quaderni di assorestauro

QA

YEAR05NR03
OCTOBER 2016

SEMINAR
ICE-ASSORESTAURO
IN COLLABORATION
BETWEEN
TABRIZ ISLAMIC ART
UNIVERSITY, FACULTY
OF ARCHITECTURE
& URBANISM

ARCHITECTURAL RESTORATION & STRENGTHENING OF HISTORICAL BUILDINGS

OCTOBER 15TH-17TH 2016

TABRIZ | IRAN

ITA
ITALIAN TRADE AGENCY
ICE - Agenzia per la promozione all'estero e l'internazionalizzazione delle imprese italiane
1926 90 2016

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Quaderni di Assorestauro

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ITA

ITALIAN TRADE AGENCY

ICE - Agenzia per la promozione all'estero e l'internazionalizzazione delle imprese italiane

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The Italian Trade Agency - ICE is the Government agency that supports the globalization of Italian firms, implementing the strategies of the Ministry of Economic Development.

The Italian Trade Agency - ICE helps to develop, facilitate and promote Italian economic and trade relations with foreign countries, focusing on the needs of SME's, their associations and partnerships.

The Italian Trade Agency - ICE sustains Italian firms in their internationalization processes, in the marketing of Italian goods and services while promoting the "Made In Italy' image around the world, and it is directly involved in attracting foreign direct investments.

The Italian Trade Agency - ICE provides information, support and consultancy to Italian companies on foreign markets, promoting and fostering exports and cooperation in all areas – industry (consumer and capital goods), agricultural technology and agri-food, services, and training - with the aim of increasing and making more effective their presence on international markets.

The Italian Trade Agency - ICE works closely with the Italian Regions, the network of the Italian Chambers of Commerce, business organizations and other public and private entities.

The Italian Trade Agency - ICE headquarters is in Rome and its network of offices around the world act as "Trade Promotion Offices and/or Sections" of the Italian Embassies or Consulates.

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associazione italiana per il restauro architettonico, artistico, urbano
italian association for architecture, art and urban restoration

Project coordinator:
Andrea Griletto

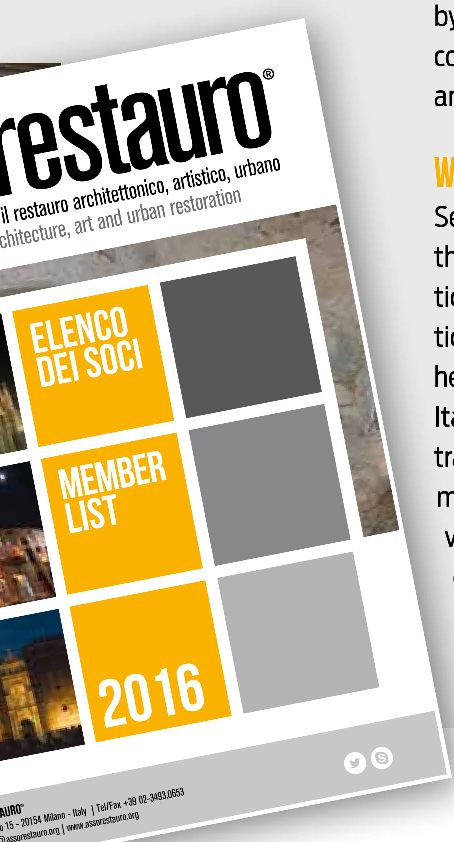
WHO IS ASSORESTAURO ?

Established in 2005 as the first Italian association of manufacturers of materials, equipment and technology, suppliers of services and specialized companies, Assorestauro represents the Italian sector of restoration and conservation of material heritage. To date, it is the sole association and a reference in the domestic and international market for anyone willing to start working in the conservation sector in Italy, to be intended in its broadest sense, that is, as a synthesis of the various disciplines involved, of the professional specialists, of the available technology and of the growing business community. If examined as a whole, the sector accounts for a large market share and has a meaningful impact on tourism, industry and bioconstruction.

WHAT ARE ASSORESTAURO'S GOALS?

Assorestauro is the National Trade Association for the Restoration Sector, representing manufacturers of materials, equipment, technology, specialist companies, designers and suppliers of services for analyses, surveys and diffusion. The Association offers its members information, assistance, advice and training both directly and through its partners, with a view to building a consistent and unitary orientation to the different sectors of the restoration industry at national and international level.

As a national association, Assorestauro is aimed at coordinating, protecting and promoting the interests of the restoration sector and it represents before the outer market, in Italy and abroad, the common positions for technical and economic issues, as well as image, by carrying out targeted activities in such relevant fields of the sector as information and communication, protection of common interests (economy, image, standards), research and development, promotion.



WHAT DOES ASSORESTAURO DO ?

Several activities aimed at promoting the professional skills in the restoration sector fall in the scopes of the Association. They include diagnostic analysis, design and on site execution, producing technology and materials, as well as contributing technological innovation, with the support of Institutions, Universities, Agencies for the protection of cultural heritage and ICE, the Agency for the internationalization and the promotion abroad of Italian businesses. This type of action includes both promotion in Italy (conferences and training seminars, trade exhibitions, courses and similar initiatives) and abroad (foreign missions, training, b2b encounters, restoration sites), where member companies are involved and offered the chance to study and penetrate foreign markets through projects co-sponsored by national and international bodies.

A BOND NEVER BROKEN

We can't deny that our countries have been somewhat distant and conflicting in the latest decades. The distance has often stemmed rather from general and external conditions than from mutual attrition. However, such distance never implied direct misunderstanding.

In spite of all this, the reasons for dialogue and collaboration between two Indo-European populations with a long historical background have never failed, so that we can now look ahead together into the forthcoming geopolitical stability – one that will necessarily be found in the area – with several more reasons to work together and, hopefully, more autonomy for action. Not by chance did Iranian President Hassan Rouhani declare on several occasions that Italy is "the gate" to Europe for the Iranian people. The previous visit to Italy of the Iranian Minister of Culture and Islamic Guidance of the Islamic Republic of Iran, Ata'ollah Seyed Mohajerani, recalled – if any proof was needed – that this "gate" is not a dull or void concept, but is rooted in Italy's key cultural role before the Islamic Republic of Iran. Our bond of cultural relations and conservation has never failed in the latest decades.

In fact, a memorandum of understanding for cultural and scientific exchange has been in place between Italy and Iran since 1958. A large number of research programmes have been started in the field of archaeology and cultural heritage conservation, which have not, at least partially, been affected by the adverse political events. In the complicated set of relations between our countries, these exchanges have been above all cultural, and then economical and political. Now that several European countries are multiplying economical and even political initiatives in Iran, Italy's knowledge in the sector of cultural heritage conservation plays a key role in supporting the promotion of Italian skills in a wide scenario now experiencing fast growth. At an early step of negotiation for possible cooperation, Assorestauro is willing to focus on two issues of major importance. The first is a topical issue for all countries, and unfortunately for Italy especially, and concerns the structural reinforcement of historic buildings, mainly aimed at seismic improvement. The second, more directly linked to restoration, is the conservation and treatment of prestigious historic finishes, which will be discussed in Isfahan next December.

We believe we will cover many principal topics in conservation and promote the widest participation of all possible stakeholders from Italy and Iran.

We expect these two encounters will be helpful to start projects and related activities next year. The more we will make joint efforts in the field of cultural heritage conservation by erecting solid foundations for scientific cooperation and business for our companies, the less the international political scenario is likely to impair direct relations between Italy and Iran. The conservation and promotion of cultural heritage are not only aimed at preserving material monuments and their intrinsic history, but are terrific instruments to make history in the first place. Meeting the expectations of today's generations and promoting hope for the future ones means promoting an international scenario that will be more respectful of the rights and traditions of all peoples.

Alessandro Zanini
Assorestauro President

italian association for architecture, art and urban restoration

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Faculty of Architecture and Urbanism of Tabriz Islamic Art University is glad to conduct this important event to be hold at university central campus in co-operation with Assorestauro, Emarat Khorshid Consulting Engineers and ITA in Oct 2015. The seminar and workshops will host academic professors chosen among the most experienced in Italy and Iran; Assorestauro companies specialized in strengthening technologies like composites, steel devices, calculations and modeling, as well as in restoration materials related to reinforcement, injections, repairs etc. The seminars and workshops will address professionals in the restoration field from the country previously contacted by Tabriz Islamic Art University and EK Consulting Engineers, Academics from different universities, members of restoration and building companies that work in the field and PhD and Master students in the field. Faculty of architecture and urbanism (TIAU) , established in 1999 after restoration of 5 historical houses, is home to 400 students and 20 academic members specializd in different field such as architecture, architectural restoration, strengheningh and urban design and is initiating to run a new master degree in restoration and strenghening of historical buildings in the near future. This conference is the first step for mutual co-operation between TIAU university and Italian institutes and universities and it is hoped that based on the M.O.U signed between the two parties this mutual interaction can be expanded in the near future.

The aim and the importance of the Seminars

The aim of these seminars is to exchange experiences in the field of Seismic Reinforcement and structural rehabilitation of historical buildings between Italian experts and Iranian one's. Both countries face high seismic areas and meantime high valuable historic buildings and it is of main importance to exchange and put together the experience of both countries to improve knowledge and practice with latest technologies and methodologies in the field. So Seminar focuses on new methods on Seismic Reinforcement and structural rehabilitation of historical buildings and introduces commonly applied methods on masonry building. (Adobe, Brick and Stone).

The seminars will discuss these main topics related to seismic strengthening: Improving the resistance of ancient building; Changing functions of old buildings and related issues; Modern approaches to seismic calculations; The Italian Guidelines for seismic reinforcement and repair; New technologies for strengthening (examples and principles). New materials for improving resistance and restoration. Due to the historical character of the city of Tabriz and its vulnearblity to seismic forces, I beleive that this conference will highlight the importance of the issue both for authorities, organizations such as municipality and heritage organization as well as academics and will pave the way for benefeting from experiences of both sides for conduction of professional as well as research projects. Preparing the Iranian guidlines for sesmic reinforcement and strenghening of historical buildings can be the first task for our university.

At the end, I should thanks Dr.Keynejad (the university principal), Prof. Berlucchi and Dr. Zanini for all their help and supports during the last several months, Dr Nezad Ebrahimi (conference scintific manager) and Eng.Roshan (conference executive manager) and also other organizations in Tabriz such as E-A Heritage organization, Tabriz Municipality and especially ITA supports, withouth which this event could not be realized.

Morteza Mirgholami
Dean of the Faculty
of Architecture and Urbanism
Tabriz Islamic Art University

دانشگاه هنر اسلامی تبریز
تاسیس ۱۳۷۸

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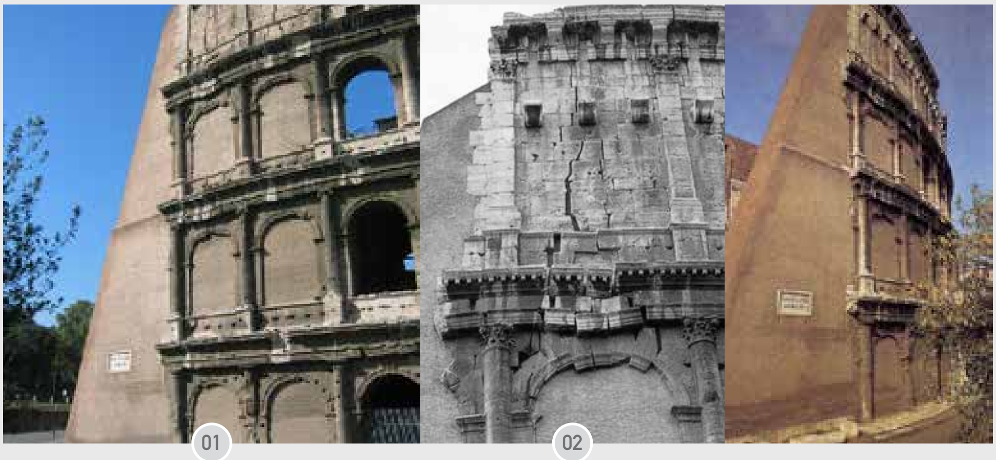
THE RELATIONSHIP BETWEEN THE PROJECT OF RESTORATION AND PROJECT STRUCTURAL STRENGTHENING

"A reasonable reassessment of empiricism"

Restoration and stability: a bit of history

The correct relationship between the conservation of a historic building and its stability is a very old problem, which has had various solutions at changing cultures and customs over time.
Already in the nineteenth century, the consolidation of the monuments was a current and controversial issue, so much so that we have witnessing of different attitudes also in the restoration of the same building.
For example is the consolidation of the Colosseum, in the nineteenth century it was precarious and it was the subject of two interventions of consolidation profoundly different a few years one after the other one.
Raffaele Stern in 1806 build a buttress to stabilize a precarious area but conserving its structural instabilities, without altering the uncertain position of the unstable blocks: an extremely actual conservation action. (figure 01 - 02 - 03)

Fig. 01-02-03
Rome, Colosseo:
Consolidation made by
R. Stern (1806)



In 1823, instead, Giuseppe Valadier intervenes with a completely different philosophy: to stabilize the perimeter ring, he reconstructs a part of the arches collapsed with their original form. Valadier however uses a different material: bricks instead of travertine. The reconstructed part is, therefore, perfectly recognizable and, therefore, the intervention is still respectful of the authenticity of the monument. (figure 04 - 05)

A completely different intervention was made by Emmanuel Viollet-Le-Duc, starting from 1849 he entirely reconstructs the crumbling towers and walls of the city of Carcassonne in medieval style. The new walls imitate those ancient, so they are a false without proper documentation: something similar to Disneyland's castles. (figure 06 - 07)

Fig. 04-05
Rome, Colosseo:
Consolidation made
by G. Valadier (1823)

04

05

These three interventions, very well known, can be considered examples of three different philosophies in the consolidation and restoration: the preservation of the historical document with the addition of different structural elements, the reconstruction differentiated with similar shapes and materials but such as to allow the recognition of intervention, and the reconstruction in style or an "ancient fake".

After nearly two centuries of discussion and debate on these strategies of interventions, we can say that now prevails certainly the desire to enhance the authenticity of the historical heritage preserving not only the visible form, but also the structural organization and the material reality, including the signs of trauma and the degradation of the past with additions also of modern materials, but recognizable. The desire is to not replace the original elements with new elements.

Fig. 06
Carcassonne (France):
reconstruction made bay
Viollet Le Duc (1849)

Fig. 07
Disneyland

06

07

The stability of masonry buildings

Keep the original material and ensure the stability is not, however, always easy.
If there is no guarantee about the stability of a building, it is condemned to destruction, especially in countries with high seismicity hazard as Italy and Iran. It's about finding the right compromise, using most of the resources of ancient structures and integrating them in the respect of a fundamental principle of restoration: "the principle of minimum intervention."
The problem of stability and safety of historic buildings occurred in Italy, in modern times, since the 70s. In the short period of about ten years, in fact, Italy has suffered serious damage from a series of earthquakes, which produced the deaths of over three thousand people, destroyed entire town centers and damaged dozens of ancient monuments. (figure 08-09)
Something very similar happened in recent decades in Iran, just remember the Manjil–Rudbar earthquake in 1990 and in Bam in 2003. For this earthquake I studied with the Polytechnic University of Milan a vegetable reinforcement for local masonry. (figure 10-11)
Following the earthquakes of the 70s has started in Italy a process of research, whether in universities or within numerous industries in the construction field, to understand how it is possible to safeguard the architectural heritage but without altering it in an unacceptable way. This research process took about forty years before landing in a significant legislative result: the Italian law for the protection of the architectural heritage from earthquake is of

Fig. 08-09
Earthquakes
in Italy – second half
of XX Century

Fig. 10
Manjil–Rudbar 1990

Fig. 11
Bam 2003

08

09

10

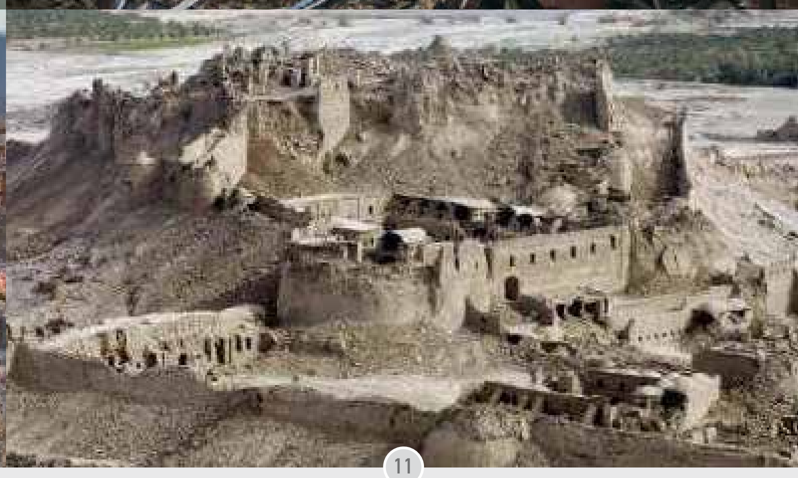


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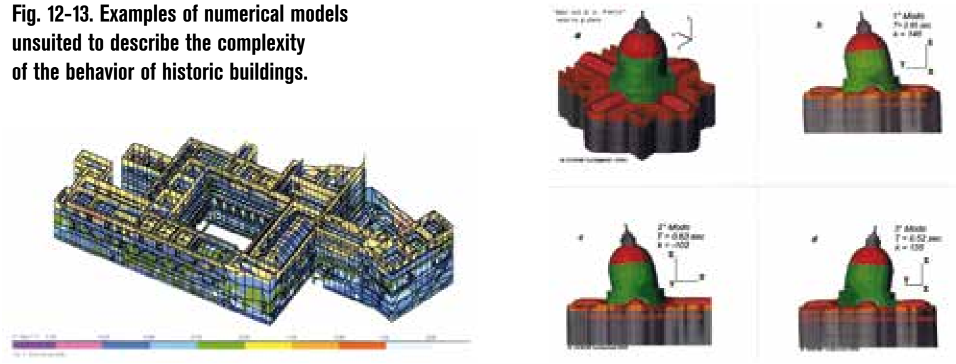
Fig. 12-13. Examples of numerical models unsuited to describe the complexity of the behavior of historic buildings.



