European Commission

JRC CONFERENCE AND WORKSHOP REPORTS

Proceedings of SAFESUST Workshop

Joint Research Centre, Ispra
November 26-27, 2015

A roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities

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Editors

2016

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JRC Science Hub
https://ec.europa.eu/jrc

JRC103289

PDF	ISBN 978-92-79-62618-0	doi:10.2788/499080
Print	ISBN 978-92-79-62619-7	doi:10.2788/252595

Luxembourg: Publications Office of the European Union, 2016

How to cite: Alessio Caverzan, Marco Lamperti Tornaghi and Paolo Negro (Editors); Proceedings of SAFESUST Workshop; doi: 10.2788/499080 (online)

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Ancient constructive devices and new techniques: the structural improvement of existing buildings between memory and project

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ABSTRACT

This paper tries to compare the results of some different researches and experiences of intervention for the preservation and structural improvement of ancient buildings. The study involved both an urban and a rural constructive context, whose peculiarities determined the different features and peculiarities of the single buildings that were examined, both from a geometrical and constructive point o view.

But also some common problems were pointed at, first of all the physical decay of metal connections and the loss of structural reliability as a consequence leading to the intervention. The most interesting aspect was the fact that traditional interventions reveal an attitude toward the reinforcement of existing structures rather than their complete replacement.

This fact introduces the topic of structural strengthening by adding modern devices, as a support of the existing ones, rather than by simply replacing them, nor even altering their way of working. A preservative principle that perhaps let restoration meet sustainability.

Keywords

Existing buildings, old structures, preservation, seismic improvement

INTRODUCTION

The importance of the architectural Heritage is undeniable in any town, especially in Italy, where the consolidated urban pattern is often a strong presence, as much in the big cities as in the smallest villages.

Sometimes old buildings build up a wide, well preserved and still living monumental site, as in Venice, which is made of a thick connective tissue of small historical houses linking huge palaces one to another in a continuous flow, like the one of water along the Grand Canal.

More often, the remains of the past are condensed in a part of the town, usually the centre, acting as a counterbalance of more recent urban settlements. And where the old is fragmentary, or even a ruin, it plays a considerable role anyway, both from a cultural-historical and an economical point of view, as a memento or even just a turist target. But, above all, we can think of an ancient artefact through a social perspective, as a landmark and a catalyst of the collective memory, often a meeting point as well, facilitating public consciousness and mutual relationships.

Whatever the age or meaning, ancient buildings are subjected to a continuous transformation, due both to the natural dacay and human changes. Involving them into a project of urban redevelopment means finding a balance between maintenance and renewal, a very difficult goal to reach without a deep knowlwdge, not

only of the formal features, but of their materials and structural peculiarities, as well as the environmental context they have been growing in, that deeply influences the constructive aspects.

THE IMPROVEMENT OF EXISITNG BUILDINGS AT THE CROSSROADS OF RESTORATION AND SUSTAINABILITY

Sustainability is one of the more advanced pattern of life and cultural perspective of contemporary society, providing a framework both of economical and social principles and of technical systems to reach the goal of a sustainable development. A widespread research is constantly in progress to find new devices and techniques, in any filed of present life. Can restoration be involved in such an apparently distant field of interest? And, if so, how?

In my opinion there can be some meeting points between sustainability and restoration, both from a cultural and operational point of view.

First af all from a conceptual perspective, both fields rest upon the second law of thermodynamics; entropy brings the awareness of the non-reversibility of phenomena, hence giving rise both the need of preserving the things of past as a cultural and ethical concern, just as the necessity of sparing natural resources.

Existing buildings- which are made of natural and artificial materials and have a functional, economical and social role, as human products and resources - can be compared to the natural resources we can rely on.

Thus the attention for the material culture of a place, as well as the concern for an aware use of local resources are either sustainable principles and concepts leading to a preservative approach to existing buildings, which pays attention to the past contructive wisdom, not just as a nostalgic icon but as an operative resource.

Such criteria as the preservation of the existing matter instead of replacing old parts with bright new ones meets the sustainable principle of saving natural resource, just as the principle of reversibility[40] and minimun intervention; or, compatibility, which leads to prefer local materials, or even the reuse, as recycling.

But the most impressive point is the basic concept of preservation, that is the acceptance of the physical and functional limits of the old buildings.

This approach conceives the intervention as a means to improve their remaining resources in order to reuse them properly but without expecting them to fit higher standards of performance than they actually are able to. This is also the idea of *improvement* rather than *compliance* to external standards of performance, giving rise to a kind of strengthening by adding new supports to the old structures, rather than replacing them. Here are some examples.

