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RESTORATION OF HERITAGE MASONRY BUILDINGS

Binda L.[1]

ABSTRACT

Restoration of heritage masonry buildings has been in the past until the sixties a job for few experts. The damage to historic buildings due to the last earthquakes, their decay due to lack of maintenance and aging have now involved in the design for restoration a great number of architects and engineers; as a consequence there is a great need for guidelines and codification for testing and application of various techniques for conservation so as for training and teaching .

After a discussion on the damage and on the decay which occurs in historic buildings, reference is made to research initiatives in the various countries. A diagnosis on the state of damage should be the first step to the design for restoration, through in-situ and laboratory survey and mathematical modeling. The choice of the type of intervention should be made after studying previously the adequacy of the technique to the real need of the building; a subsequent control of the effectiveness of repair or strengthening should be carried out using NDE when possible. The existing codes and recommendations and the future development and necessities are then discussed.

1 Prof., Department of Structural Engineering, Politecnico di Milano, Piazza L. Da Vinci 32, 20133 Milano, Italy

INTRODUCTION

Long debates have taken place and are still in progress among historians, archeologist, architects, scientists on the philosophy of restoration. The Venice Chart, 1964, is usually considered as a milestone for conservation; nevertheless the development and improvement of the knowledge produces a continuous renovation and updating of the subject.

Apart from any cultural discussion or peculiar theoretical interest what is really important is the respect which is due to all the historic buildings, no matter if they are really important monuments or only small poor dwellings of the historic centers. Therefore during the last years the word "conservation" has been used much more frequently than others. This is due to the fact that historic buildings, rather than being reused as a sort of container for new functions and/or adapted to heavy loads, have to be preserved and respected even if difficulties for their utilization can be encountered. Furthermore, the definition of "safety" and "safety factors" for existing masonry structures, especially when situated in seismic areas, is being more and more carefully studied by structural engineers and researchers, consequently the philosophy of structural strengthening and retrofitting has changed in the last years.

In order to develop and propose a design for conservation a deep knowledge on the state of damage of the buildings is needed; this goal can be achieved only by applying a right methodology of investigation on site and in laboratory in order to measure the values of the most important parameters to be used for the input of the structural analysis. The results from the survey and from the structural analysis should allow for a diagnosis of the state of the structure and materials; then a design for the restoration can be prepared.

Taking into account the historic and architectural value of the building, the state of conservation or damage, the eventual accidental loads (seismic, settlements of soil, etc.) which might occur, the future use and of course all the safety problems, the most suitable techniques (repair, strengthening, retrofitting, substitution of decayed elements) for the intervention should be chosen.

Then summarizing, the milestones for an appropriate restoration design of masonry structures should be: (i) research into historic documentation and preliminary visual investigation, (ii) geometrical survey, monitoring and NDE, laboratory analyses and testing on samples cored from the structural elements for the measure of physical, chemical and mechanical parameters, (iii) evaluation of the state of damage and its causes (lack of maintenance, soil settlements, decay of materials and structural elements, etc.), (iv) structural analysis, (v) diagnosis, (vi) choice of the suitable technique for intervention on the basis of laboratory testing. A continuous control of the building during and after the intervention should be carried out, in order to detect possible unexpected changes in the state of stress and deformation and to test the effectiveness of the technique applied (e.g. control the results of grouting or reinforcement with non-destructive or slightly destructive testing).

Taking into account the complexity of structures and materials, particularly in the case of masonry walls, the non-homogeneity of brick and stone-work, the synergetic effects of the different causes of damage it is clear that the design for restoration should be the result of a multidisciplinary research.

Unfortunately the designer cannot always call for a team of experts; therefore architects and engineers claim for codes of practice in order to have at least guidelines for the operations they have to accomplish. This request has not yet been satisfied in many countries, simply because codes of practice for restoration do not exist. At an

international level some work has been done but much more is needed to reach consensus on guidelines or standard.
Much more has been produced at national level but only in few countries (US, Italy, Greece, Slovenia) were the dramatic effects of earthquakes have convinced researchers, experts and politicians of the necessity of guidelines for conservation and protection of historic buildings.
The small scientific community which started the research on masonry restoration has become larger and is now working very hard and producing continuous improvement of the knowledge on history of technology, material properties, structure behaviour, nondestructive and destructive evaluation, techniques for repair and strengthening.
Nevertheless still gaps exist between experimental results and mathematical models, data from NDE and elaboration for their practical use, proposals for use of new materials and knowledge for their practical application.