January 2008! It is an innovative law that allows differentiated interventions for normal existing buildings, and for monumental constructions, in order to protect the great Italian architectural heritage.
Until the 70s in no Italian universities of engineering and architecture, but, I think, neither European or in other part of the world, has made research or deepened teaching on topics such as the stability of masonry buildings, the behaviour of arches and domes and dynamics of bell towers and minarets, or about the use of innovative materials (FRP) for consolidation.
Engineers and architects studied the structures only in steel or reinforced concrete, and the only solution that we knew to consolidate masonry structures was to insert in the ancient buildings some modern structural elements (steel frames or reinforced concrete panels) which took the external stresses and loads for entire, replacing the old structures.
The results of the first interventions were therefore uncertain and in many cases dangerous or unacceptable as opposed to the need for conservation of monuments.
Even traditional calculation methods soon proved totally inadequate to describe the complexity of the historical structures without tensile strength and built with traditional methods. Even the most modern methods on the market, with numerical finite element models, mostly elastic, have proven unreliable. (figure 12-13)

By the time engineers and architects have understood that, to save the historic buildings without unnecessary and heavy interventions or excessive additions, you must make the maximum from the ancient structures stamina. To do this it's necessary to take the knowledge of past builders, based on their thousand-year experience on the behavior and criticality masonry construction (empirical knowledge).
If we study the ancient manuals, until the early nineteenth century, we find that the approach of the ancient builders to stability was deeply different from ours.
By building thick walls the problem for them was not the strength of materials, but the balance. The manuals contained the description of the main mechanisms of instability of individual structural components generated from equilibrium crisis.
The method of analysis based on the possible movements of the structures, divided into rigid bodies, is now called, with modern terminology, kinematic analysis, since it is based on virtual movements of rigid bodies (instability mechanisms) and studies the situations of equilibrium limit.
For centuries builders had constructed thick walls for which the issue was the balance and

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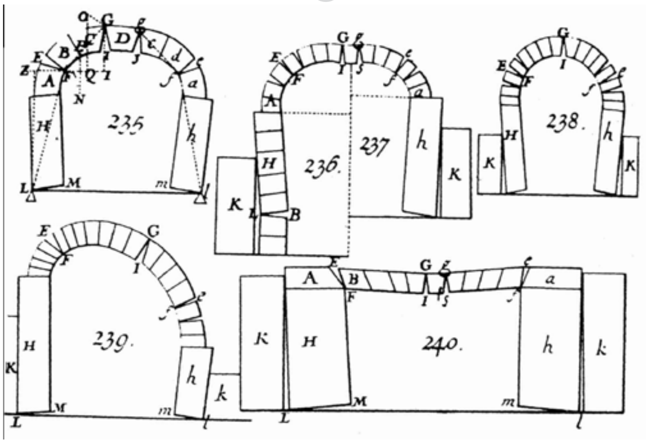

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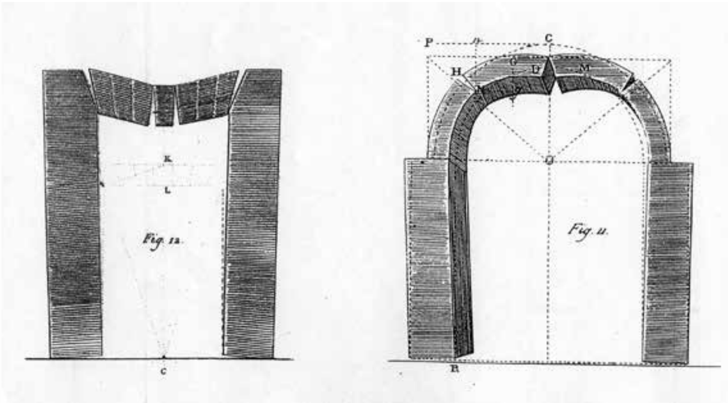

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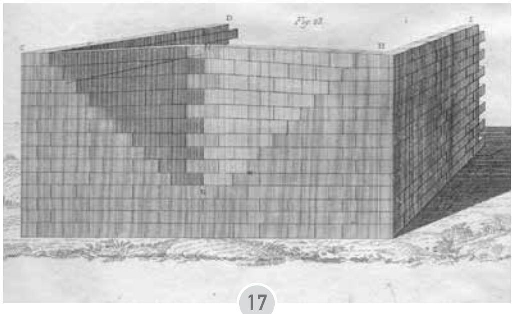

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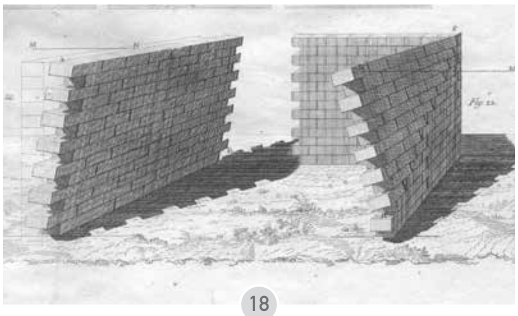

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Fig. 14-15-16-17-18
Kinematic analysis:
instability mechanism

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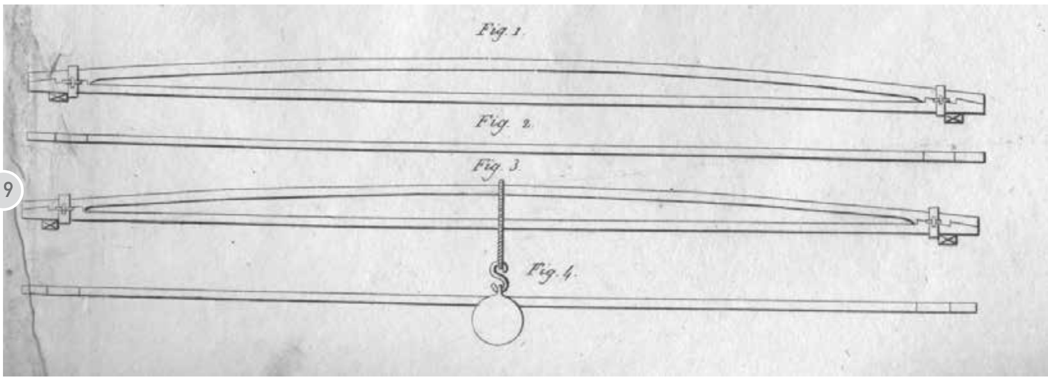

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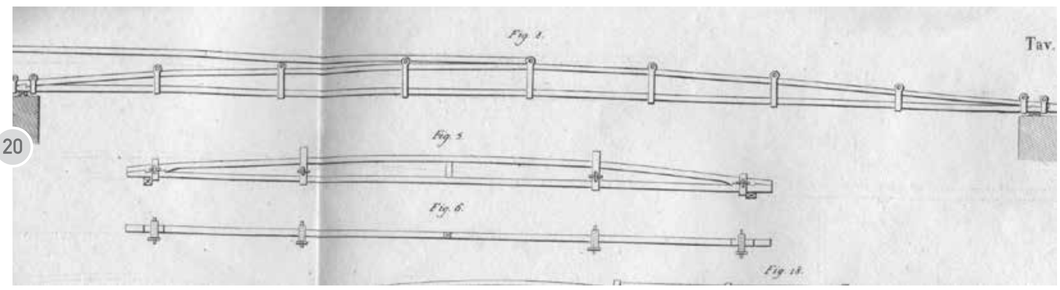


Fig. 19-20
Rondelet:
first iron "beams"

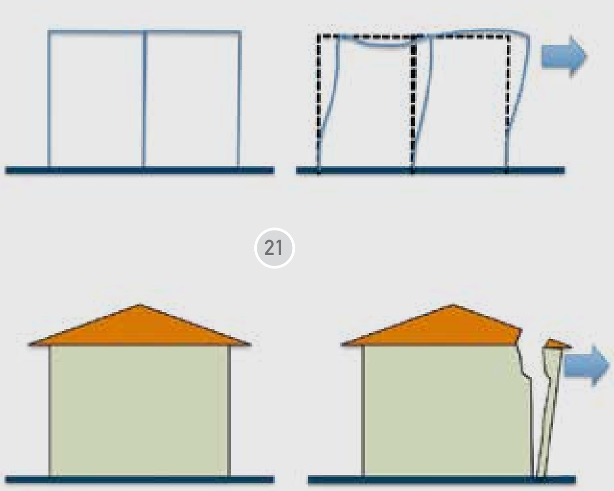
not the resistance of the materials and had gained enormous experience on the local crisis mechanisms (empirical knowledge). (figure 14-15-16-17-18)
The beginning of the nineteenth century marks a major change in the architecture by the widespread use of iron.
At the time of introduction of iron elements in constructions, suddenly it was posed the question of shape and strength of the beams made with it. The resistance is linked to the internal tensions that break in the material. (figure 19-20)

Not being able to use the experience and empirical knowledge, it was necessary to invent a new science (mechanics of materials) to assess internal stress and cracking of the beams, pillars and frameworks (stress analysis).
Since the beginning of the nineteenth century, for nearly two hundred years universities have studied only the predictive calculations of steel structures and reinforced concrete, forgetting the experience on masonry buildings, up to the modern numerical models.
Only facing earthquakes and the destruction of historic buildings, in the second half of the last century, particularly in Italy, we realized that the stress calculations were inadequate, even the most sophisticated with computers and numerical models, and that we have to return at the kinematics analysis based on the identification of local instability mechanisms.

The main reasons for which the numerical methods on the market find it difficult to describe (figure 21) the behaviour of masonry constructions are:
_ the limited tensile strength of the masonry, which does not allow the diffusion of the stresses and the presence of a global behaviour,
_ the lack of isotropy and homogeneity of masonry.

Fig. 21
Difference of behaviour between framework structure and masonry structure

The analysis of local mechanisms, defined empirically on the basis of previous experience, has become the method of analysis recommended by the rules.



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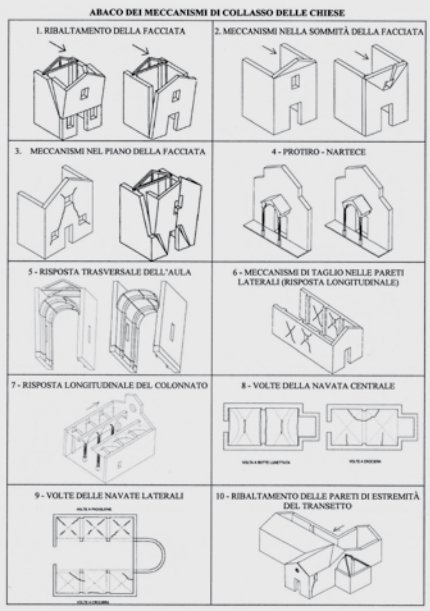

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Fig. 22
Mechanisms of local instability illustrated in Italian rules

The Italian law of 2008

In 2008 it has been approved in Italy a law for the protection of historical and architectural heritage by the earthquake. This law provides different rules for normal and for monumental buildings; also recognizes that in masonry buildings the collapse is achieved, in most cases, for lost of balance of limited portions of the building (the instability mechanisms), for which it suggests the use of the kinematic method for the detection of local criticality.

The law warns against an uncritical use of the global finite element calculation models, especially those made with elastic finite elements, as they provide for the most unreliable results. The law also recognizes that it is not possible, in most cases, to make the historical buildings as safe as new ones without damaging the authenticity, then it allows for monumental buildings to have a security level lower than normal buildings.

Much importance is entrusted to historical analysis and the survey. Of utmost importance is the knowledge of the building response and similar buildings to earthquake (empirical knowledge).

The law contents:

"When the building does not show a clear behaviour of the whole, but rather tends to react to the earthquake as a set of subsets (local mechanisms), the verification with a comprehensive model hasn't compliance with respect to its actual seismic behaviour.

... The mechanical model, even if developed with the most accurate analysis tools, it is anyway inadequate ... the intervention can be fully satisfactory in the face of qualitative assessments of the structural behaviour based on observation of the construction and historical analysis.

The objective is to avoid superfluous works, thus favouring the principle of minimum intervention ...".

Even for non-protected historic buildings there are similar rules. A Ministerial Circular of 2009 contents:

"[In buildings without rigid floors] *the global verify can be done through a comprehensive set of local checks, provided that the totality of the seismic forces is consistently distributed on the relevant local mechanisms and is properly takes into account the forces exchanged between the structural subsets considered".*

In other words, the seismic analysis in masonry buildings, aimed at the enhancement of the ancient structures, consists in: to study the behaviour of individual building elements in masonry (walls, arches, vaults, steeples and minarets etc.); to know their historical behaviour; and to recognize, with careful inspections and surveys, any defects (badly performed walls, risk of tipping of the walls, rotten beams, lack of connections between the walls, and inadequate links between the wooden structures, lack of tie-rods etc.). It is a way of studying the buildings that is completely different from the design of a new building of reinforced concrete, for these we sit in the studio and make global virtual models. It is a method of study based on the experience, static sensitivity and accurate qualitative knowledge of empiricism type. If we look the drawings in the recent Italian rules we find that they are identical to those of the eighteenth-century manuals: they describe local collapse mechanisms. Address an study in this way it will be understood that there are few different kind of buildings in masonry and that the instability mechanisms are always the

same. You will find that the first problem is the tipping of the walls out of their own plan; you will find that the arches push and rotate the walls, you will even find that the domes push; you will find that, in general, with simple tie-rods and rings you can hold together the buildings and prevent the frequent instabilities, saving the ancient structures.
Certainly remain the problems due to unreliability of some walls, such as those of Bam (which I analysed), but you will find that our colleagues in the past had often faced the problem of inconsistency of the walls (for example, those made by clay) and that they had solved the problem by placing the layers of plant fibres to hold the compact walls.
Understanding the mechanisms is also possible to perform calculations for the quantification of consolidating elements, but it is much easier and more reliable a calculation that starts from a local specific criticality well understood, than a calculation starting from the study for an entire building, not able to consider details of those problems that are the main cause of collapses. During these meeting days various technical solutions will be presented mostly aimed to preserve the old structures while respecting the fundamental principle of minimum intervention.

Islamic Examples

As examples of restoration methodology beforehand described, I would like to show some works of consolidation and restoration made by Studio Comes on Islamic buildings.

