMENT

The improvement of a building aims to "achieve a greater degree of safety without, however, making a substantial modification to its global dynamics". A critical reading of this definition might ask on what basis the degree of safety is to be considered "greater", and how one identifies the "global dynamics" of a structure, but this would take us into a theoretical labyrinth. We would argue that the global dynamics of a building depend on

construction rather than the narrower concerns of structural engineering: the original spatial and typological configuration of the organism ensures a degree of global resistance. The aim must be to recuperate the building's original efficiency, and the first step is to eliminate the effects of degeneration. The mere fact of enforcing obligatory coefficients is a distortion of the original construction concept.

Thus once we have accepted the concept of improvement as conservation and functional repristination of the original organism, two methodological consequences follow:

- the identification and conservation of the construction, and hence structural, typology of the historical building;
- Conservation interventions carried out with traditional materials and techniques, which are able to reconstitute the original organism and ensure a degree of durability that conforms to its history.

Various research projects have been undertaken in Italy in accordance with this cultural orientation, with three priorities: recognising the mechanical, physical and chemical properties of traditional materials, [D'Agostino S. 1998] identifying the original construction concept and the canons of the ancient builders'art [Giuffrè A. 1991, Di Pasquale S. 1996], and demonstrating the high degree of intrinsic safety "built into" the historical monuments[D'Agostino S., Frunzio G. 1994, Conforto ML, D'Agostino S. 1995, Conforto ML, D'Agostino S. 1997].

At the same time it is deeply disappointing to note that at the international level an obsessively technical approach to conservation still prevails, governed by a "hi tech" culture based on the newly available materials. While the interventions carried out in this spirit seek to introduce localised structural "reinforcements", they adopt materials and techniques, which are totally at odds with the construction organism being treated. Moreover they refer to a recent "state of the art" which totally ignores the centuries of experience underlying the canons of the art of the ancient builders.

Thus walls which over the centuries had been effectively restored by renewing the fabric are now enveloped by means of "application of reinforced concrete blocks or electrically welded metallic grids". Creating openings for windows or doors now involves "surrounding the openings with reinforced concrete or metallic frameworks connected to the adjacent walls by injected boreholes". In many cases statutory norms prescribe the systematic destruction of arches, vaults and freestanding flights of steps, or at least the total transformation of their original structural function. These tacit obligations, based on rough-and-ready techniques developed on building sites in the last fifty years which ignore the material culture of construction, give no quantitative indications whatsoever, leaving them to be applied at the discretion of operators unversed in the traditional art.

In the years 1975-1996 in Italy, in spite of numerous learned research projects concerning wall structures in seismic areas, it became impossible to repair such structures by means of "renewal of the fabric with brickwork", while international norms about arches, vaults and flights of steps were transposed indiscriminately to the national context. Yet it would not take much to interpret this intervention typology in the light of historical knowledge and conservation principles, of vaults and stairs, strengthening the openings with traditional plat-bands and brick pillars, renewing the fabric of walls without subjecting them to the stress of random perforations and subsequent injections. In a world in which there is ever greater awareness of the need to recuperate the traditional arts and crafts, a return to ancient skills in the context of the vast sector of conservation of our building heritage would be a sure sign of civilised progress. Indeed, the strategy we have outlined goes beyond what is appropriate for a correct conservation, and even beyond the ever more imperative social and economic considerations: it requalifies structural engineering, in the sense of both returning to its historical roots and acting on the most recent recognition of well-planned interventions using traditional technologies as being particularly cost effective[Ceradini V., Giuffrè A. 1991, Baratta A., Colletta T, Zuccaro G. 1996].