THE NEGLECTED BUILDINGS: LACK OF MAINTENANCE AND MASONRY DECAY

When at the beginning of the XX century reinforced concrete was discovered as a wonderful material for durable and strong structures, masonry as a structural material was practically forgotten in most of the countries.
Strangely enough masonry was still used as load bearing or facing material in rich countries for fashionable villa or luxurious buildings and in the poorest countries as the only material for a shelter, in that case frequently made with raw materials (adobe, pisè, etc.); but even in the developing countries where cement was hardly available concrete became the most appealing material and a way to show the country development .
Starting from the thirties the research on masonry materials was practically abandoned in most of the countries, apart from the few examples concerning modeling and experimental research on masonry arches (Pippard, 1936; Kooharian, 1953; Heyman, 1966); in the fourties and fifties a good deal of research was carried on in the US on bond and adhesion between mortars and bricks (Voss, 1933; Anderegg, 1942); the research was developed with a certain continuity in some countries like UK, Germany and US, but mainly dealing with the use of new masonry (Johnson, 1967; Gross et al., 1969; Sahlin, 1971; Lenczner, 1972).
If new masonries were seldom studied, no better destiny was reserved to existing buildings. Only few experts in restoration took care of the most important historic buildings; this situation continued also after the second world war. In fact after the reconstruction of the historic centers heavily bombed, the historic part of the cities was left in most European countries, to the voluntary initiative of the local authorities; they sometime preferred to demolish old decayed buildings and dwellings and built up new commercial and industrial centers.
In many countries the historic centers continuously damaged by the lack of maintenance were left to the poorest part of the population and their decay became more and more deep. But also the most important constructions as churches and palaces were left for long time without maintenance under the increasing aggressivity of the environment due to air and water pollution (Fig.1). The decay increased slowly but more and more deeply until the tragic effects of the most intense earthquakes (Skopje, Friuli, Irpinia) destroyed not only poor masonry buildings but also churches and towers (Fig.2); these destruction could have been at least partially avoided if maintenance and retrofitting of the oldest structures should have been done. The events obliged then professional people and researchers to become finally involved in the

masonry structural and physical behaviour. The first reactions were of course against masonry as a load bearing material under horizontal dynamic loads: no ductility, low tensile strength, no continuity are the weakest points for masonry. Furthermore some structural engineers were convinced that a poor design had certainly been made in the past when the laws governing the strength of materials and the structural behaviour were practically unknown. Moreover if the safety coefficients was calculated adopting the modern rules, very low values could be found for masonry buildings.
The rush for reconstruction and protection of vulnerable buildings was pushing to find some solutions. Therefore during the seventies and eighties the fear that masonry, as a poor material could very badly stand any dynamic event, convinced the structural engineers that heavy reinforcement and concrete elements should be inserted into the masonry structures so that they could respond to the seismic loads (Figs.3, 4,5).
After some experience researchers became aware that this way was no longer reasonable and safe; heavy interventions were done without much respect for the existing structure and architecture (in some cases only the facades had been and are still now spared) but also with very rough engineering principles or even wrong modeling were applied. New knowledge was demanded, but survey procedures and analytical models for the diagnoses and repair techniques suitable for the existing buildings were not updated, while codes and standard for testing were available but only for new masonry.

Fig. 1 - Effect of lack of maintenance on a brick masonry.

Fig. 2 - Church of S.Maria di Fossale (Friuli) damaged by the earthquake of 1976.

At the beginning only few pioneers were working very hard on masonry materials and structures research (Hilsdorf, 1969; Nuss et al., 1978; Mayes & Clough, 1975). But in few years the development was very quick. The IBMaC started in 1967 in US, Austin, Texas, followed by the NAMC and Canadian Masonry Symposia in the seventies. Special issues as the Masonry International Journal in 1987 in UK, the TMS Journal in 1985 in US were published, followed by other national and international colloquia and workshops.

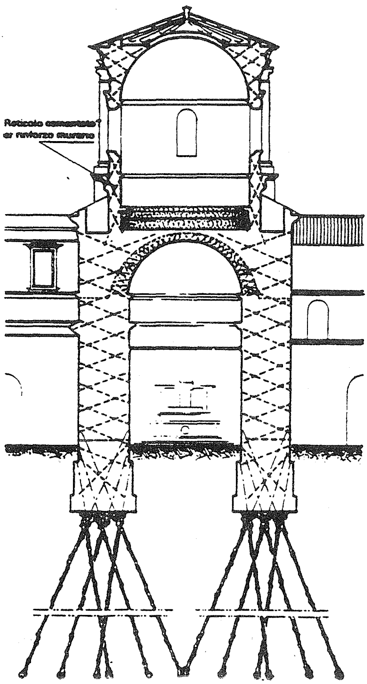
Nevertheless restoration was still a subject for architects and historians, while only a restricted number of scientists, mainly chemists, physicists and geologists were taking care of the decay of brick- and stonework due to the aggression of the environment. The first International Colloquium on Deterioration of Stones took place in Bologna (Italy) in 1973.

The Skopje earthquake followed by the Friuli and Irpinia earthquakes tragically produced the occasion for the need of common work on existing masonry structures between US and European researchers. In 1983 the IABSE Symposium hold in Venice was the starting date of a long collaboration between some Italian and US researchers. The organization of two Workshops ITA-USA in Italy (1986) and US (1987), supported by CNR and NSF (NSF & CNR, 1986, 1987), was followed by common research. Since then a US group of researchers from Boulder, CO, Atkinson, Noland & Ass., B. Shing, B. Amadei from Boulder University and groups from Italy, L. Binda, G. Baronio (DIS, Politecnico, Milan), P.P. Rossi (ISMES, Bergamo), C. Modena (Padova University) and Slovenia, M.Tomaseviçz (Lubjana) are working on NDE, experimental and numerical modeling, repair and retrofit of masonry structures. The common research was supported by CNR, NSF, NATO. Other collaborations were also set up between the University of Pavia (G. Macchi, M. Calvi) and Rome (C. Gavarini, A. Giuffrè) and the University of Berkeley (V.V. Bertero), San Diego (M.J.N. Priestley).