_ Consolidation of the Karajosbegova Mosque and its minaret damaged during the Bosnian war: the consolidation was made by old stone with hand finishing. (figure 23)

_ Consolidation of Ayyubbid Hall in the Citadel of Damascus: the vaults are consolidated with tie-rods. The dome has a geometry that remembers the traditional architecture but with modern design. (figure 24)

_ Consolidation of the Minaret Al-Hadba of Mosul: the minaret has a great declivity that will be reduced with a work on its foundations, like Pisa Tower, without damages on the ancients walls. The trunk will be consolidated with hooping of carbon ropes hidden inside the mortar joints. (figure 25)

Fig.23
Mostar: the town after the restoration and an old worker

Fig. 24
Damascus:
consolidation
of the
Ayyubbid Hall

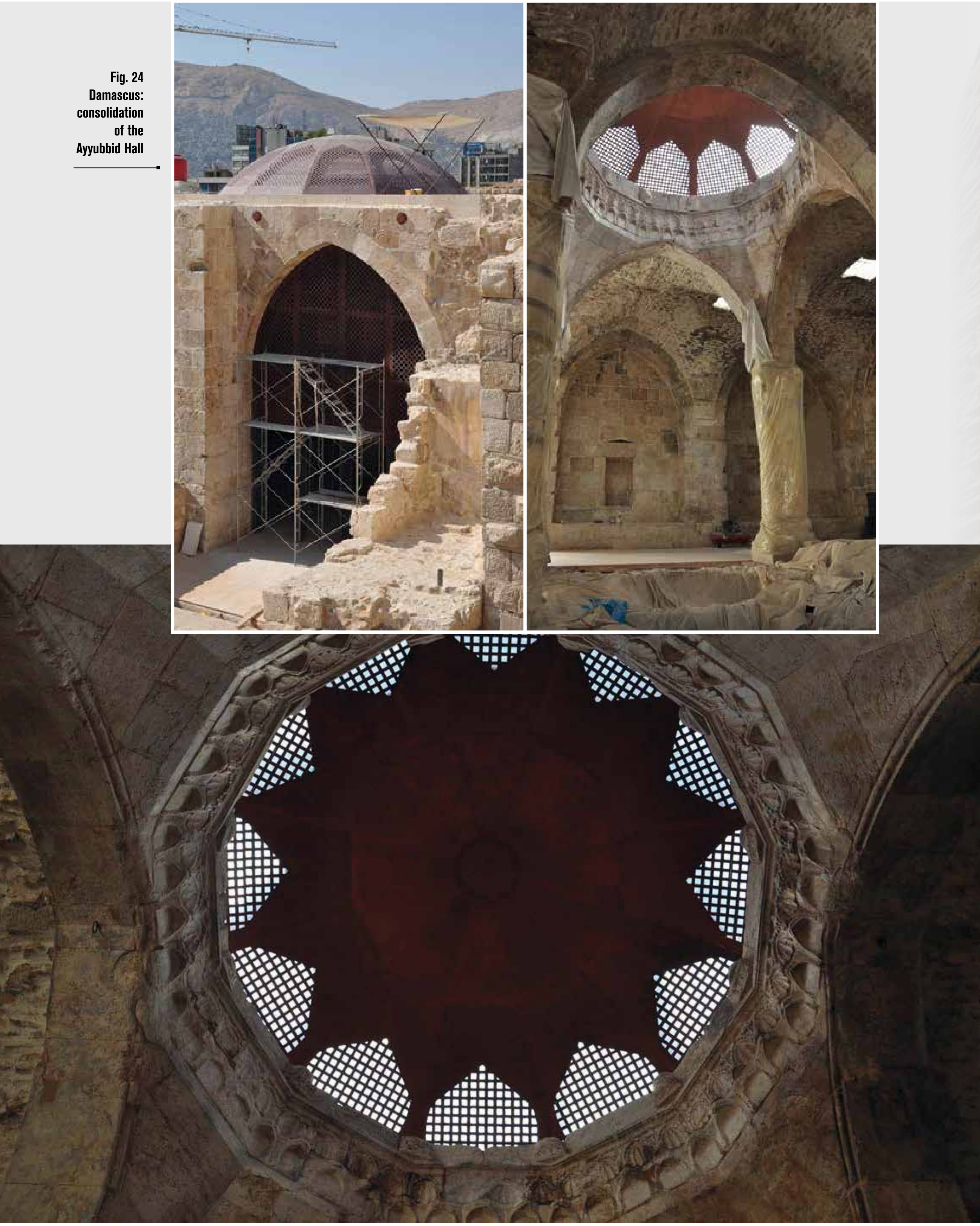
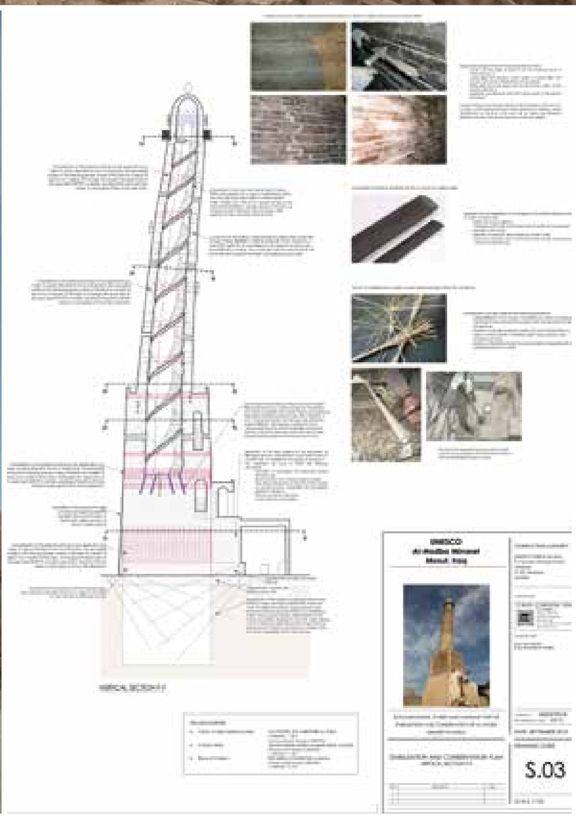
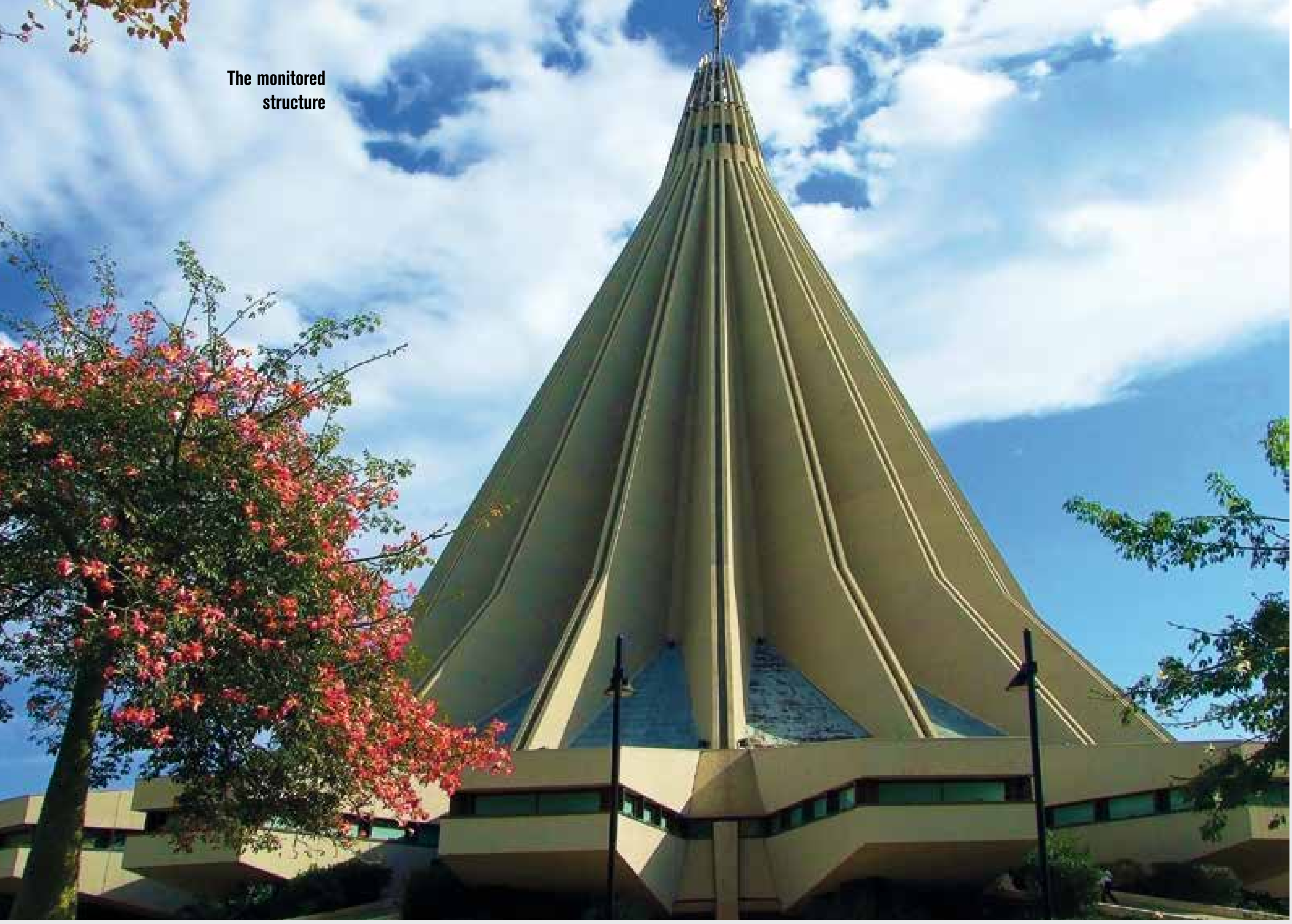


Fig. 25 Pictures of the Al-Hadba Minaret of the Mosque of Mosul and the consolidation project





The monitored structure

Giuseppe Bovio

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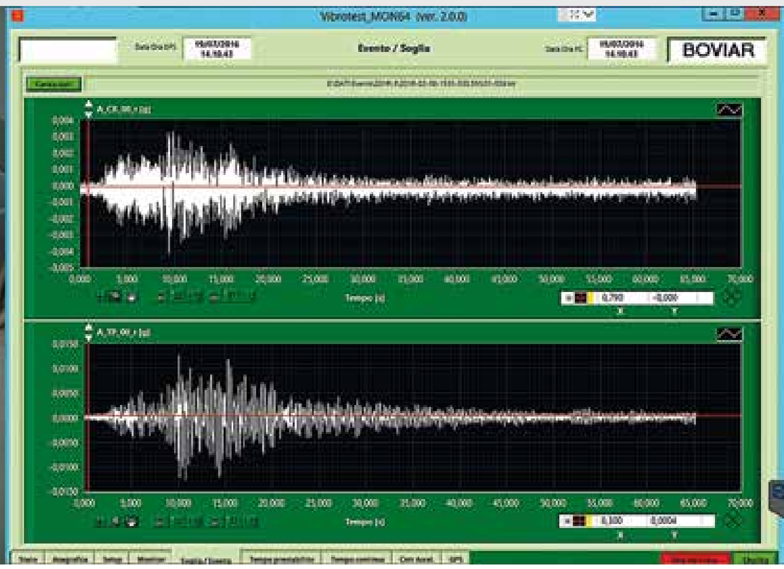
MONITORING, DIAGNOSTICS AND INVESTIGATIONS PROJECTS

The religious building “Our Lady of Tears” in Siracusa is one of the constructions included in the Italian network of structures permanently monitored by the National Department of Civil Protection. The building is made in bare concrete and consists of a crypt, a clear area for the audience, some 4000 m2 large, on the ground floor, and a majestic dress-shaped dome resting on 22 reinforced concrete pillars. The dome has a base diameter of 71,40 m and a height of 74,30 m. The area where the building is situated is rated as medium-high

Dynamic Data Logging system, the Acquisition Modules

Monitoring instrumentation installed. Seismic accelerometers installed in triaxial configuration



Static Data Logging system: Displacement Transducers with customised holding device.
Temperature and Relative Humidity Indoor Sensors

SCADA (Supervisory Control and Data Acquisition) SOFTWARE
Supervision Software for data displaying, transmission and automatic ingestion into the database of the OSS (Italian Watch Centre for Seismic Risk)

seismic risk and so in 2006 the whole dome was lifted and its original supports were replaced with energy-absorbing elements in order to mitigate the risk. A site-specific integrated monitoring system was implemented by Boviar by installing different sensors all over the construction for monitoring 2D and 3D displacement at the dome-base interface; wind velocity with direction; and acceleration. This continuous control system is 24h/day actively linked with database of OSS (Italian Watch Centre for Seismic Risk) of the Italian Dept. of Civil Protection as well as to the Dept. of Structural Engineering of University of Naples “Federico II”.

ADVANTAGES

Continuous watch and supervision monitoring services of all events relating to the building with treshold-log triggering system, data transmission and automatic ingestion into the database of the OSS (Italian Watch Centre for Seismic Risk).

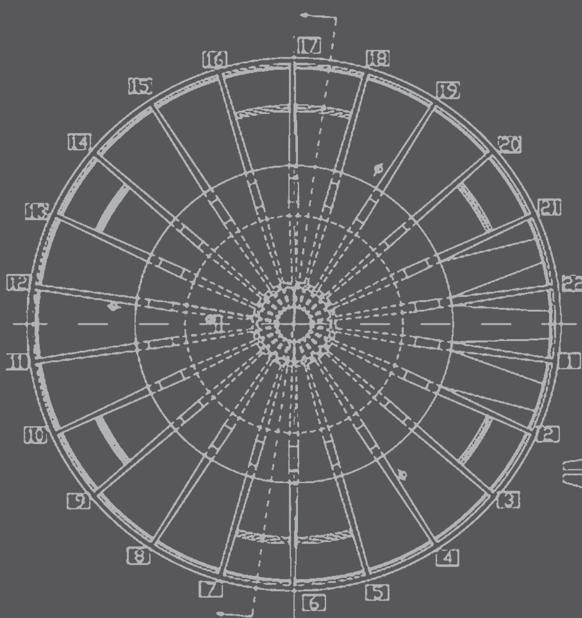
Some relevant reference projects Boviar was involved in:

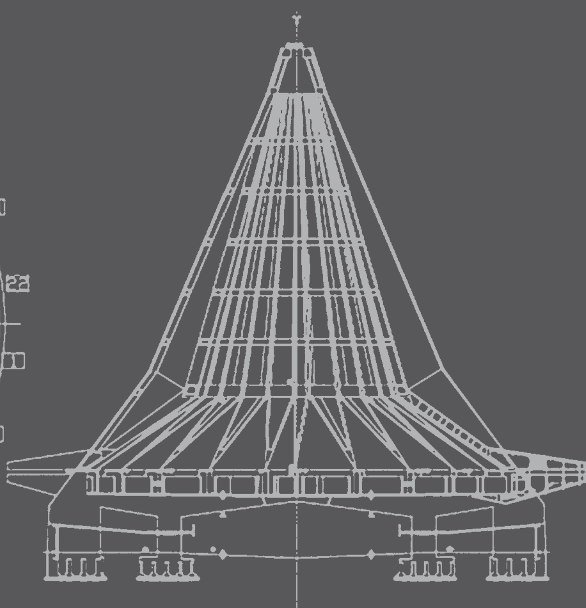
_ Supply of an automatic web-controlled monitoring system with accelerometers and displacement sensors at Palazzo Ducale in Venice

_ Consulting and supply of special flat jacks in consolidation project of Duomo in Pavia

_ Supply of a dedicated GPR system for archaeological investigations in Agrigento Temples Valley

- Instrumentation supply and on-site installation of a "turn-key" remote-control monitoring system for the dam "Ponte di Chiauci", including piezometers, inclinometers, water level stations, accelerometric stations and watch-house control centre. A SCADA software for either web-oriented or local supervision and control of the whole system was also included.
- Emergency Maintenance and Modernizing Works of a monitoring system for displacement, meteorological and vibrational measurements including a remote control data management system shared with National Service for Civil Protection and University of Naples. This complex system was set up at "Madonna delle Lacrime" Church in Siracusa (Sicily) in order to monitor the huge dome after the adaptation intervention, carried out through an unprecedented technique, to new seismic safety standards.
- Supply of instrumented flat jacks, vibrating wire strain gauges and data loggers for Rome Metro (Piazza Bologna)






_ Supply of an automatic web-controlled system for monitoring temperature of soil and exhausted gassy nitrogen at Mestre-Venice tramway system (PMV)

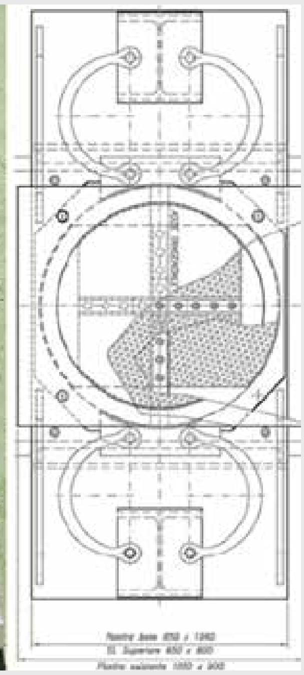
_ Hire of a dynamic / static monitoring system complete with accelerometers and wireless displacement transducers. Installed in cooperation with IUAV University of Venice at “Anime Sante” Church in L’Aquila, damaged by the earthquake.

_ Investigations of frescoed vaults of Chiesa S. Francesco in Assisi after earthquake of 1997

_ Supply of WEB-GIS for collecting and integrating different kinds of measurement data relative to risk areas in South Italy..

_ SCADA software for controlling dewatering operation during the construction work of Line 6 Naples Metro.