Venice: condition of the site and constructive peculiarities

The first example comes from a research about Venice constructive systems and their behavior over time, lead within an agreement between the Iuav University of Venice and the Venice Heritage Superintendence, with the support of a local defence institute (Corila)[41]. Many buildings and bell-towers[42] were studied, focusing on the so-called “legamenti” (links) which are an essential part of the constructive culture in Venice, where the building system is based on diffused joints between thin structures (the so-called *fiube*), rather than on massive walls and rigid connections, because of the site peculiarities, first of all the unreliability of the ground[43].

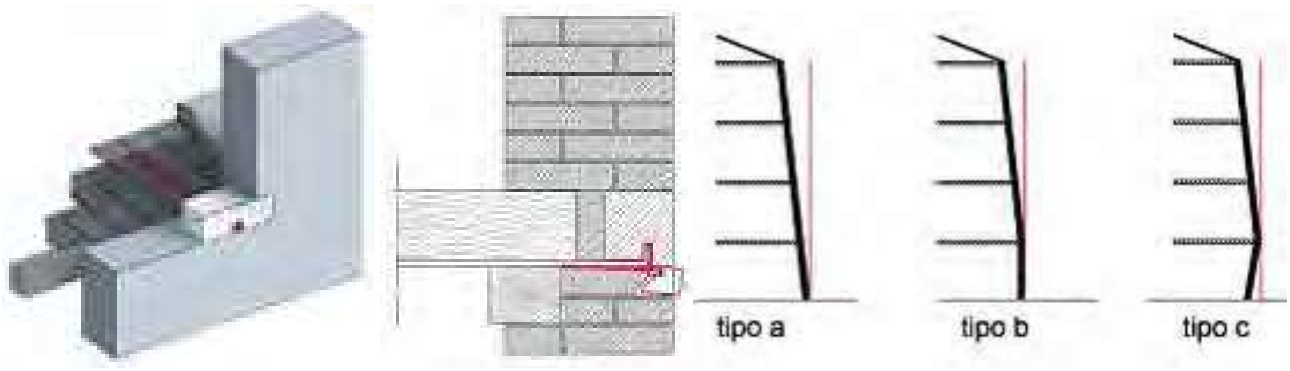
[40] Doglioni, F., Squassina, A., 2003.

[41] Doglioni, F., Mirabella Roberti, G., 2011.

[42] Lionello, A., 2011.

[43] Lupo, G., 1998; Squassina A., 2007, 2009a; Doglioni, F., Squassina, A., Trovò, F., 2007.

Figures 1-2 – Venice, Ca' Dario, whose irregular geometry is partially intentional and partially due to structural damages. On the right: lines of *fiube*, along the façade of Fondaco del Megio



Figures 3-5 – Scheme of a fiuba and of its way of damaging by oxidation;

on the right: a-b intentional slopes inward of facades in Venice; c – structural problems due to the loss of efficiency of connections (taken from Doglioni, F., Mirabella, G., 2011)

Allthough Venice is a monumental site, the nature of the place and the difficulty both in finding and shipping materials, developed a general economic view where cheapness was a principle explaining the widespread reuse of materials and architectural elements, as well as the presence of stratified buildings.

Figures 6-8 – Stratified connections of different periods in a medieval building and (on the right) in a "barbacane" (stone-and wooden shelves)

Moreover, the constructive culture is grounded on praxis, that is on a continuous process of revisoin and amendment of previous systems, following the behavior of the ground, with a full awareness of the nature of the site, of its needs and of the available resources.

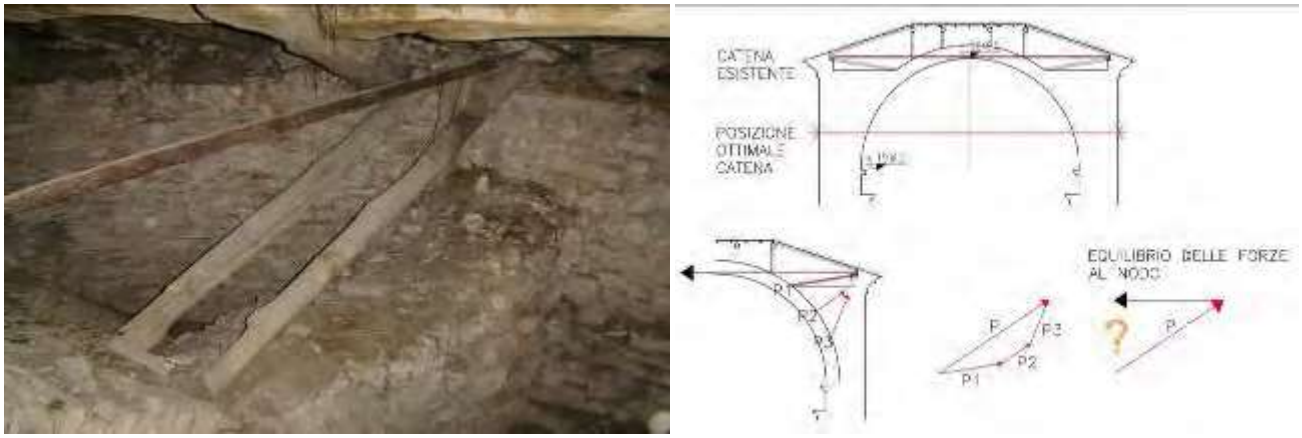
Perhaps this is the reason of the diffusion of punctual and elastic - most times stratified - supports and connections, that act as improved solutions over time but within the permanence of patterns and an overall structural framework.