CONSERVATION PROJECTS

The formulation of projects of improvement starts from the recognition that each historical building is a record of material history. One must then go on to reconsider the original construction concept in terms of the unity of structure and construction, so as not to compromise this unity. In addition, it is important to have a good knowledge of traditional materials and the canons, which guided the ancient builders. A methodology for a correct conservation has in fact been available for some time, but all too often ignored in the day-to-day conduct of restoration projects. The first stage is to carry out a structural survey, which sets the historical building in the spatial context in which it was first envisioned, without separating structural concerns from the overall construction. Furthermore the wall structures must be considered as resistant to traction, as they were originally

[D'Agostino S. 1997]. The survey should include a linear elastic assessment and identify the tension distribution, generally not significant, providing a configuration, which is statically acceptable. The zones under the greatest stress must be identified and collated with the extent of degeneration. Interventions of structural restoration and improvement must use traditional materials and techniques so as to renew and strengthen the damaged areas without distorting the original configuration. Quite simply, although this truism continues to escape all too many "experts", the mere fact of restoring the building to its original configuration is every bit as much of a guarantee for its future as it has been for its past. Once technological progress is oriented according to the principles of correct conservation, important results will follow in the space of a few decades. One of these will be more realistic calculation models, and intelligent systems able to hold at bay the insidious dangers of seismic activity without compromising the material integrity of the historical building. In addition, it will be possible to guide the industrial production of bonding agents and materials which are compatible with those traditionally used and suitably long-lasting.

CONCLUSIONS

The paper presents the theory behind "improvement", stressing the cultural perspective, which seeks to conserve ancient monuments by preserving their historical and material integrity. Thus the paper sets out the methodology underlying structural improvement, general planning criteria and appropriate intervention techniques. It underlines some aspects of consolidation based on both the reinterpretation of ancient artefacts in terms of a modern structural concept, which has proved highly damaging for a series of outstanding monuments, and on the strategy of improvement. The objective, involving research projects in Europe too, is to extend the criteria for anti-seismic safeguarding presented here to the architectonic heritage.

REFERENCES

Baratta A., Colletta T., Zuccaro G., *Seismic risk of historic centres. A preliminary approach to the Naples' case*, La Città del Sole, 1996

Bellomo M., D'Agostino S., *Ingegneria strutturale e costruito storico come costruito archeologico*, Proc. 4th Inter. Symp. on the Conservation of Monuments, in the Mediterranean, Rhodes, 1997.

Benvenuto E., D'Agostino S., Grimoldi A., *Structural restoration of ancient monuments subject to seismic risk: methodological problems*, Proc VIII Europ. Conf. on Earthquake Engineering, Lisbona, 1986

Ceradini V., Giuffrè A., *Vulnerabilità e conservazione nel quartiere della Graziella in Ortigia*, Atti V Cong. Naz. di Ingegneria sismica in Italia, Palermo, 1991

Conforto ML, D'Agostino S., *Sulla concezione strutturale dell'architettura antica, un caso emblematico: la sostruzione romana.*, Atti XII Con. Naz. AIMETA, 1995

Conforto ML, D'Agostino S., *Resistenza meccanica e comportamento strutturale di alcuni prototipi costruttivi dell'area mediterranea*, Proc. 4th Inter. Symp. on the Conservation of Monuments, in the Mediterranean, Rhodes, 1997.

Corsanego A., D'Agostino S., *Italian guidelines for interventions on ancient architectonic complexes of great value in seismic area.* Europ. Con. of Earthquake engineering, 1992

D'Agostino S., Frunzio G., *Structural restoration of archaeological monuments in seismic area*, 10th Europ. Conf. on Earthquake Engineering, Vienna, 1994

D'Agostino S., Frunzio G., *An Italian approach to the preservation of historical monuments*, STREMAH, Creta, 1995

D'Agostino S., *La resistenza a trazione dei materiali lapidei e delle malte nelle antiche tipologie costruttive*, XIII Cong. Naz. AIMETA, Siena, 1997

D'Agostino S., *Tecnologie di intervento per il restauro statico del patrimonio monumentale. Sintesi della ricerca e risultati conseguiti*. Atti II seminario nazionale di studio "La protezione del patrimonio culturale. La questione sismica" Roma 1998

Di Pasquale S., *L'arte del costruire. Tra conoscenza e scienza*. Marsilio, Venezia 1996

Giuffrè A., *Analisi delle murature*, Atti V Cong. Naz. di Ingegneria sismica in Italia, Palermo, 1991

Giuffrè A., *L'ingegneria sismica in Italia*, Atti III Cong. Naz. di Ingegneria sismica in Italia, Roma, 1991

Le Goff, J. *Documento/monumento*. Encoclopedia Einaudi Vol V, G. Einaudi Ed., 1978

Foucault M., *L'archèologie du sovoir*, Gallimard, Paris, 1969