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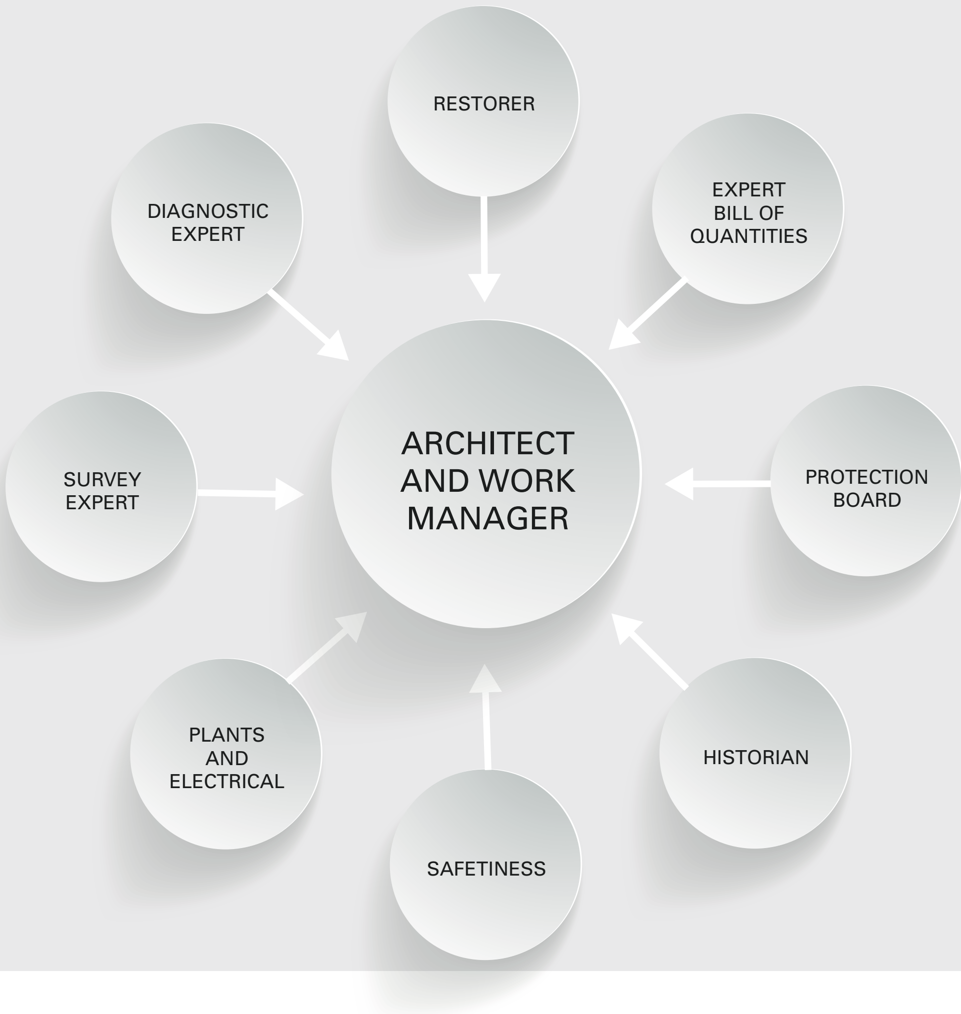
THE IMPORTANCE OF A MULTIDISCIPLINARY APPROACH IN RESTORATION PROJECTS

The restoration project is a very complex task that involves many disciplines and many professionals: the restoration of the mosque of Sheik Suleyman is an example of how to run a multi-disciplinary design and it is also an example of complexity to be able to conserve all changes that have occurred in more than a thousand years of history.
The designer architect and construction manager is a kind of "orchestra conductor" (fig. 1) who must be able to engage and communicate with different specialized professionals, such as the expert of diagnostics and surveys, the restorer, the structural engineer, the engineer who deals with systems and heating and cooling, the art historian, the head of safeness of the site and last, but not least, must be able to interact with the Protection Board. All these specialists need to be coordinated by a figure that has multidisciplinary experience and that is able to understand the needs of the individual specialist.
In Italy, the state of the restoration discipline can be considered in a very advanced stage, but we can affirm that, despite the theory of restoration had taken life since 1800 with great Italian scholars then systematized with the paper of Venice, the restoration approaches are still not uniform.
If we look at the restoration of St. Peter's Basilica in Rome, or at the restoration of the facades of Procuratie Nove in Venice (St. Mark's Square) we see that the level of cleaning



01

The architect is like an Orchestra Conductor

02

03

The surface represents a palimpsest of history of the building

Important remains of Byzantine decorated plasters could suggest some works to valorize them

of the monumental surfaces ranges from being very respectful of the patinas to deeper cleaning approaches depending on the approval of the local ministerial authorities.

There are examples in Italy of renovations incorrectly called restoration where ancient buildings see the brutal insertion of new parts in total disrespect of the original structure while in other cases the mere opening of a window can be seen as "incorrect" by the local Superintendence Authority. A designer could ask: what are the guidelines for the restoration? Theoretically the Cultural Heritage Ministry imposes almost complete preservation of the monument, but in fact this practice is not uniform and depends on the individual protection board. The importance of the Italian experience lies mainly in the method with which you deal with a restoration project: in all cases, despite different end results, the study and the level of knowledge refer to a well defined methodology; any project that needs to be submitted for approval by the Superintendent assumes historical research, deep visit of the construction site, surface analysis, a careful geometric survey and orthophotos, a stratigraphic survey, a survey of the degradation, the knowledge of chemistry and physics of the materials that form the building, the diagnostic analysis support etc.

All these steps are essential and are now a standard of any successful project: the knowledge of the building is the first phase of the project and it's very important; you have to be able to know every material to respect it; the project is not realized in the studio but is done on site by studying and deeply understanding the building and obtaining from the building itself its maintenance history.

Fig. 4. The old pictures can give a reliable reference as a starting point for restoration project

Fig. 5. A realistic and precise 3D project can give a perfect idea of final result and suggest possible changes or implementation before starting the works

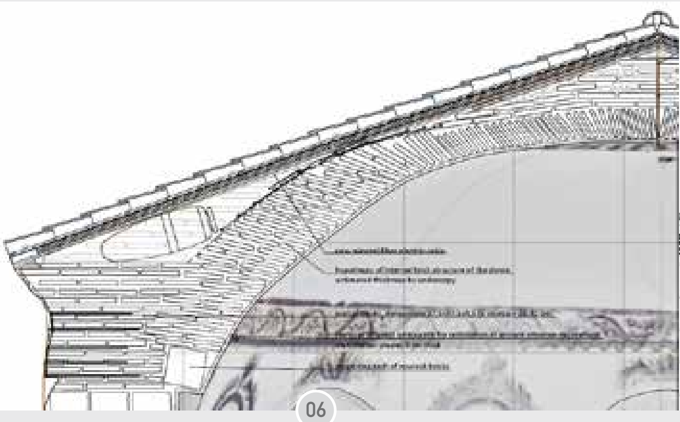
04

05

You need to look closely at the surfaces to understand the phases of construction in order to be almost “advised” by the building about the needs and the necessary works: “to know, to maintain”, can be a slogan that well represents this approach.

The restoration project should not override the monument but should remain in the background: a beautiful Italian definition by a friend architect Marco Ermentini is to create a “Shy Restoration”, a restoration in which the designer agrees not to be at the center of attention, not to be the artist who puts his signature but only the “Preserver”, who is responsible for handing down to posterity what has come to us form the past.

We prefer a restored building rather than a redone one: it is clear that a case like the mosque of Sheik Suleyman with more than a thousand years of history is a perfect palimpsest of interventions and stages (fig. 2). Perhaps we start even from a mausoleum or a Roman tomb, transformed into a Byzantine baptistery (fig. 3), later a mosque modified further and painted and richly decorated in 1700. How can we do a project that guarantees that all these stages and this story are not deleted? We can for example refer to the photographs and prints from the 1900 and use these photos (fig. 4) as a time reference of an important phase that had not yet seen the actions of the very low quality recent decades works and start our project since that time without wanting to return the mosque to an indefinite period (Byzantine or Ottoman) or worse without wanting to create a hybrid that never existed. The project drawn up with the help of all experts of Assorestauro and VGM just wants to delete the recent very low quality additions and wants to enter the services and technological systems in respect of this story and this succession of stages. Some attached pictures show how the long work done by the design team has been to design and predict every possible intervention still in the design phase (fig. 5) to avoid any variation or surprise during construction, which make the works longer and more expensive, as often happens in Turkey but also in Italy. A careful multidisciplinary project is the only solution that allows us to treat on the same plan not only the architecture but also the historical aspect, the structural one, the systems, the lighting and the archaeological point of view so as to avoid having an aspect that is considered dominant than the other. The restoration project should always proceed in parallel to check the inconsistencies and incompatibilities, such as the lighting system and the electrical system must be designed in parallel to the architectural aspects, not in a different hierarchy but all equally important.



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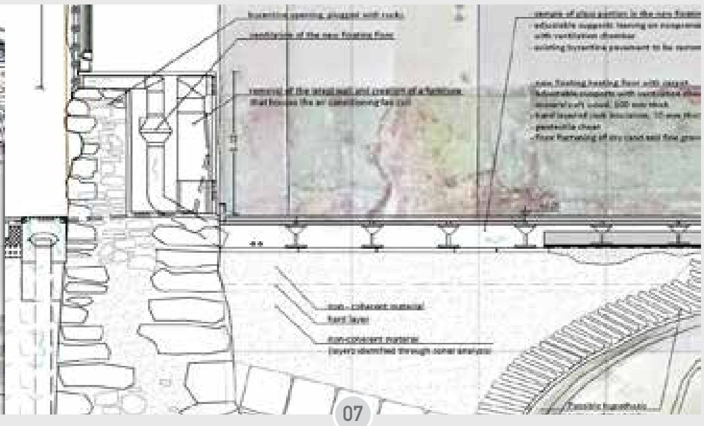


07

Details of the project: all aspects are included, roof insulation, strengthening and electrical cable path, vent and floating heating floor

The detailed project and the details of the tables presented in this paper show that the great work done by our study with the support of all the experts of design team has been to include in the project drawings all information been obtained by the individual specialists, so the graphics represent a sort of x-ray of the building (fig. 6, 7): the masonries are not designed on hypothesis and represented with AutoCAD patterns but report the real composition of the building and are made thanks to the close visual analysis and all diagnostic investigations.

Energy aspects are just as essential to a modern restoration, the proposal involves the construction of a plant floor radiant formed by floating floor elements (fig. 8) detached and respectful of the remains of the Byzantine pavement below and provides a lighting LED specially designed and verified in its effectiveness (fig. 9, 10).

The study conducted on to the heating and cooling will allow a great energy savings estimated in 74% warming compared to an electric carpet heating in winter (fig.11) and a saving of 15% compared to a standard air-conditioning system (fig. 12), also if it were possible to connect this system to a series of solar panels it could have a system with zero power consumption and completely autonomous

The toilets, the space for ablutions and technical rooms are designed with contemporary forms and materials to form a clear insertion element which would break away from the monument and that meets modern requirements (fig. 13).

In the same contemporary architectural style was designed a new access to the crypt, currently difficult to access through a simple hatch (fig.14).

What are the conclusions that could be drawn from this brief paper, and what may be in my view some different approaches between Turkey and Italy? From what I could see in Italy the need to provide a detailed implementation plan is now uniquely defined before any contract, the project must already take into account the surrounding environment, the rules, the architecture, the history, the structure and energy performance with careful analysis and a forecast of everything that might be unexpected.

The advantages are that once contracted the work, there are no further delays and that will not be necessary to require further approval from Protection Board with the time and cost of construction becoming reliable and trustworthy.

In Turkey, from my limited experience, there is great attention to the architectural and

Fig. 8. Detail of the proposed heating and cooling floor

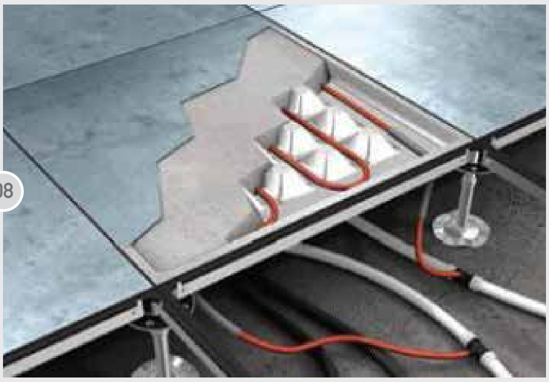
Fig. 9. the proposal for a new led low consumption chandelier with hidden leds that enlighten the frescoes of the dome

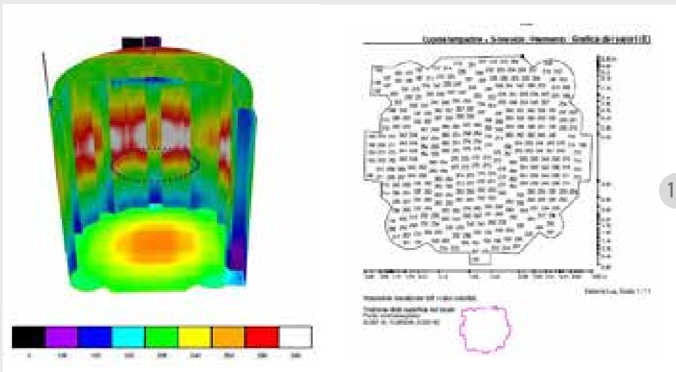
Fig. 10. Illuminance calculations of the new lighting proposal

historical aspects, there is a tendency to delegate aspects merely to the so-called implementation project (structural and system detailed project),; projects in some cases can be carried out by the technicians of the successful tenderer and they generally involve new approvals and changes to the original contract rates and conditions, all with lengthy and unpredictable outcomes.
We hope that this example will serve to appreciate the importance of multidisciplinary design and to realize that even in restoration field it is possible to avoid changes and increasing of costs during construction.

09

08





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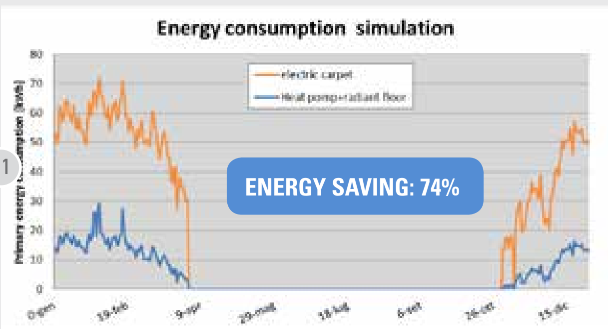

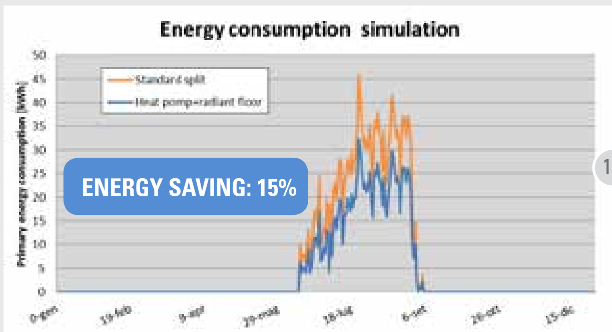

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Energy consumption simulation and comparison between HVAC system and previous electric carpet during winter heating

Energy consumption simulation and comparison between HVAC system during summer cooling and standard air conditioning system

13

The new insertions have been designed with contemporary style not to alter the ancient monument

14

The section shows the proposal for new entrance to crypt

Claudio Modena
Università degli Studi di Padova

CRITERIA AND TECHNIQUES FOR REPAIRING AND STRENGTHENING THE ARCHITECTURAL HERITAGE: RESEARCH AND APPLICATIONS

The preservation and valorisation, and then the use according current necessities, of architectural heritage are more and more becoming a major social and economic, besides cultural, issue in many countries. The consequent necessity of ensuring a "minimum accepted level" of structural safety to the involved construction typologies – far from being dealt with by structural engineers in the same way as they treat "modern structures" – is a real challenge, especially considering that they are frequently exposed to severe environmental hazards (like earthquake).
Problems in fact are raised ranging from the same definition and choice of the "conventional" safety level, to the tools and methodologies that can be used to perform reliable structural analyses and safety verifications – being clearly and universally recognised the strong reliability limits in this contexts of even the most sophisticated modern ones– and to the selection, design and execution of appropriate materials and interventions techniques aimed to repair and strengthen the built heritage while preserving as much as possible of its cultural, historic, artistic values.
Important lessons have been learned in this context in Italy from the effects of recent earthquakes (Friuli 1976, Irpinia 1980, Umbria-Marche 1997, L'Aquila 2009, Emilia 2012, Amatrice 2016), all having had destructive effects on historic centres, even when previously subjected to retrofitting interventions, thus demonstrating that even the most innovative solutions can be ineffective, and even dangerous, if not appropriately designed and executed.
Strong debates are still raised on all such issues, but some achievements are to be considered definitely accepted by the majority of the scientific and technical community as they have found appropriate recognitions in the most recent codes and recommendations at national (the Italian Guidelines for evaluation and mitigation of seismic risk to cultural heritage) and international levels (ICOMOS – ISCARSAH International Scientific Committee for Analysis and Restoration of Structures of Architectural Heritage: "Recommendations for the analysis, conservation and structural restoration of architectural heritage",