An improvement was so promoted not only on earthquake engineering, but also on: (i) durability of masonry materials (Binda & Baronio, 1985; Binda & Baronio, 1987), (ii) NDE of existing masonries (Berra et al., 1992; Schuller et al., 1994), (iii) in-situ detection of the state of stress and of deformability of masonry (Atkinson et al., 1995), (iv) procedures for testing the effectiveness of injection techniques (Schuller et al., 1994; Binda et al., 1994). Two workshops were organized in Milan by L.Binda (CNR-GNDT, 1992) and in Trento by C. Modena (Prov. di Trento, A.N.I.A.C.C.A.P., ITEA, 1993) on the last subject.

A third ITA/USA Workshop on Learning from Practice, A Review of Architectural Design and Construction Experience After Recent Earthquake was organized in Orvieto in 1992 by L. Binda, N. Avramidou and M. Comerio, supported by NSF and CNR (National Science Foundation, Washington D.C., C.N.R., Rome, 1992).

A good liaison between the groups dealing with research in retrofitting and restoration of existing buildings has also been established through two RILEM Committees: 76LUM, chaired by Prof. .. Hendry and closed in 1990 and 127MS still ongoing, chaired by L. Binda. The first one was mainly dealing with mechanical tests on masonry and masonry materials, the second one with durability, NDE and on-site mechanical tests. Through these two Committees relationships were established between organizations and researchers from Australia (Page, Lawrence), Canada (Maurenbrecher), US (Noland, Borchelt, Grimm), Italy (Binda, Baronio, Modena, ISMES), Netherland (Bekker, TNO), UK (De Vekey, Forde, Hendry, West), Germany (Stöckl, Schubert).



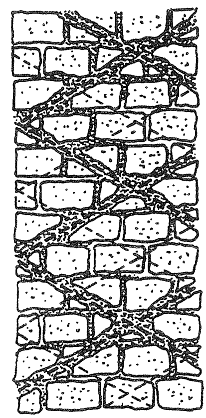


Fig. 3 - Heavy retrofit of masonry structures: the "reinforced truss".

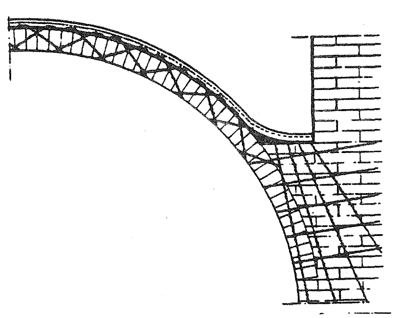


Fig. 4 - Example of jacketing and insertion of concrete beams.

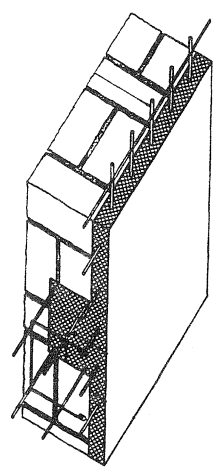


Fig. 5 - Reinforcement of a masonry vault.

Other connections, of course, were set up in Europe between the researchers who where in the meantime working in other organizations very active in research for restoration, e.g. the University of Karlsruhe (F.Wenzel, H.Hilsdorf), the University of Bath (D.A. Cook), the University of Leuven (D.Van Gemaert, K.Van Balen), the University of Padova, Milan, Rome and Neaples, the Institute for Testing and Research in Materials and Structures, Ljubljana (M.Tomazevic), LCPC in Paris, TNO, Netherland, BAM, Germany, BRE, UK and the University of Athens. Finally a great improvement to collaboration is now given in Europe by the EEC research contracts from different projects like ENVIRONMENT, BRITE EURAM, Human Capital and Mobility Networks and by EUROCARE and EUROLIME.
Even if the mentioned initiatives and others also in other countries in Africa (Egypt, Morocco), Asia (India, China), South America (Peru, Argentina, Brazil) are giving a great improvement to NDE, testing, mathematical modeling and retrofitting there is still lack of knowledge and probability that the past mistakes can be repeated several times more.