Figures 9-11 – Modern repairs using new materials and traditional systems

One can find, on the facades of Venice, many layers of tie rods and such links as “forks”, connecting single parts or broken elements, at the same time letting them mutually move, adapting to the adjustments of the ground. And where a concrete structure was experimented, it proved to be inadequate because of its rigidity. That’s why tradition is not a dogma but a kind of constructive necessity in Venice.

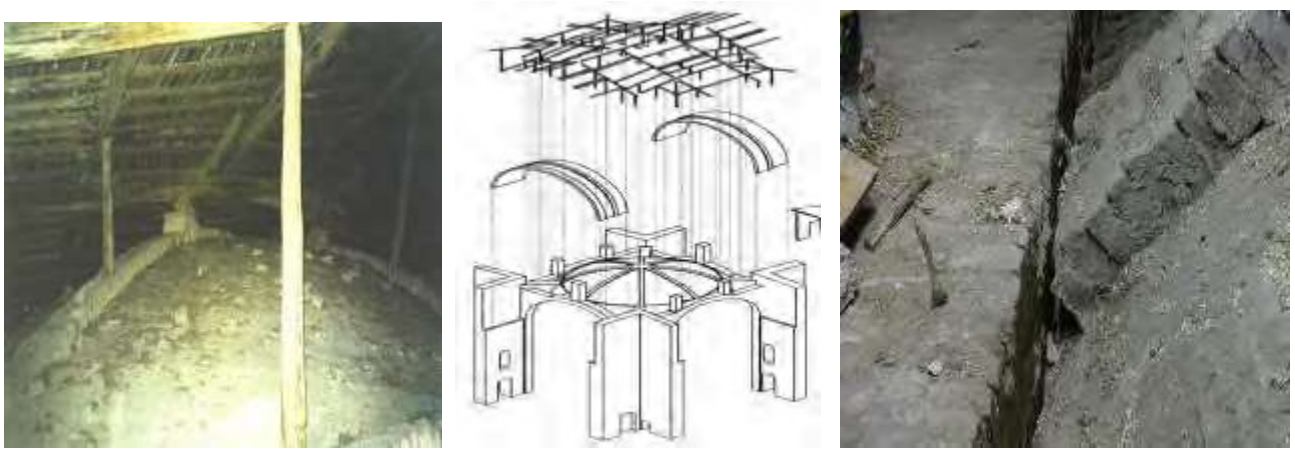
Rural contexts: rough materials and refined techniques

Within rural contexts, any architectural aspect (building orientation and exposure, as well as the structural arrangement or the inner distribution and functional layout) reveals a constructive wisdom though formal features are often essential; shapes usually simply follow the function, facilitating the everyday life and work of inhabitants. Where existing, decoration is simple. Good sense seems prevailing over any formal aspect.



Figures 12-13 – Botticino (Bs): a peculiar connection between dome and walls in a church; (on the right) cross section with the scheme of working of the device

Though we can find some extremely peculiar, yet refined structural systems, deserving an attentive intervention, taking care of ancient devices, rather than renovating the whole structure, in a word respecting both the matter and the constructive logic.



Figures 14-16 – Immages and scheme of working of the roof and (on the right) the damage due to the earthquake

Thus some wood-to-metal or wood-to-masonry ties sometimes carry out some interesting and refined connections, such as the ones which were observed in a rural roof of an old Lombard church[44].

In this case, the wrong perception of unsteadiness, given by the irregularity of the rough wooden structures, almost lead to the idea of a hasty replacement, after the church was damaged by an earthquake, in 2004. Thanks to such modern analysis as the FEM (Finite Element method) the rural roof turned out to be safe, just in need to be reinforced through modern links improving its earthquake resistance[45].