NDT: thermography and sonic tomography compared to georadar

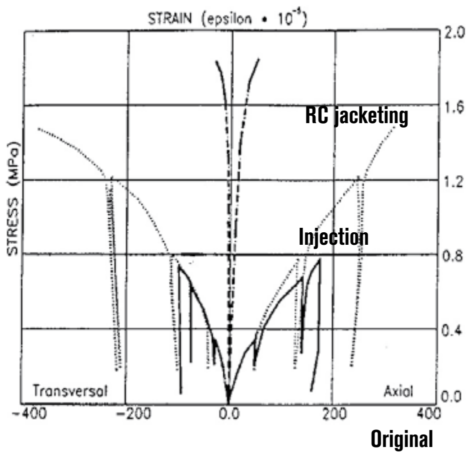
MDT:
core drilling
and flat jacks

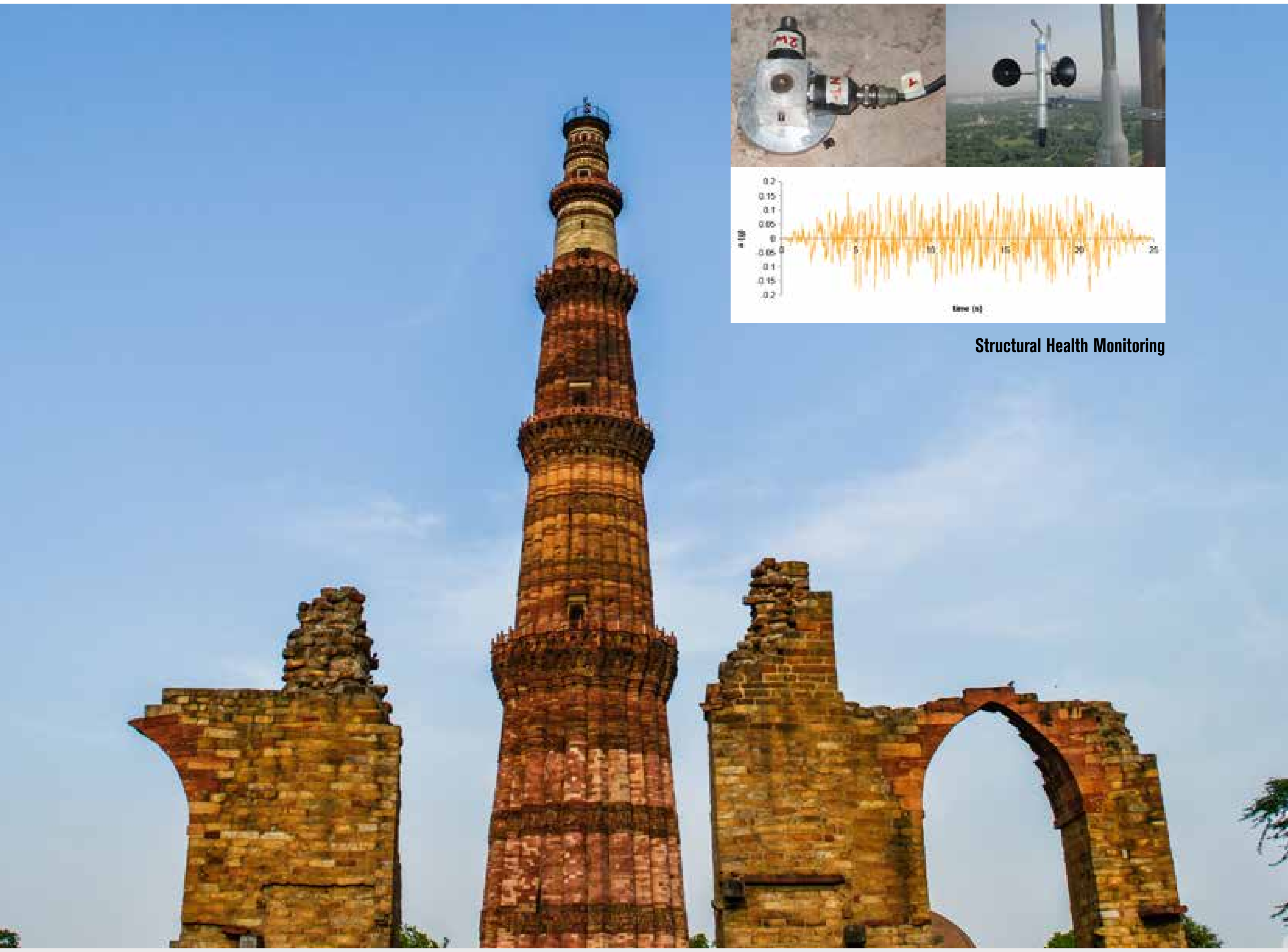
and ISO 13822: “Bases for design of structures - Assessment of existing structures” ANNEX I (Informative) Historic Structures).

The most recent advances of the research in the above mentioned fields, and the contents of the cited codes and recommendations are briefly presented, together with some practical case studies, making particular reference to a research project funded by the European Union in the ambit of the FP7, conducted by 18 partners from different European and non European Mediterranean area countries, and coordinated by the University of Padova (www.niker.eu).

A wide range of tools and methodologies are first of all available for the “assessment” phase of the real mechanical/structural characteristics of an historic building, ranging from in situ non destructive (NDT), minor destructive (MDT) and destructive tests (DT), to different structural modeling approaches (finite element models, discrete element models, rigid blocks analyses) and to combined numerical/experimental procedures (models identification and calibration, structural health monitoring).

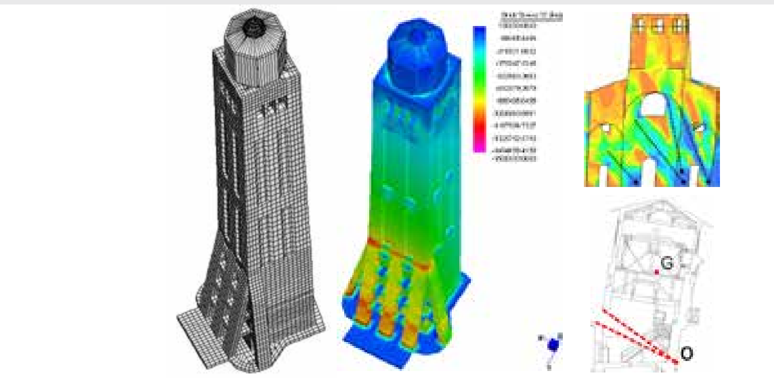
DT: in situ
destructve
shear and
compression
tests





Structural Health Monitoring

Then the variety of intervention technologies comes, specifically tailored for strengthening typical structural components (masonry walls and piers, arches, vaults, floors, roofs) made of different materials (catted and rubble stones, clay bricks, timber, cast iron) and to improve the overall static and seismic performances of an historic building.



Structural modeling via linear/non linear FE and rigid blocks limit analyses

Reinforced repointing using FRP rebars

Multi leaves stone masonry injection and transversal tying

Vaults strengthening by using natural/artificial fibers and lime mortars

Example of steel ties connecting intersecting walls

Case studies are then presented dealing with different structural typologies in different service conditions, like the Church in Venice or the fortress e in L'Aquila

Church of Santa Maria Gloriosa dei Frari
suffering severe damages
due to differential soil settlements

Spanish Fortress severely damaged
by the 2009 earthquake

Michele Taddei

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PECULIAR TECHNOLOGY FOR MASONRY STRENGHTENING

Over the last recent years a greater and greater attention to the existing building heritage and to the activities aimed to the preservation of both buildings with high architectural value and those belonging to the category of traditional buildings has been developed. Among the restoring interventions of existing buildings there are often strengthening works, in which one provides the embedment of metal anchors into masonry or wood: stitching of cracks, bonding between reinforcement metal anchors and the existing structures, tie-rod or reinforcement ring put to contain the action of pushing elements such as arches and vaults, connection between floor slabs and outside masonry walls, embedding of anchorages inside the walls in order to increase their resistance and the global behaviour of structures also for seismic upgrading. Modern researches, materials and operating technics permitted to develop a special technology that, remembering the functioning of traditional strengthening systems, guarantees the best results from technical point of view, complying with the existent and with the constructive logic of the building.

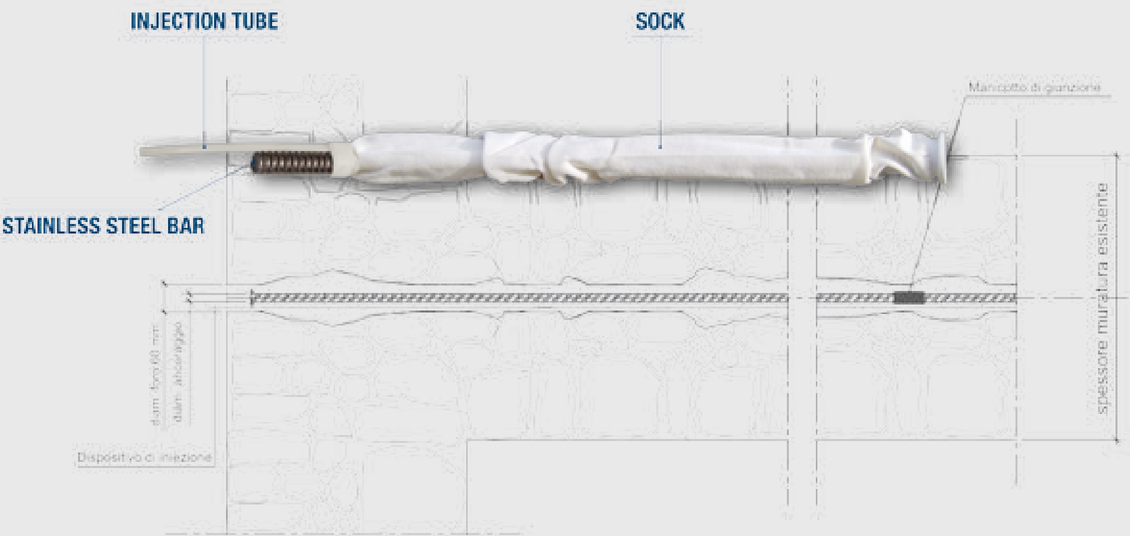


PALAZZO VECCHIO | FIRENZE



G-BOS, BOSSONG ANCHORS FOR CONTROLLED INJECTION

The system is composed by a strong element, a high strength stainless steel bar -AISI 304 or AISI 316- (ft nom 750 N/mm2 - fy nom 650 N/mm2), with full thread along the entire length. It is provided of a sock with the function of controlling the coaxially carried injection of the grout. These two elements, together with the grout, are fundamental to make integral the reinforcing element to the masonry. Besides allowing good injection operations, avoiding unexpected and often damaging spread of grout in voids and cavity that can be present in the existing walls, the sock guarantees the adherence of the injected material to the substrate throughout its entire length and a homogeneous distribution of stress thanks to both the adherence of injected material and the mechanical interlock that the injected grout develops with masonry. The line of anchors for controlled injection is complete with a range of accessories in AISI 316 stainless steel, couplers, turnbuckles, nuts, to fulfil the different needs of each project; Bossong can provide un-tensioned steel reinforcements, pre-stressed tendons, vertical anchors and anchors with every degree of tilt.



DIATONI AND DIATONOS, ARTIFICIAL TRANSVERSAL CONNECTORS

Ancient masonry building are usually made with stone or brick masonry multi leaf walls. The presence of transversal connectors, made of large stones placed transversally, necessary to create connections between masonry leaves, is an important parameter to assess the masonry quality and weakly connected masonry leaves needs to be strengthened, with the insertion of new transversal connection, to mitigate their seismic vulnerability. Compared with usual retrofitting techniques the use of artificial connectors made of a stainless rod inserted into a grouted fabric sleeve allows an immediately effective reinforcement: by injecting with pressure the grout, it is possible to increase bonding with masonry and restore the stress state in the area around the hole. The use of socked injected anchor as transversal connection also guarantees minimum impact on existing masonry thanks to reduced size of borehole diameter and to full control of injected grout that is completely contained by the fabric sleeve with no spread in void and cavity within the masonry.
The effectiveness of the artificial connectors can be improved by introducing a pre-tensioning procedure.
Thanks to the post-tensioning force, the reinforcement can act as an "active system," able to be engaged even for service loads and for low-intensity seismic activity, providing extra tensile strength to the masonry material. A further improvement can be obtained by providing a mechanical interlock between the new connector and the masonry substrate: the hole can be countersunk at both ends and the fabric sleeve, thanks to its flexibility expands, molding itself into the shape of the hole, thus providing mechanical as well as chemical bond.
The effect of pre-tensioning and countersinking produces a confinement of the masonry material and increase the level of connection between leaves.

SEISMIC DESIGN AND QUALIFICATION FOR ANCHORS

A correct design in seismic conditions considers how the building reacts during the earthquake. This means takes in account the displacements and deformation in its structural elements that cause the opening of cracks in the concrete components. For this reason, all anchors designed to transfer seismic loads must be suitable for use in cracked concrete and their design must be based on the assumption that the cracks in the basic material may have a cycle opening and closing all along the earthquake. This is in brief the principle on which the EOTA European standard (Organization for Technical Assessment) are based for the qualification and the design methods of post-installed anchors (mechanical and chemical) in seismic area: ETAG 001 - Annex E: guideline for assessment of metal anchors (mechanical and chemical) under seismic action. EOTA TR045: design of metal anchors for use in concrete under seismic actions up until the Eurocode 1992-4 become effective. Specifically, two test protocols are identified depending on the seismicity of the area and the class of importance of the building on which work has to be performed (please see the table below). The levels are: C1 only for non-structural uses and for levels of low seismicity. C2 for structural uses and non-structural uses and for all levels of seismicity. The C1 test protocol includes everything that is recommended already in the United States regulatory document ACI 355-2 and provides 10 tests to be performed with tensile and shear seismic simulation for every diameter of the anchor to certify. On the other hand, the test protocol C2 is stricter and provides a minimum of 30 tests per diameter and tests in which the anchors are qualified for the load cycling and in cracks up to 0,8 mm in width by simulating the inversion of the moment through the active compression of the concrete around the anchor. As you can see country with seismic importance as Italy are almost completely in the category C2. For this reason, Bossong S.p.A. was one of the first companies in Europe to focus on this qualification for its products in order to offer reliable and safety solutions also in earthquake situations. Bossong range of products selected for fixing in seismic area has, as top products, two chemical anchors: EPOXY21, pure epoxy resin, ETAG 001-5, Option 1, Seismic Annex E-C2. Leed tested, Fire resistance test, InPP Underwater test, COV etc. V-PLUS, vinylester resin styrene free, ETAG 001-5, Option 1, DTA Sismique ReBar. Leed tested, Fire resistance test, InPP Underwater test, COV etc. In Bossong range of products you can find also mechanical anchors specific for fixing in seismic area as SZ e B-Zplus ETAG 001-2 Seismic C1 e C2. Swiss Shock approval, Fire resistance test, ICC-ES approval etc.

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THE TRAJAN MARKETS AND THEIR GREAT HALL

The Conservation Problems and the Structural Intervention for the Improvement of the Seismic Safety

INTRODUCTION

The Great Hall Vault of the Trajan Markets is one of the largest and very impressive among the survived original roman vaults. It is made by roman pozzolanic concrete with a very thick shape which allows a nearly monolithic behaviour, just reduced by the possible negative effects of many cracks. But the weaker structural elements, in case of seismic actions, are the supporting structures. These last are today not sufficient and/or not sufficiently laterally counteracted to resist to the horizontal actions associated to seismic effect on the Great Vault mass.
On site investigations have been devoted to the identification of the geometry of the main structural parts and elements as well as of the mechanical features of the constituting materials of the Great Hall Vault and of its supporting structures. These surveys have suggested to carry out some numerical analyses which have shown the weak behaviour of the supporting structures. Thus it was designed, numerically verified and finally applied an adequate retrofitting intervention, based on the use o reversible techniques.

THE STRUCTURE BEHAVIOUR BEFORE THE RETROFITTING

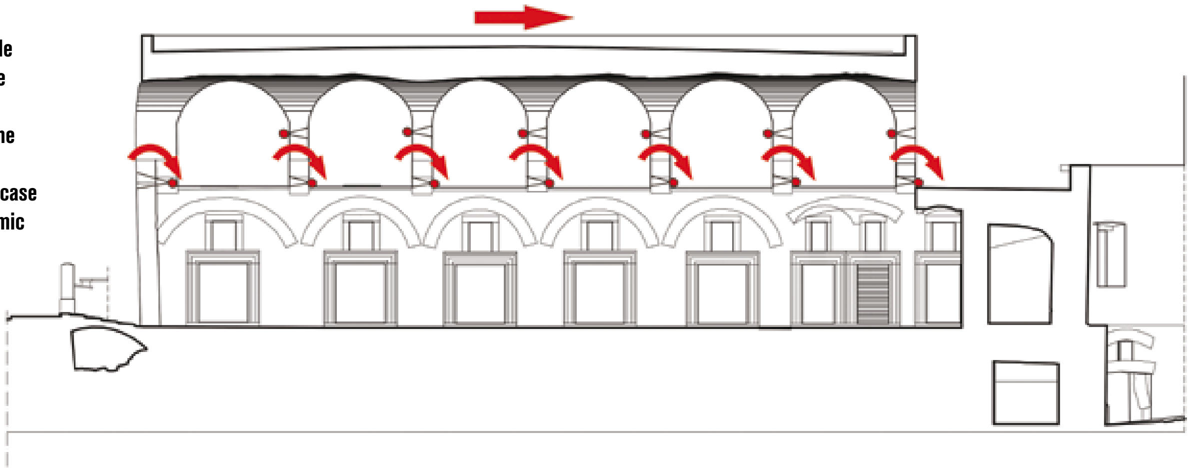
The transversal behaviour and the crack patterns

The Great Hall structures, that surround and contain the Great Room, only apparently from a thick body with a squared plan; on the contrary they are two bodies, separated by a Great room itself (Fig. 1). These two buildings develop their plan parallel to the Great Vault axis, in the NE-SO direction. Thus, both of them are weaker in the transversal NO-SE direction.
Among them, the northern one appears more sound as it is less high and transversally thicker.