INVESTIGATION, MODELLING AND DIAGNOSIS

As it was previously mentioned, due to the choice for safety but also to lack of knowledge, some heavy techniques were applied after the damages caused by the earthquakes. The use of new high-strength and high-tech materials was welcome together with the introduction of concrete elements, reinforced injection of cementitious grouts and jacketing of walls, arches and vaults. The idea behind this choice was to give masonry continuity, ductility and tensile strength in order to repair and prevent further damages. Figs. 3,4,5 show some of the adopted techniques; also without knowing further details, it is clear that the repair was heavily changing the behaviour of the previous structure. Furthermore in the case of external surface decay in historic buildings which were frequently attributed to air and water pollution (acid rain, dry deposits of pollutants, sulfation, etc.) without taking into account the lack of maintenance, only the use of surface treatments was taken into account particularly where a deep deterioration was detected and no substitution of the damaged units was allowed. Treatments were usually based on new synthetic organic or inorganic materials (silicon, epoxy, resins, ethilsilicates, etc.) consolidants or water-repellent applied to the surface with different techniques; these treatments were not always successful due to the impregnation of the material, the changes in stress and stiffness of the treated surface, the low permeability to water and water vapour (Fig.6). The bad effect were incremented in the case when the masonry contained moisture and salts.
After some negative experiences it became more and more clear that the choice for the type of intervention has to be dependent on a previous diagnosis based on an appropriate survey, so that every detail of the construction could be previously known (the history of the structure, its evolution along the centuries, the geometry, the crack pattern and the time-dependent movements, the soil and structure settlements, the distribution of the decay). Afterward the values of the mechanical, physical and chemical parameters useful for mathematical modeling of the structure behaviour must be experimentally measured; the final step for knowledge of the state of the structure should be the structural analysis based on simple or complex models.

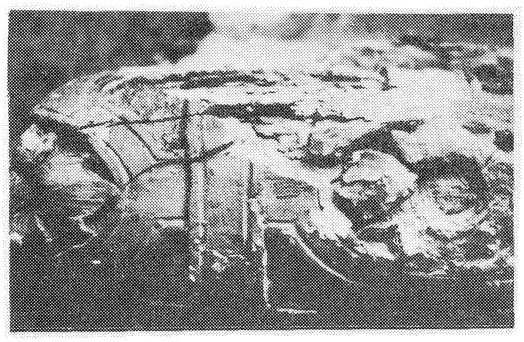


Fig. 6 - Failure of a treated terracotta surface containing alkaline salts.

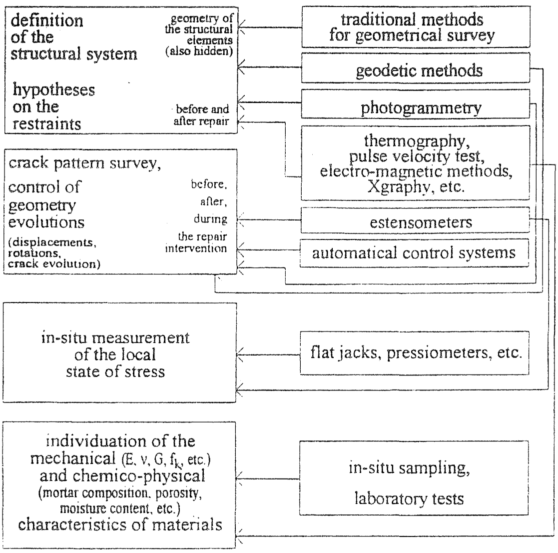


Fig. 7 - Required information and corresponding investigation techniques..

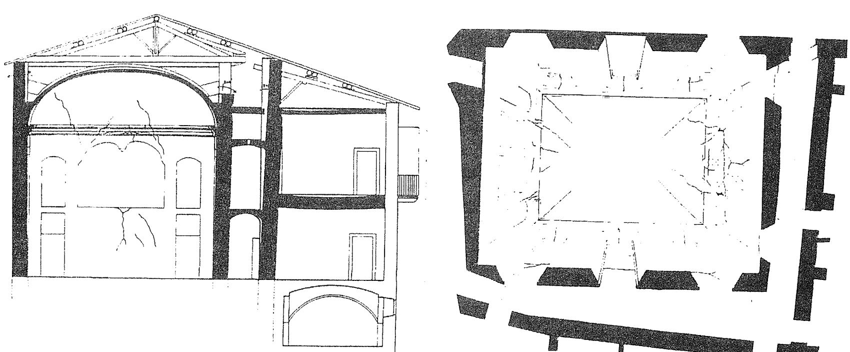


Fig. 8 - Villa Crivelli, Inverigo, Italy:
a) crack pattern of the theater; b) geometrical effects due to the thrust of the vault.

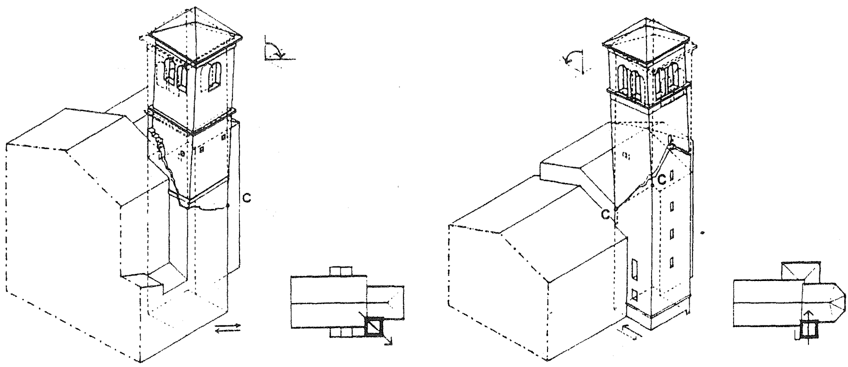


Fig. 9a,b - Assumed collapse mechanisms interpreted through the detected failure path.