Figures 17-19 – Result of the FEM (Finite Element method, by Prof.Ing.S.Lagomrsino, ing.S.Podestà, University of Genua); (on the right) the intervention of improvement of the earthquake resistance of the dome (from Squassina A., Tonoli, S., 2008)

This is the logic of seismic improvement, providing the old building against earthquakes but avoiding any alteration of structual logic and way of working, that keeps on relying on the original structures.

The Lombard case shows how the most refined techniques can help preservation but different means of analysis can contribute to a deeper knowledge of the building and of its vulnerabilities, as well.

[44] Squassina, A., 2014.

[45] Squassina, A., Tonoli, S., 2008; Squassina, A., 2009.

For example, the direct observation of material marks of transformation by a stratigraphical reading[46], can help in understanding past behaviors and events, such as raising, enlarging or unification interventions, as well as new openings or the closing of previous ones, but also structural alterations and problems, cracking and seismic damages and repairs[47].

The goal is the comprehension of old buildings and of the level of their residual efficiency, in order to enhance their performances, without making them loose their character nor altering the way of working, both from the material-and-structural or functional point of view.

Following a perspective where preservation and sustainability maybe can meet, old buildings could be lead toward future through a conscious development of their constructive memory, that is not just as untouchable relics or as single pieces of art, but as an active presence within the everyday life of the community.

CONCLUSION

Contributes to the Roadmap

The results of the study cannot lead to a conclusion; on the contrary they raise a reflection and several questions. The main one: law requirements aim at defining standardised answers, both form the conceptual and technical point of view. How can we reach an improvement, following the law in such peculiar contexts requiring a very individual approach, without altering the nature and way of working of the existing structures?

A second aspect is the fact that a deeper analysis is needed to understand peculiarities. This paper aims at underlying the importance of preliminary knowledge, both about the material and structural aspects of existing buildings. These ones deserve to be seen as individuals, not simply as geometrical objects. Such an approach opens the issue of method, pointing at the meaning of some different kinds of surveys, so as to understand not only the formal features of old buildings but also to record those signs and traces both of transformations and previous structural damages, because they can reveal the vulnerabilities with regard to earthquakes[48].

On the other hand, a second important issue is the importance of relying on the remaining capabilities of old structures, improving, strengthening them but not altering their way of working, nor the material and structural nature of the existing buildings.

This aim often requires a change in the order of precedence, first of all as what concern function, that should not be indifferently superimposed to the building, disregarding its actual strength and structural resources.

The fact is that, though it is not easy, we should try to figure out improvement as a balance among different goals: safety and comfort from the one hand and respect for the material and structural features, even if this means a not perfect adaptation to standards.

[46] Doglioni, F., Squassina, A., 2011.

[47] Doglioni, F., Mirabella Roberti, G., Bondanelli, M., Squassina, A., Trovò, F., 2008.

[48] Doglioni, F., Petrini, V., Moretti, A., 1994 and Doglioni, F., 2000.

Open Issues

1 – Law: singularity versus standard / improvement vs compliance

Have we to make the old buildings perfectly comply the requirements of law? Or may we expect the law to adjust in respect of the peculiarities of old buildings? I.e.: when we are planning the improvement of an old building in accordance to the law (for example the seismic law, or the eco-save law), if requirements are too strict we could change the building irreversibly.

May we rely on notwithstanding the current regulations in order to preserve the peculiarities or the way of working of the buildings we are going to reinforce? May we expect a lapse, a limit which we can move up to?

Or have we to accept the law to drive the destiny both of old and new buildings indifferently?

2 – Technique to maintain or to renovate?

On the one hand, a continuous technical progress makes new materials and objects available, and allows more and more analysis, providing both knowledge and operative instruments.

On the other hand modern life standards are very different in respect of old ones. Thus ancient buildings are lacking in services and modern comfort devices. Though a new use is a way to preserve, often upgrading and refurbishment are simply conceived as a radical way to make old things accomplish new requirements which sometimes depend on our needs as consumers. In this case, doesn't technique look like a bare instrument of exploitation?

Are we able to conceive an idea of intervention in which technology is at the service of a proper and sustainable employment of the existing buildings, making use and preservation meet, that is improving but, at the same time preserving them?

Can we afford a branch of technique to develop proper means of analysis and intervention for old materials and structures, without reducing them to the analytical model of new and different materials as, for instance, reinforced concrete? A challenge for research.

An idea of restoration in terms of sustainability maybe can give an answer to such questions.

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