Fig. n. 1 The Great Room, in the centre, which divides the Northern building, on the left, from the Southern one, on the right; note the lower level of Via Biberatica respect the Hall

Fig. n. 2 The Southern building weak behavior and the collapse mechanism in case of transversal seismic action

Fig. n. 3 The possible overturning collapse mechanism of the pillars supporting the Great Vault, at the “matronei” level in case of longitudinal seismic action



Vice versa, the Southern one is thinner and higher as it starts from the level of Via Biberatica (Fig. 1).
The weaker conditions of the Southern building is clearly shown by the crack pattern, also, with a tendency to the detachment of the Southern façade on Biberatica Street. Moreover it is necessary to take into account that these two buildings have to support the big mass of the Great Hall vault, under static and seismic actions too.
From this point of view, it is important to notice the weakening of the transversal wall, in the Southern building, caused by the doors placed near the Southern façade, at the same level of the Great Hall pavement.
The seismic action of the past, are the causes of the cracks on the arches over the doors said before and of the cracks on the transversal walls, in the lower level, just under those doors and near the southern façade; cracks that show a clear weak condition under the Great Vault thrust (in NO-SE direction) with also a clear tendency to a detachment of the Southern façade on Biberatica Street (fig. 2).
It must be taken into account that, before the retrofitting, the transversal seismic acceleration of the Great Vault mass is alternatively supported only by the Southern building and only by the Northern one (changing the sign of the acceleration itself); as it is easy the arise of hinges in the key and in the springing of the Great Vault (Fig. 2).
Moreover, this behaviour may be accentuated by the different transversal stiffness of the two building, as this difference can easily cause opposition of phase in the transversal oscillations of the two buildings.

The longitudinal behaviour, parallel to the Hall axis

The seismic action longitudinal component founds a very weak structural configuration of the supports at the “matronei” level.
All the supporting pillars and the counteraction lateral arches have their main stiffness planes in the transversal direction while the weaker ones are in the longitudinal direction (Fig. 3). It is important to notice that the present masonry structural configuration is due to the restoration works carried out in the twenties and thirties of the last century, when they were demolished all the not original roman masonry added along the centuries and

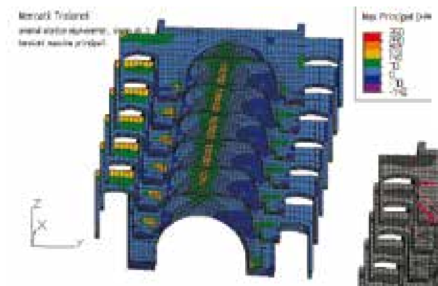



Fig. n. 4 a/b The maximum principal stresses in the Vault and in the pillars with the transversal static equivalent seismic action

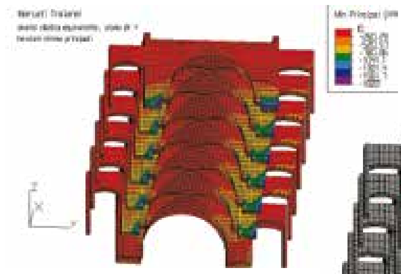
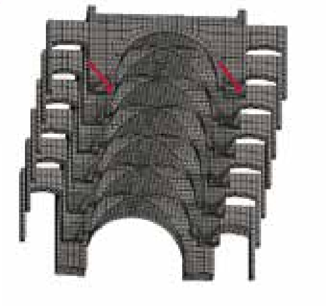



Fig. n. 5 a/b The minimum principal stresses in the Vault and in the pillars with the transversal static equivalent seismic action

especially in the XVI century. Thus, and especially at the "Matronei" level (Fig. 3), the structure is weaker than in the period from XVII up to the XIX centuries and also weaker than the original configuration, as some roman structural elements (some secondary vaults) are disappeared, along the past centuries.

The numerical analysis

The analytical study of the vault and its surrounding structural elements was carried out by means a numerical 3D model developed for the static and dynamic structural behaviour evaluation, using the Algor program produced by Algor Inc.
The 3D Finite Element mesh is refined in such a way to describe with an adequate accuracy all the constructive details, using 3D "brick" finite elements.
In Table 1 the material mechanical characteristics (specific weight, Young Modulus and Poisson coefficient) used for the different part of the structures are reported.
About the seismic spectral acceleration, the present Italian Code states a ground acceleration of around a=0,192g at the building foot, which means an amplified acceleration of around a=0,260g at the Great Vault level.
In the Figures 4 and 5 are reported the results of the seismic static equivalent analysis in the transversal direction while in the figures 6 and 7 are reported the static equivalent analysis in the longitudinal direction.
In the figure 4, all along the intrados of the vault key there are tensile stresses that reach the 210 KPa and justify the deep and large cracks visible before the last restoration.
It is important also to notice in figure 5 the strong compression stresses in the foot of the short pillars supporting the Vault: the minimum principal stresses reach the 1822 KPa.

Table 1. Material mechanical characteristics

Material	Weight [kN/m^3]	Young Mod. [kPa]	Poisson mod.
Caementicium	15	2.000.000	0,15
Travertine	24	20.000.000	0,10
"cocciopesto" Mortar	18	200.000	0,20

However the worst situation arise with the seismic action in the longitudinal direction. The static equivalent analysis reported in figure 6 shows the risk of overturning for the pillars engaged along their weaker section axis: the vertical stresses reach 1142 KPa in the compressed side; while reach 311 KPa in the side on tensile stress. The little arches that laterally counteract the vault (figure 7) are unable to resist to the longitudinal seismic action, as in this case they are bent horizontally reaching tensile stresses up to 350 KPa.

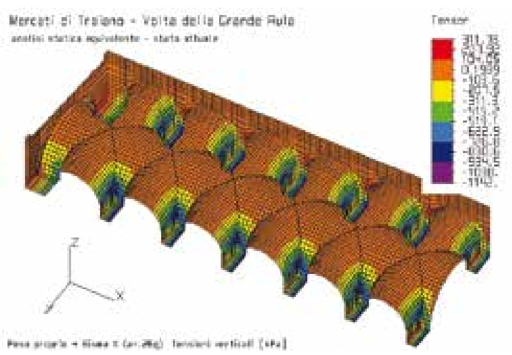
THE REINFORCEMENT INTERVENTION AND RETROFITTING

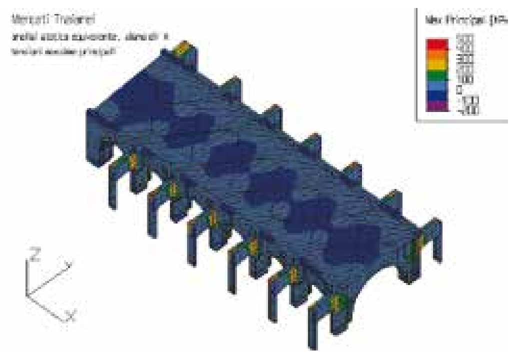
The intervention philosophy

Evaluating the opportunity to "improve" structural behaviour seismic behaviour of an historical building, it is important to study its global structural behaviour, but it is also necessary to check if each structural element may compromise, with localized failures, the structure as a whole.

In the case of the Trajan Markets Great Hall, there is a clear "global" weakness in the transversal structural behaviour, due to weaker configuration of the Southern building, in case of seismic actions in NO-SE direction; but, in the same time, there is a "localized" weakness of the pillars supporting the Great Vault in case of seismic actions in NE-SO direction.

Fig. 6 a The vertical stresses in the pillars with the longitudinal static equivalent seismic action





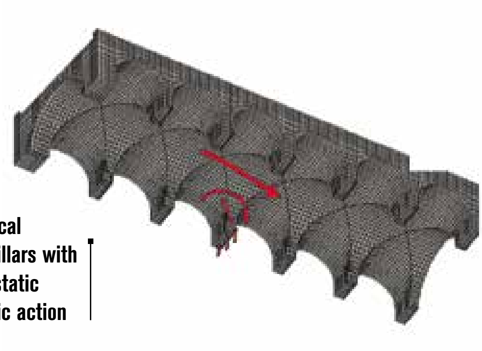


Fig. 6 b The vertical stresses in the pillars with the longitudinal static equivalent seismic action

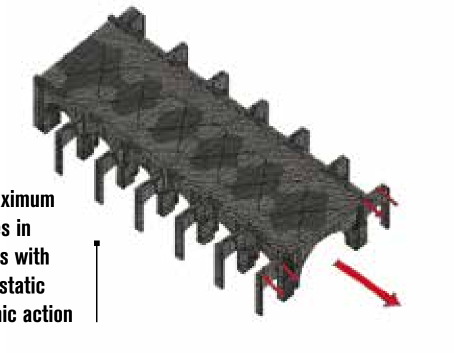
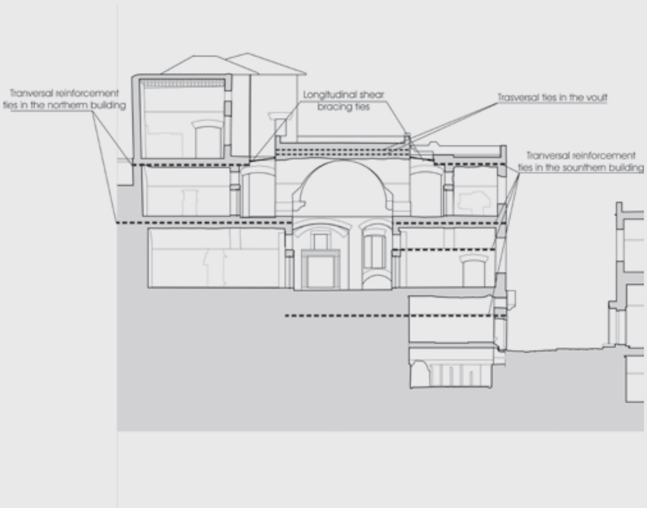


Fig. 7a/b The maximum principal stresses in the lateral arches with the longitudinal static equivalent seismic action



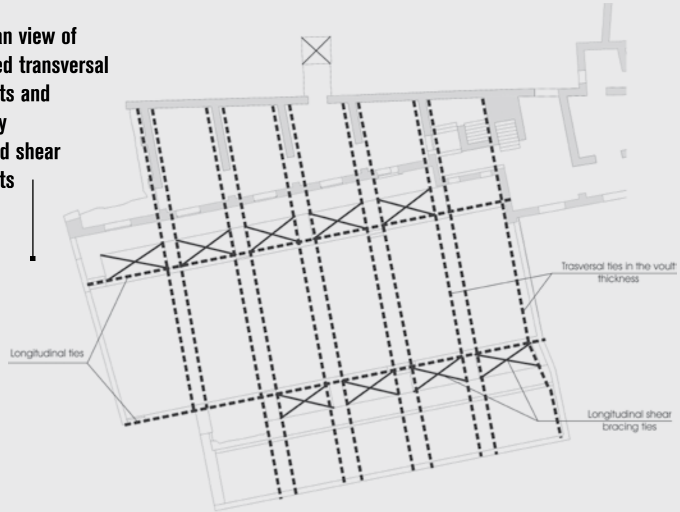


Fig. 9 The plan view of the distributed transversal reinforcements and the diagonally counterbraced shear reinforcements

Fig. 8 The distributed transversal reinforcements at the different levels

The failure of only one of these pillars may cause the collapse of all the Great Vault. In the case of historical buildings, the seismic behaviour improvement has to be obtained with the minimal alteration of the original structure.
Thus it is better to apply a “diffused” and reversible intervention instead of a more strong and concentrated one, which last is necessarily more invasive and, thus, also less reversible. A “diffused” intervention has to be extended as more as possible to all the structure, in such a way to better connect the different structural elements, to guarantee their collaboration and, thus, to use more efficiently the original strength.
On the contrary, too localised interventions may cause the alteration of the original global behaviour, more higher stresses concentrations and, thus, also possible local damages. In the case of the Great Hall, for the transversal (NO-SE) seismic component, it was necessary a “diffused” reinforcement of the shear walls, mainly in the Southern building.
At the same time, for the longitudinal component (NE-SO) of the seismic actions, it was decided to not to try the reinforcement of the single pillars supporting the Great Vault; on the contrary was designed a shear braced horizontal stiffening to connect. Both the sides, the vault mass to the Northern and the Southern buildings.

The transversal reinforcement

The intervention is a system of horizontal ties, distributed on each transversal wall of the two buildings supporting the Great Vault, in such a way to improve their shear strength in the NO-SE direction. More in detail, in the weaker Southern building these ties are distributed not only on each shear wall but also on each level, as shown in figure n. 8.
Moreover, as shown in figure 9, for each shear wall it is placed a couple of bars nearby each side of the wall itself, instead a single one, in such a way to be less invasive, avoiding to drill horizontally those walls for all their length. To guarantee the collaboration of both the buildings in counteracting the Great Vault mass thrust during a seismic action, they are placed horizontal connections over the two series lateral arches among the two buildings and the Vault itself. Then they are placed also some ties, across the Vault, inside its thickness, also to counteract the effect of possible not in phase transversal oscillations of the

two buildings. Thus it is placed a system of horizontal distributed ties also in the Northern building, but only at the III and IV level, in such a way to involve its transversal shear walls all along their length. The distribution and the number of these ties placed in the two buildings and in the Vault, allow to reduce their diameter down to 22 mm.

The longitudinal diagonal braced shear reinforcement

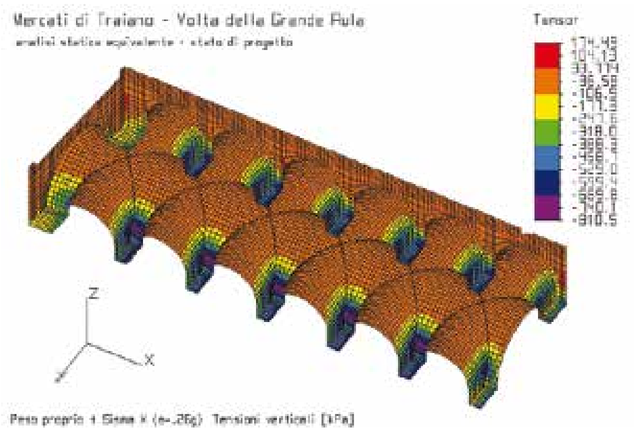
The intervention is a system of nearly horizontal stainless steel diagonally counterbraced shear reinforcement, placed in the free spaces among the Great Vault and the lateral buildings, just over the "matronei" level (Figures 8 and 9). This shear reinforcement is designed in such a way to transfer to the two lateral buildings, parallel to the Hall axis, the main part (around the 65%) of the longitudinal seismic action involving the Great Vault mass, reducing the overturning moment on the pillars supporting the Vault itself. Four free spaces on each side are occupied by the diagonal counterbraced reinforcement and each diagonal is made up by two tie bars with 22 mm of diameter (figure 11). Thus during a longitudinal seismic action 16 diagonal braced tie bars work together at the same time.

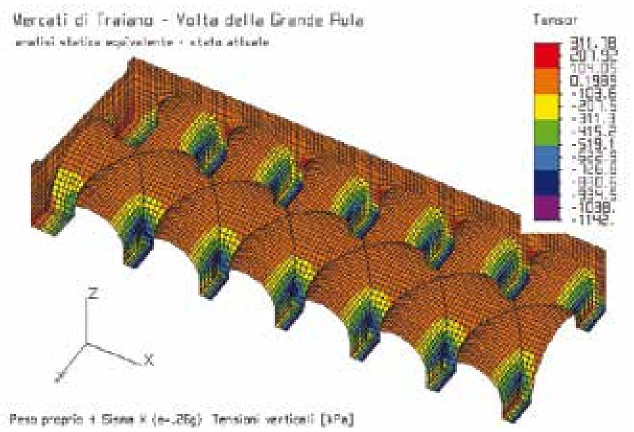
The numerical analyses

The numerical model, which simulate the reinforcements through stiffening boundary elements along the two longer side of the Great Vault, show a clear improvement in the Vault structural behaviour. Particularly in figure 10 is reported the stress reduction in pillars supporting the Vault, in case of longitudinal seismic action: compared to the case without reinforcements, the static equivalent analysis shows as the vertical stresses are reduced from 1142 kPa to 810 Kpa, on the compressed side, while the tensile stresses are reduced from 311 kPa to 174 kPa.

Fig. 10 a The vertical stresses in the pillars after the intervention on the left, and without the intervention on the right

Fig. 10 View of the southern lateral longer side of the Great Vault with the diagonally counterbraced shear reinforcements placed in the free spaces between the Vault itself and the Southern building, nearly the ending of the work





Conclusions

The Trajan Markets Great Hall shows a high sensibility to seismic actions.

This fact is due to the weakness of its supports: the weak structural behaviour of the Southern building, in case of transversal actions, and the weak behaviour of the pillars at the "matronei" level, in case of longitudinal actions. While in the first case there is an indirect risk of collapse for the Vault, related to the possible partial failure of the Southern building, in the second case, with the longitudinal component of the seismic action, there is an immediate risk of collapse of the Vault as a whole, related to the easily overturning of the pillars. The intervention designed and already applied, with its "distribution" calls the collaboration of all the supporting structures, reducing the efforts of the single structural elements.

In this way, avoiding stresses of this intervention typology is a warranty for the possibility to use the future probable improvements in the retrofitting techniques.