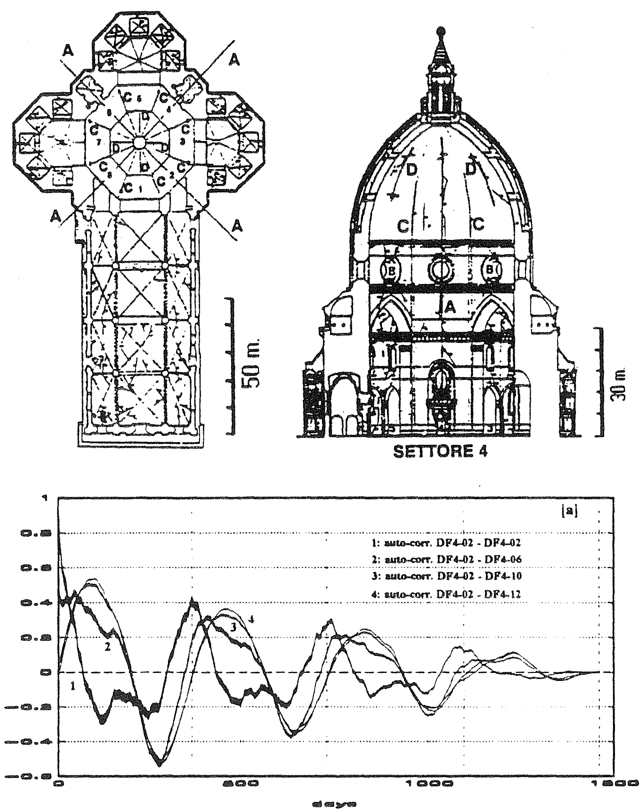


Fig. 10 - S.Maria del Fiore, Florence, Italy:
a) position of the major cracks denominated A,B,C,D on the dome; plan.
b) position of the major cracks denominated A,B,C,D on the dome; section.
c) curves displacement-time obtained as a correlation of the monitored readings.

Destructive and non-destructive investigation

Prevention and rehabilitation can be successfully accomplished only if the diagnosis of the state of damage of the building has been carefully carried out. During the recent years non-destructive and destructive evaluation procedures and techniques used in other fields (medicine, steel, concrete) have been discovered and widely applied. Nevertheless it is very often difficult to apply the results of an investigation, even a positive one, when the designer is not sufficiently skilled; in that case a great amount of data remains useless or can be used incorrectly.

It must be clear that even if there is a need for consulting experts in the field, it is the designer or a member of a designing team must be responsible for the diagnosis. He must actually: (i) set up the in-situ and laboratory survey project, (ii) constantly control the survey, (iii) understand and verify the results, (iv) make technically acceptable the use of the results including their transfer as input data to mathematical, (v) choose appropriate models for the structural analysis, (vi) arrive at the diagnosis at the end of the complete study.

Several investigation procedures have been implemented in the recent years; the attempt is to use as much as possible non-destructive techniques. Nevertheless there is a very little possibility at present to correlate NDE test data to masonry performance (Working Group NDE Conf., Boulder, CO, 1992). Fig.7 tries an attempt to describe the needs and the correspondent procedures (Binda et al., 1994). Unfortunately most of the procedures can give only qualitative results; therefore the designer is asked to interpret the results and use them at least as comparative values between different parts of the masonry (e.g., qualify the different parts of a masonry structure or walls through the value of sonic velocities or wave forms, when sonic tests are applied)

The geometrical survey, the measured loss of verticality or horizontality in the load bearing elements and the type and distribution of cracks in the crack pattern is the first information to be collected; the type of cracks and their geometry can help understanding the causes of damage (Fig.8a,b). Furthermore the type of cracks and their direction help in interpreting even a mechanism of collapse (Fig. 9a,b) (Doglioni et al., 1994).

Where an important crack pattern is detected and progressive growth due to soil settlements or temperature variations is suspected, the displacements and deformations of the structure as a function of time have to be known; sometime the crack pattern evolution can lead to collapse. A monitoring system can be installed on the structure in order to follow this evolution; this type of survey is frequently applied to important constructions, like bell towers (Pavia towers and Pisa tower) or cathedrals and the system may stay in place for years before a decision is taken for repair or strengthening. Fig. 10 c shows the evolution in four years of some of the main cracks of the dome in S. Maria del Fiore in Florence (Fig.10a,b) (Chiarugi et al., 1993).

The state of stress of a structure cannot be described experimentally as the state of deformation; nevertheless methods based on the stress relaxation, like the flat jack test, the shove test or the borehole dilatometer test can be useful to measure locally the state of stress or the deformability of the masonry, giving not only a numerical value in local situation, but also the possibility of calibrating the mathematical models through experimental measurements (Rossi, 1990).