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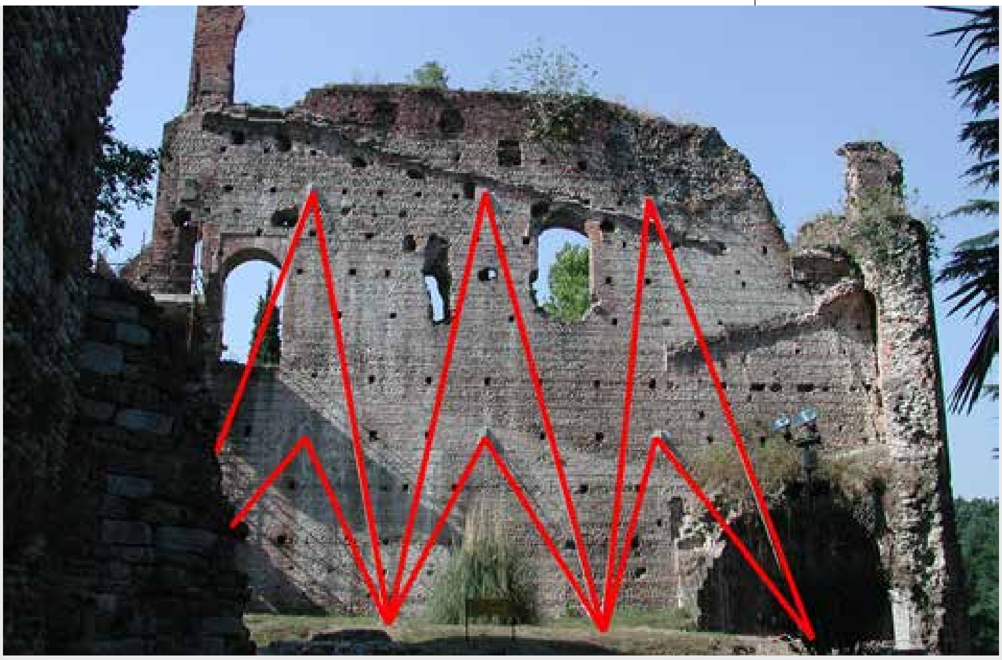
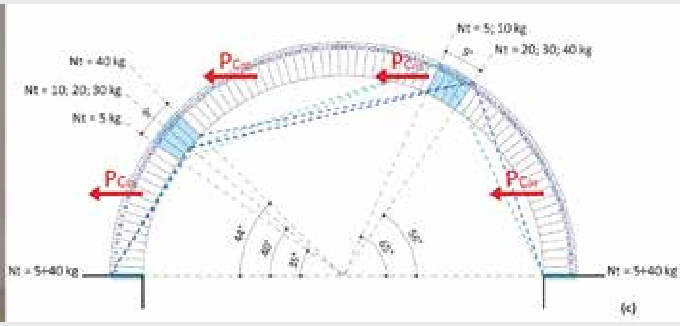
ARCHITECTURAL RESTORATION AND SEISMIC REINFORCEMENT OF HISTORIC BUILDINGS

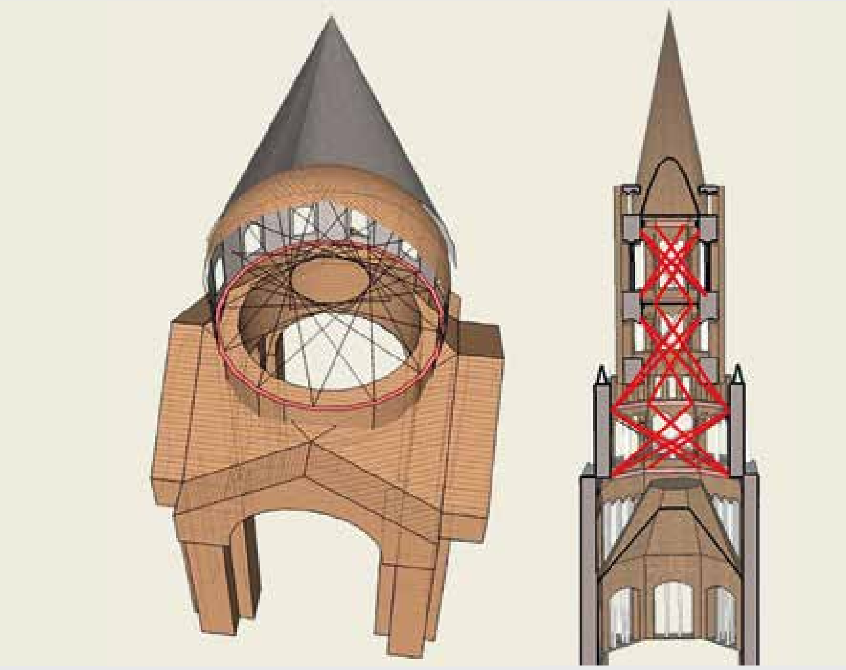
The adjectives “necessary, focused, minimum, optimum, lightweight, compatible, durable, inexpensive and reversible” are all criteria very often required in a structural consolidation project concerning historical heritages.
On this last term, “reversible”, I believe that in close etymological sense no intervention can be defined “completely reversible”, since, even after its removal, the building will preserve memory and traces of the past. However, it should be appropriate to accept and include the concept of “reversibility” into the design process.
Furthermore, I suppose that the consolidation intervention must manifest itself only to those who want to see it, but should remain subdued for those who prefer the original image of the building.
Lastly, but of course not less important, the intervention must be structurally effective in response of vertical and horizontal loads, especially seismic ones.
Thus, the “way” to perform the intervention becomes the fundamental question to ensure the unrepeatable originality of the historic monument.
Geometry, materials and loads are the mechanical parameters that characterize the building, involving the resistance and the stiffness of the whole structure after a consolidation intervention.

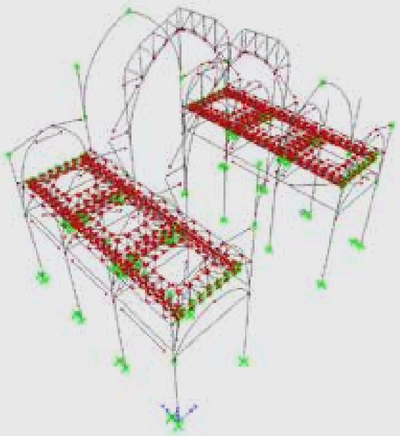


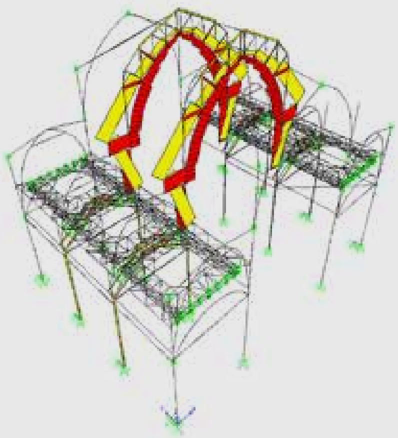
The most common trend among designers is to propose changes to the geometry or the materials, but very often changes to the loads would be easier and more effective to be implemented.
For example, it's well known that placing an archive on the ground floor instead on the first floor, or adding new loads on a vault, to be symmetric or opposed to existing ones, or simply better distributing the new loads on a floor, could be the optimal solution and the most affordable.
In the last decades, the experiences of the author in the field of consolidation of ancient buildings have demonstrated that exist some alternative ways of intervention, that act on loads for strengthening the structure. Some of them are here described, sending to the website www.jurina.it for detailed information.
First, it must be highlighted the importance of temporary consolidation of historic buildings, mainly if not in use or even in ruins. These are frequently subjected to structural instability that causes serious and irrecoverable losses of precious antique materials and sometimes causes risks for people nearby the building. There can be also situations of post-earthquake damage that require interventions for structural safety, where efficacy, easy operability as well as cheapness are needed.
The most usual safety systems make use of props or scaffoldings which, although providing versatility and good resistance, at the same time can be bulky and do not allow free access to the building.
As an alternative to scaffolding, the use of steel stay cables can ensure an adequate level of safety and a reduction of lost space. Some example are represented by the masonry wall of Trezzo sull'Adda (Milan- Italy), the temporary encirclement of the Torrione di Cassina de'Pecchi (Milan- Italy) and a proposal for Pompei Regiones (Italy).
As a further possible solution, in recent years, polyester straps offer excellent confinement possibility, incrementing resistance to traction, with the possibility of pre-tensioning the system by means of "ratchets", so that an immediate and active intervention can be obtained.

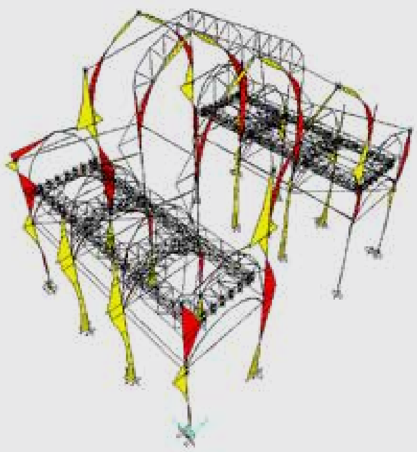


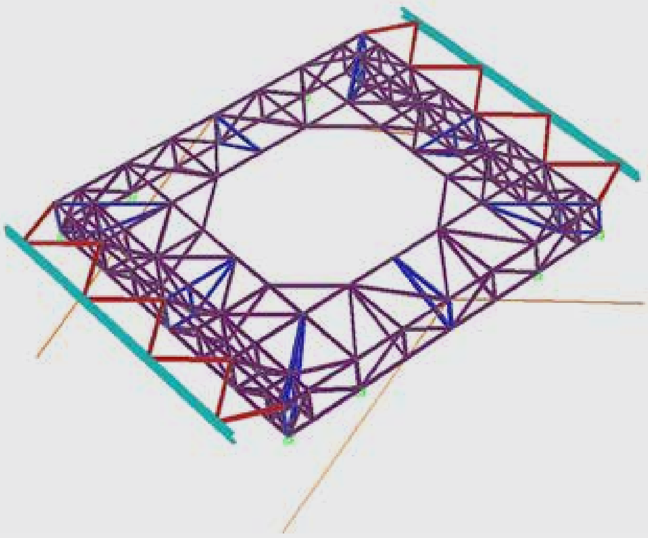
Some applications of this technique were realized for the dome of Villa Arconati in Bollate (Milan- Italy), for the tower of Masserano Palace in Biella (Italy), for Gorani tower in Milan and proposed for the ancient tomb of Imedghassen in Batna (Algery).
Regarding the definitive consolidation of arches, vaults and domes it has been developed by the author the so called "RAM – Reinforced Arch Method". The solution consist in modifying the distribution of loads acting on the arch, vault or dome so that the combination of the old loads plus the new loads could become the "right one" for the given and known geometry of the masonry structure.
Steel tensioned cables, placed at the intrados or extrados, give rise to a distribution of radial forces applied to the surface of the arch, whose value depends on the local curvature. This new load distribution induces a pure axial compression between the blocks so that the thrust line is re-centered, such avoiding or retarding the formation of plastic hinges.
Large scale experimental tests were conducted to measure the improvement of safety obtained with the adoption of RAM Method. More than 500 tests were undertaken by the author, where the arches were subjected either to vertical loads or to horizontal-seismic loads.

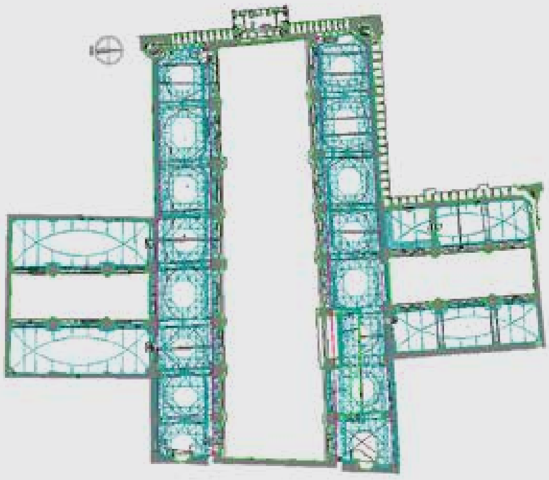




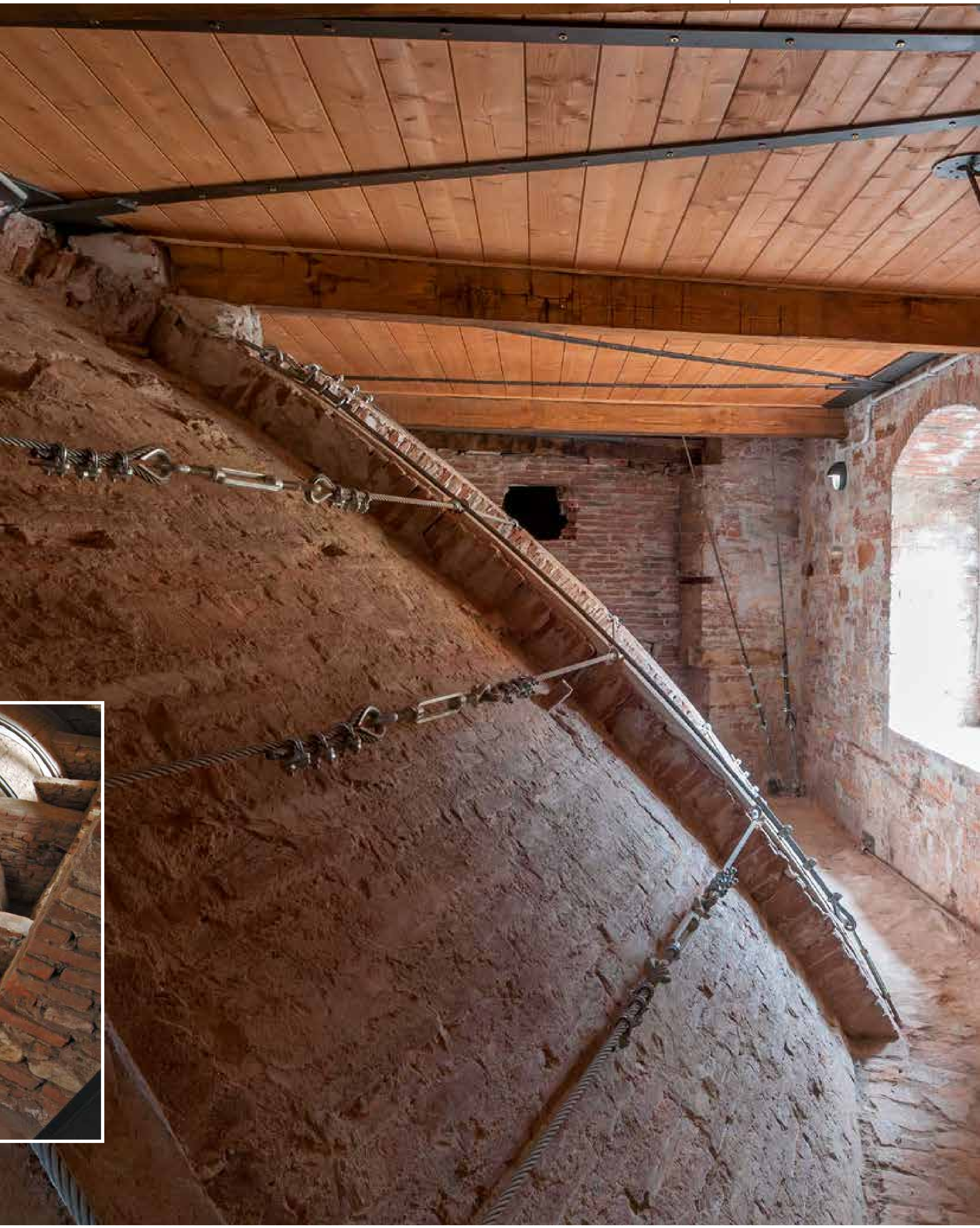








Tests showed that the RAM technique induces a significant increase of the collapse load and of the ductility.
Recently, the RAM solution was adopted for the consolidation of the dome of Santa Caterina church in Lucca (Italy), in the consolidation of Cremona Cathedral, of Colorno Cathedral (Parma - Italy), for the depressed vault of Galleria dei Poeti in Masino Castle (Turin-Italy) and proposed in many other situations.
Another solution for the consolidation of masonry arches, vaults and domes is represented by the so called "Graffetta Method". The clamp is composed by an horizontal element (a steel rigid beam, stiff enough to support bending moment) and two inclined ties, tangent to the arch, inserted in the abutments. Ties are able to contrast the horizontal thrusts of the arch, preventing the formation of plastic hinges. "Graffetta Method" was applied to Cremona Cathedral, Manta Castle and Masino Castle (carriages room).
Even high isolates walls, or slender structures, typical of many historical buildings, are particularly vulnerable when subjected to horizontal seismic loads.
This is another interesting challenge that the designer is called to deal with. Thus, the use of diagonals stays and "light diaphragms " made by steel cables can be a solution able to brace the cantilever and to give it back the necessary structural safety. Examples include the Forte Fuentes in Colico (Italy) and the proposals for the bell tower of the Abbey of Chiaravalle Milanese (Italy) and Echmiadzin (Armenia).
Finally, a recent proposal refers to the consolidation of masonry columns through the insertion of a circumferential thin stainless wire, tensioned, stretched inside the joint between the bricks. This addition, very simple and minimally invasive, significantly increases the ductility and strength, without modifying the stiffness of the masonry columns and, from a formal point of view, it is particularly respectful of the existing material.



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CARPI CATHEDRAL. DOME ANTI-SEISMIC REINFORCEMENT

Stabilisation and anti-seismic reinforcement for the Assumption Cathedral, damaged by the earthquake, with the reinforced plaster technique on the dome

A jewel of Renaissance architecture, the Assumption Cathedral was built starting in 1514 by the will of Alberto Pio, humanist prince and patron of the arts, and under the supervision of the Sienese Peruzzi, who made use of Bramante and Raffaello's ideas for the construction of St. Peter's Basilica in the Vatican. Construction work continued throughout the 1600s and 1700s (the dome was built in 1768), and the Cathedral underwent refurbishing and renovation also during the nineteenth century. Currently, the oldest parts, i.e. the 16th century ones, still feature the classical style envisaged by Peruzzi, and also include the 17th century addition of the three naves.