Naturally the results obtained in situ have to be controlled with laboratory tests carried on materials sampled from the construction. Non-destructive evaluation techniques can be applied for several purposes: (i) detection of hidden structural elements , like floor structures, arches and piers, (ii) qualification of masonry and masonry materials, (iii) evaluation of the extent of mechanical damage in cracked structures, (iv) detection of the presence of voids and flaws, (v) evaluation of moisture content and rise, (vi) detection of surface decay. Correlation of the ND data to mechanical or physical properties is very difficult in the case of masonry mainly due to its non-homogeneity. Dynamic and estensimetric monitoring, infrared thermography, radar investigation, ultrasonic and sonic pulse velocity are the most sophisticated methods applied to in-situ investigation, but other simpler like the rebound hammer, the probe penetration, the drilling or pull-out tests, etc.

Structural analysis for diagnosis

The results of the in-situ and laboratory investigation should be used as input of mathematical models implemented to study the behaviour of masonry structures. Fig. 11 shows how the results can be finalized for the model.
Modeling of a masonry structure is a difficult task, since masonry does not respect apparently any hypothesis assumed for other materials (isotropy, elastic behaviour, homogeneity).

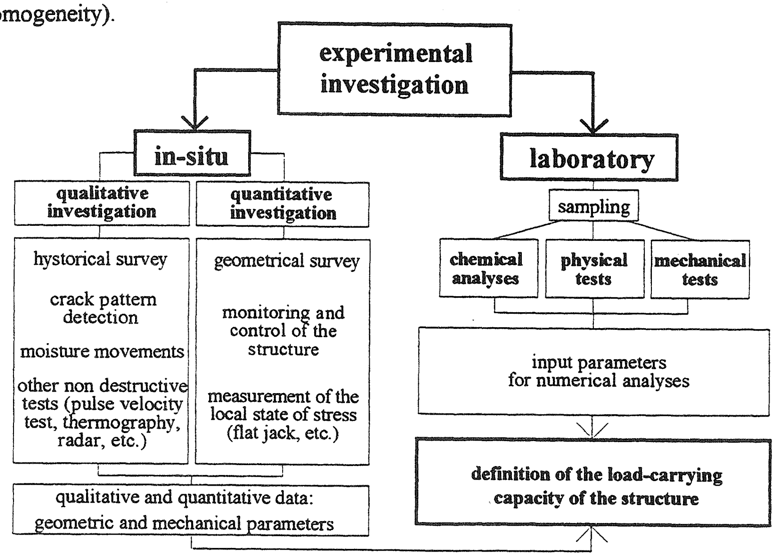


Fig. 11 - Aiming of the experimental survey to the structural analysis.

In the past decades several attempts have been done to assume models used for other materials, but the results were very poor. Elastic models can give an indication on the mechanical behaviour of the structure (Fig. 12) but they cannot follow the behaviour beyond the elastic range (Meli & Sanchez-Ramirez, 1993). Nonlinear models can be very heavy to handle and costly. In the case of badly damaged and complicated structures several elastic computations can be carried; this methodology was followed for the leaning tower of Pisa (Fig. 13) under different hypotheses of collaboration of the various parts of a structure (Macchi et al., 1993). Sometimes the calculation has to be based on engineering considerations and the structure subdivided into substructures before a FE analysis is carried on (Fig. 14a,b,c) (Ronca & Castiglioni, 1992).

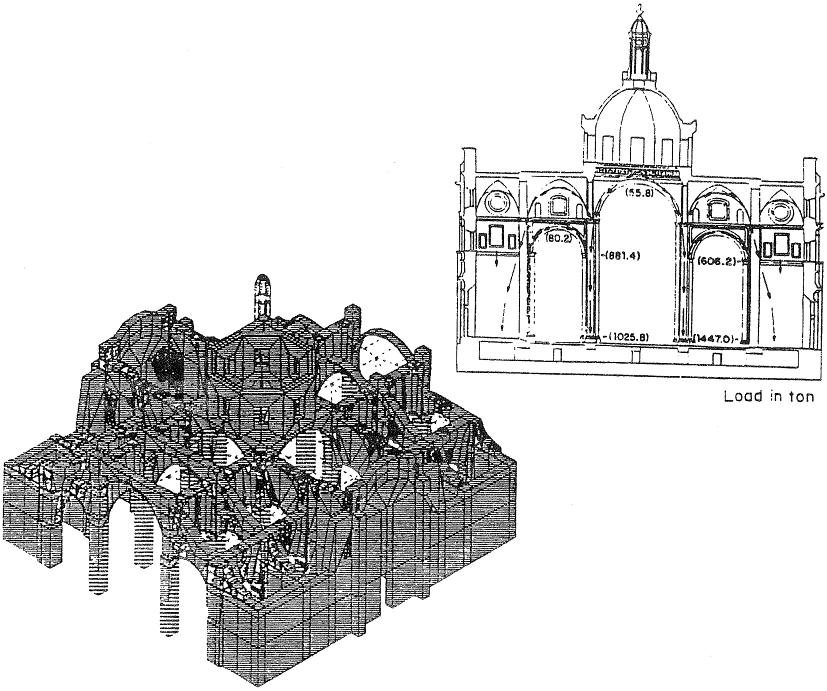


Fig. 12 - Mexico City Cathedral, central portion:
a) flow of self-weight loads under the central dome;
b) state of stress of the due to gravity from a FE analysis.