ANALYSIS OF THE DAMAGE

Although it retained its overall integrity, the Cathedral suffered extensive damage during the 2012 earthquake that made it unfit for use and led to the closure of an entire block of Carpi's historic town centre.
The facade and the dome suffered the most serious damage. The facade was shaken by an outward motion that caused clearly visible horizontal cracks in the responds and the tympanum. The summit cross, although tied with a steel cable to the underlying wall, fell on the back of the facade, breaking through the wooden roof and the underlying brick ceiling near the main entrance.
The surface wave motion also resulted in part of the masonry falling out of the two buttresses on the counter facade and the collapse of the four spherical ornaments of the facade, leading to the collapse of two other roof portions. The dome turned out to be the most extensively damaged element, both in terms of dangerousness and extent.
The dome underwent a previous structural consolidation (internal chaining to support the inner ceiling), the shaking of the earthquake caused the point of least resistance to break (near the large window located south-east: collapse of the lintel and wall below), where there are also two X-shaped shear cracks. Furthermore,

the masonry placed over the internal ceiling fell out, also featuring a vertical crack. The side naves show a number of detachment cracks due to the east-west motion of the building in the arch connecting the ceiling of the central nave and the aisles. In the face of such damage, an instrumental diagnostic survey and remodelling of the structure has made it possible to prepare a project for consolidation and seismic improvement in several stages, concerning both the dome and the masonry ceilings.

OPERATIONS ON THE CEILINGS

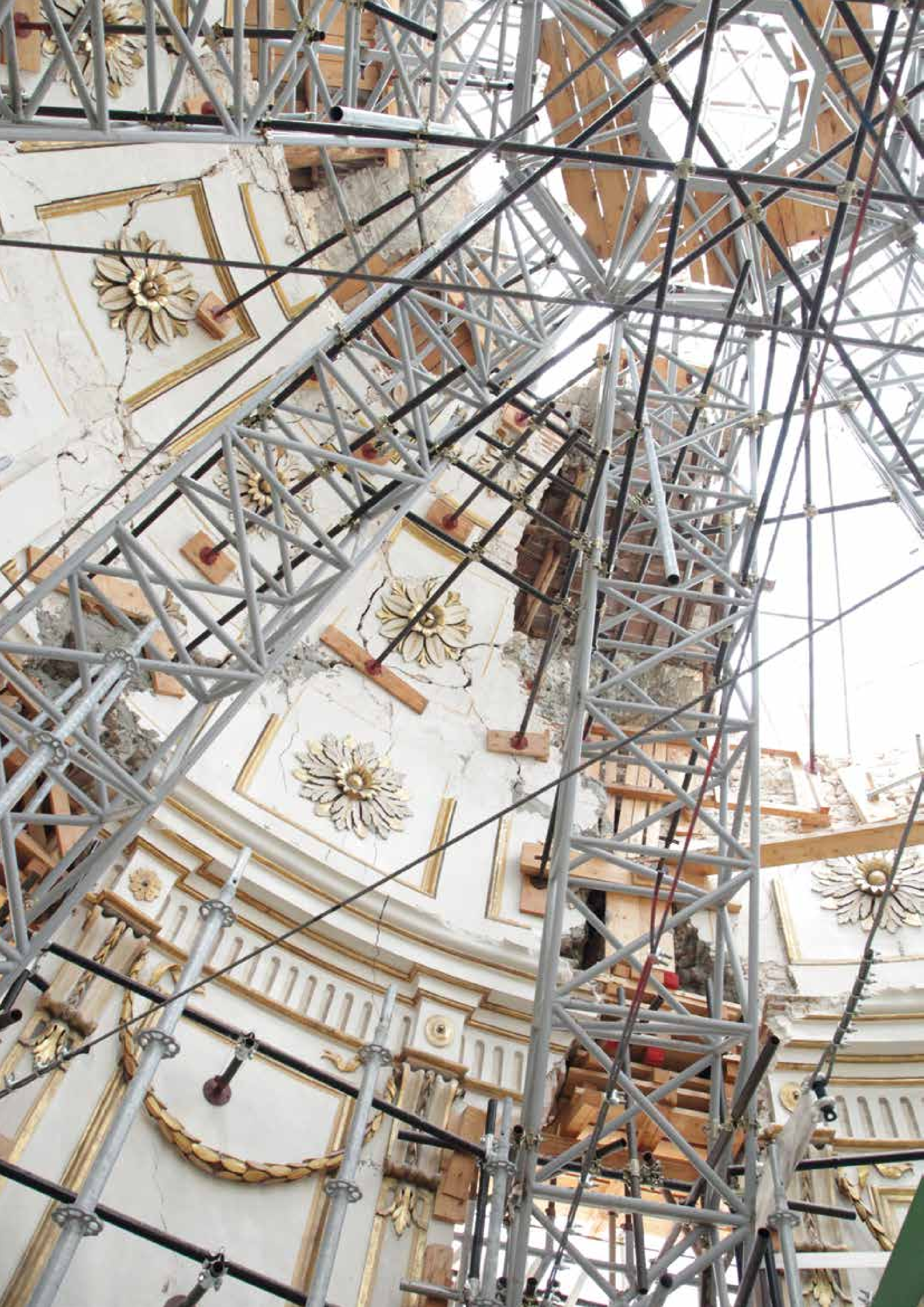
To mechanically improve the ceilings it was decided to use the BETONTEX®-EPOXY system consisting of Carbon Fiber Reinforced (CFRP) reinforcements, able to absorb the tensile stresses induced by the horizontal forces that are generated in seismic conditions, assuring an improvement in the structural behaviour of the ceilings without undermining stability. Polymeric matrix fibre-reinforced products based on continuous carbon fibres (CFRP) are anisotropic composite materials, which show a predominantly linear elastic behaviour up to collapse. Application of this type of reinforcement has assured adequate seismic improvement with the main features being lightness, high mechanical performance and anti-




corrosion properties. The CFRP system has adapted perfectly to the setting, respecting the original structure of the building of historical interest and minimising invasiveness issues in the masonry, with easy installation in the limited installation space available to operators and assuring outstanding results in terms of safety. Since the substrate was degraded, inconsistent and non-planar, it was necessary to proceed with the removal of the deteriorated part and subsequent application of mortar 25 mpa compression resistance, to assure adequate mechanical surface resistance of the substrate on which to apply the carbon tapes. Impregnating the fabric is an important stage for effectiveness of the reinforcement since the resin that the matrix consists of has the purpose of transferring the stress to the fibres. These operations, in fact, were entrusted to a specialised team, adequately trained. The operation was carried out by installing 750 linear metres of unidirectional 300 gr/m2 carbon tape in 20 cm strips, following the layout indicated by the structural project and according to the required installation cycle. In particular, after application of the epoxy primer, a first, thin layer of impregnating thixotropic resin was laid. Subsequently, the unidirectional carbon reinforcement was laid, taking care of running the “bubble roller” over the entire surface to completely remove the air between tape and ceiling surface. Finally, a second layer of impregnating resin was laid. Connections between the tapes and the masonry are further assured by the application of carbon fiber connectors.

OPERATIONS ON THE DOME

The basic criteria for design choices in dome reinforcement was to carry out a “widespread” operation on the entire surface maintaining the principle of minimal invasiveness to respect the building’s history, i.e. not only preserving the original materials but above all without changing the existing structural behaviour, with the aim of assuring a significant improvement with regards to behaviour under shear actions. The operation was carried out using the reinforced mortar technique, RI-STRUTTURA SYSTEM, made with Glassfiber Reinforced Polymer (GFRP) net 66x66mm mesh to be installed with GFRP corners and connectors. The system was selected taking into account the priority to assure, in addition to the necessary mechanical and resistance performances, the required durability of the installation upon changed climatic conditions as well as breathability of the areas concerned by the installation. The structural reinforcement was carried out by installing the GFRP mesh on the dome’s internal walls together with natural lime mortar.



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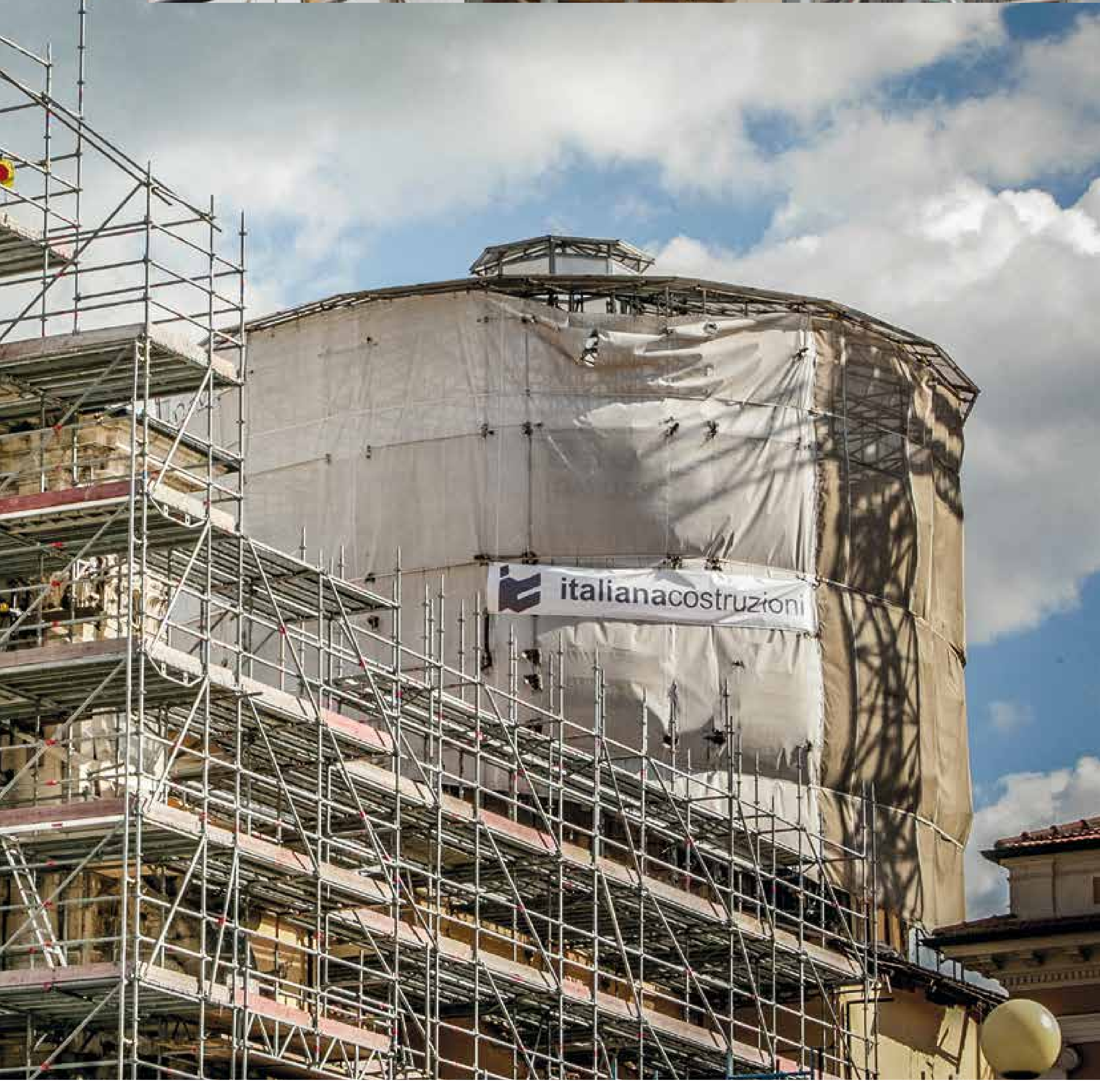
ENHANCEMENT AND PROTECTION

The Project of salvation, consolidation and restoration of the church of Santa Maria del Suffragio

The Church of Santa Maria del Suffragio, called by the people "of the Holy Souls" is an eighteenth-century religious building located in Piazza Duomo in the city of L'Aquila. A quick chronicle shows how the Church occupies a special place, both in terms of religious and historical importance, among the religious buildings in L'Aquila; many in fact have been seriously damaged by the earthquake of 1703 that are restored, partially rebuilt, modified or modernized but always taking into account the initial construction. The Confraternity of the Suffrage, with its modest headquarters in Via Roio, obtains instead the authorization to build a new building on the main square of the city, in the same square of the cathedral. The construction of the building was carried out in three main stages, alternating finishing operations with decorations according to the financial resources of the Confraternity.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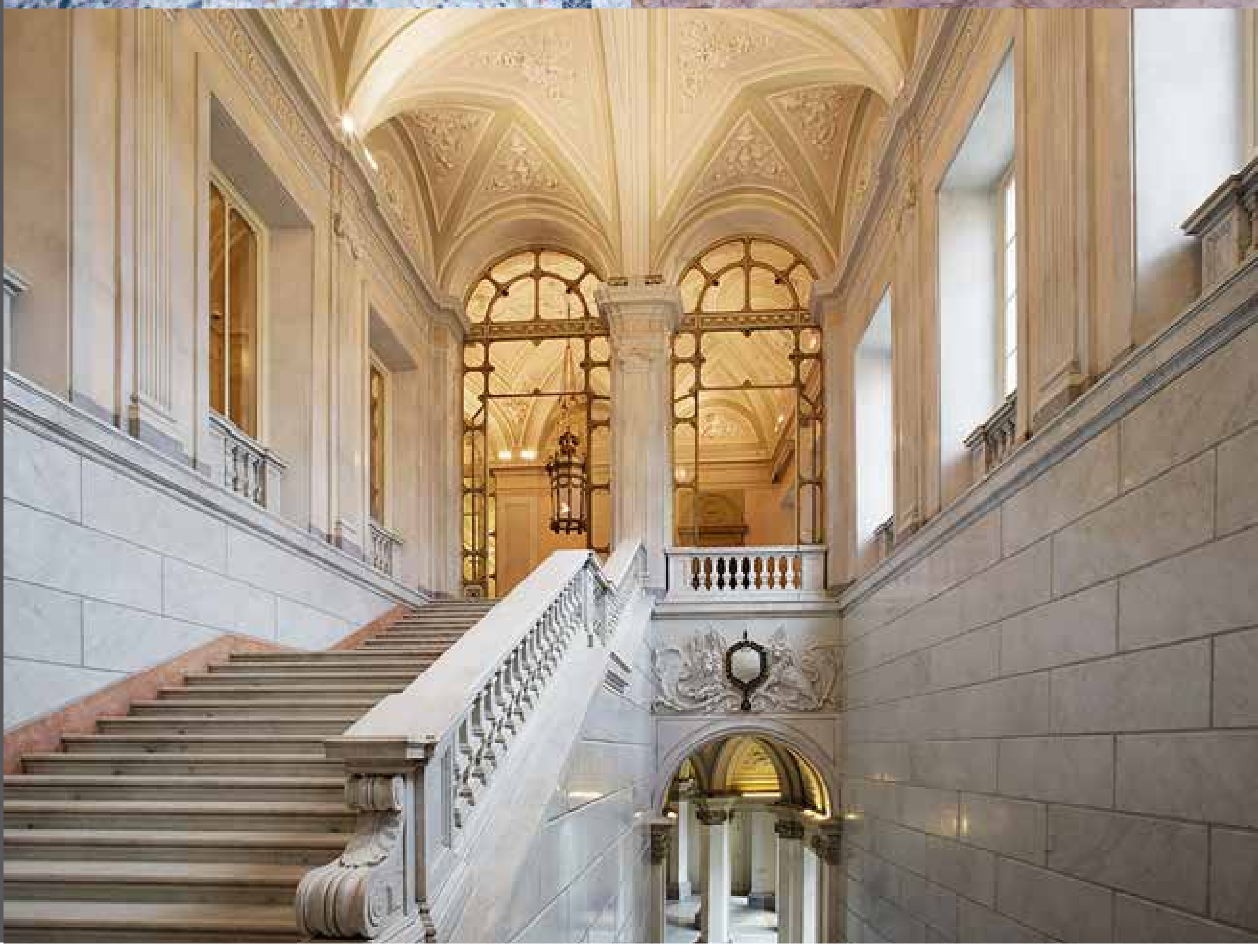
The restoration and rehabilitation of Monza's Villa Reale and its gardens

Due to the mentioned requirements of functional self-sufficiency the project involved completion works of the stairs in the southern wing confining with the Main Building, so as to make them accessible to the visitors of the Central Body. The main goal of the work was to combine the ancient historical and artistic elements of the central body of the Villa with features that could support the economic intervention. This way, in parallel to the refurbishment of the historic rooms on the noble floors of the main building, the project included the following interventions:

1. the requalification of the Belvedere floor with the selection of new intended uses
2. the regeneration of the spaces on the ground floor functional
3. adaptations for a new enjoyment of the Villa.




SEMINAR IN ISFAHAN
اصفهان
10-12
DECEMBER 2016
RESTORATION
& CONSERVATION
OF DECORATIVE
SURFACES
(ORNAMENTS)
COLLABORATION
BETWEEN ISFAHAN
UNIVERSITY OF ART

NEXT MEETING IRAN

quaderni di assorestauro

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