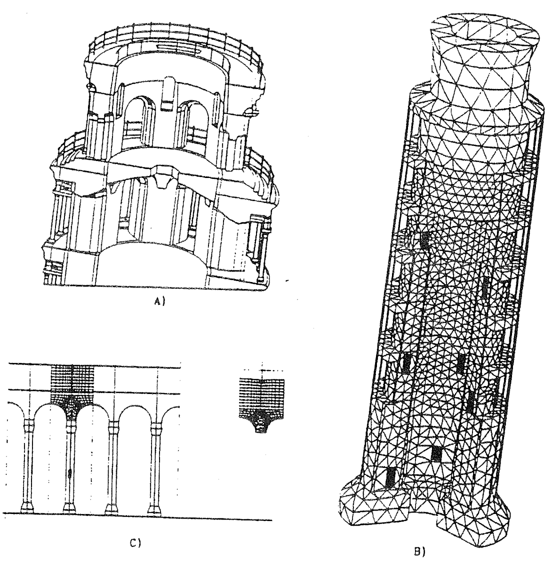


Fig. 13 - Modeling of the leaning Tower of Pisa:
a) numerical model,
b) FEM,
c) sub-structuring of the colonnade system.

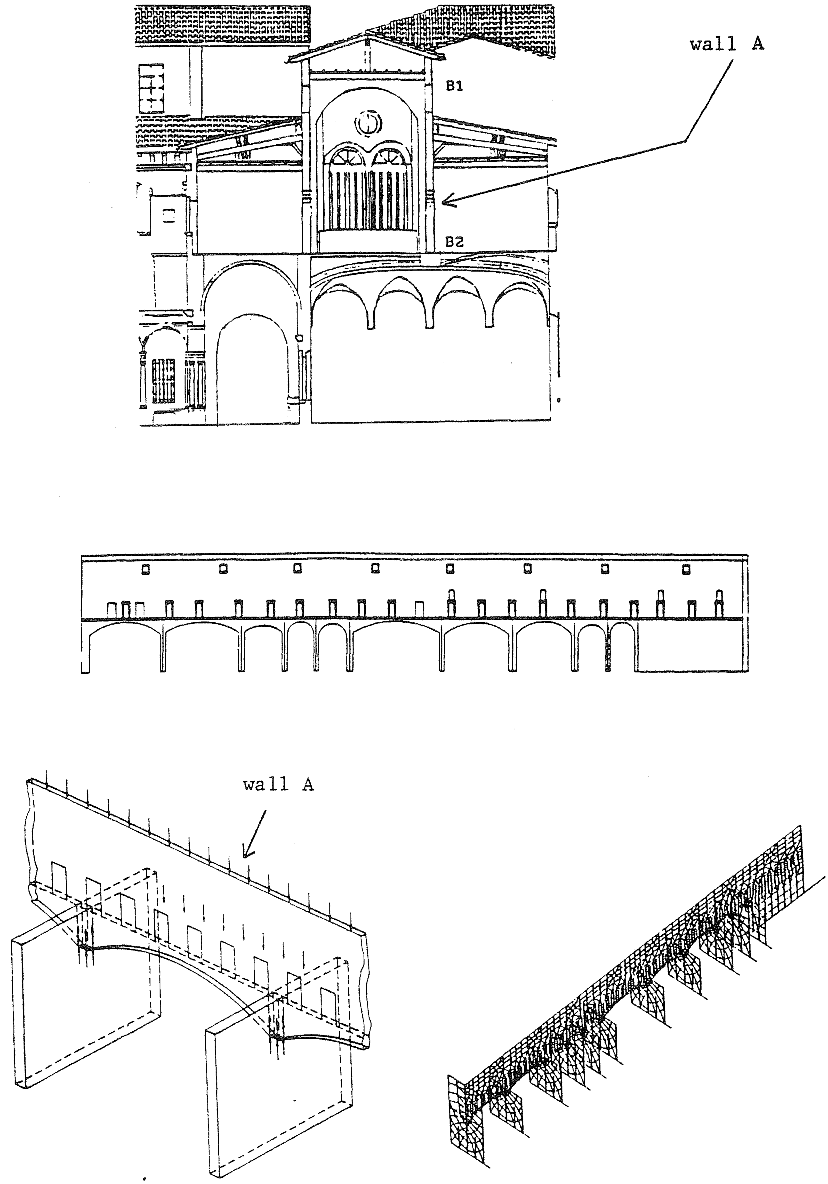


Fig. 14 - S.Faustino, Brescia, Italy: sub-structuring of a wall system:
a) Section of the building
b) Longitudinal section of wall A
c) Substructure
d) Finite element model of the substructure

Fig. 15 presented by the author in 1983 (Binda et al., 1983) tries to give some guidelines; since then new proposals were made on computer methods to adapt them to the lack of continuity, anisotropy, non-homogeneity, non elastic behaviour and large displacements, typical features of the masonry structures (Amadei et al., 1995; Jankulovski et al., 1995).
Nevertheless most of the models have still to be calibrated on experimental parameters and research still needs to be done even if a high improvement has been given in the last five or six years.

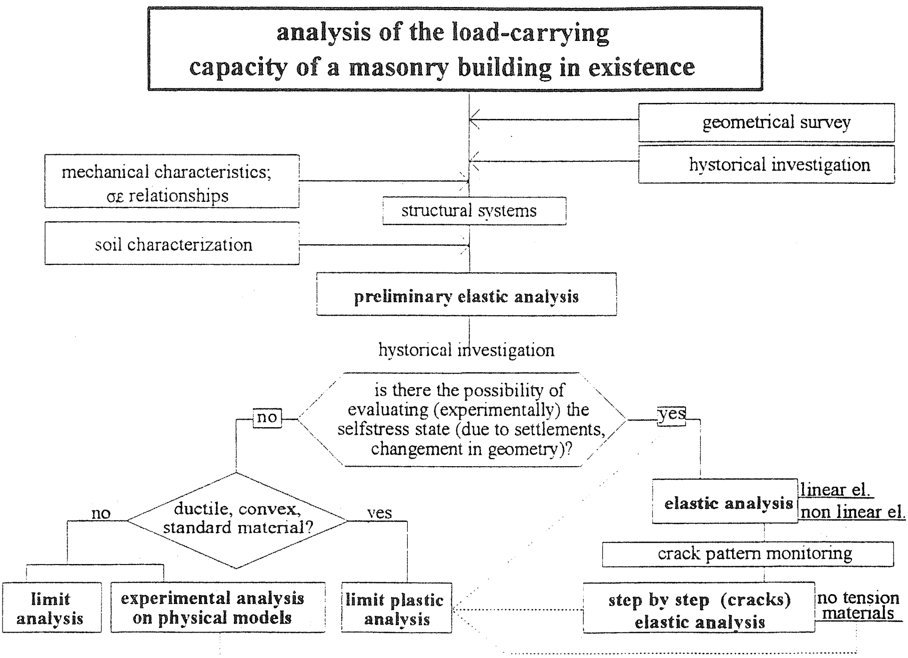


Fig. 15 - Phases and alternatives of numerical analysis for existing structures, 1983.

CALIBRATION OF REPAIR AND STRENGTHENING TECHNIQUES

As it was previously mentioned the techniques for repair and protection were adopted in many cases under the pressure of urgency, like in seismic areas or of the fascinating idea that new advanced materials could help better than traditional ones to reach a better performance of the historic buildings. After successes but also failures now a more careful approach is being adopted even in seismic areas. Everybody has to bear in mind that strength is not the only important parameter in restoration, but stiffness, physical (porosity, moisture movements) and chemical (composition, possible reaction binder aggregates) parameters are also to be taken into account. Safety factors should be stated with a new approach for historic buildings based also on the limits to the performance which can be required to them. New guideline have been given for example to the Italian Ministry of Cultural Properties for restoration of Monumental buildings in seismic areas where repair and improvement is suggested rather then heavy changes to the structure, also subject to a previous survey and diagnosis aiming to a deep knowledge of the existing structure (Corsanego et al., 1993).

Durability of the surface treatments should be better known together with their effects on the masonry assemblage rather than on the single components (stones, bricks) as it was done previously. Research and enquiry on durability of treatments should be done in order to achieve a better knowledge (Fig.16). But also laboratory research should continue in order to develop testing procedures (accelerated ageing tests) (Amadei et al., 1995) for the materials used in protective or consolidant treatments; when necessary also outdoor models should be used even full-scale models of buildings (Fig.17). Finally procedures for measuring the rate of decay and comparing the durability of non treated materials and treated materials (Fig.18).

Effectiveness of strengthening techniques should also be studied further in order to: (i) classify the type of problems and necessities, (ii) classify the type of masonry and masonry materials, (iv) set up procedures for the control of the technique in laboratory and on site, (v) implement mathematical models for the analysis of the repaired structures.

Research has been done in these last years on the effectiveness of the technique of jacketing of the walls and of the technique of injection by grouts. Full-scale on site testing have been made and application of mathematical models for the case of jacketing (Gelmi et al., 1993). Testing on small-scale models under horizontal loads have also been carried on to study the response of masonry buildings repaired by injection of grouts, and compared to other techniques (Tomazevic et al., 1994).

A procedure for testing the effectiveness of the injection technique for multiple-leaf stonewalls was set up in (Binda et al., 1994). After having classified the section of the studied wall through a geometrical survey (Fig.19), the size and distribution of the voids is attempted. Some material is cored from the rubble filling of the wall and specimens are built up into transparent cylinders which are injected with different grouts in order to control their injectability; the cylinders are then tested in compression. Flat-jack tests are carried out on the building to be repaired in some check-points before and after injection in order to measure the improvement of the injection (fig. 20). Subsequently samples are cored from the walls to check the penetration and diffusion of the injection.

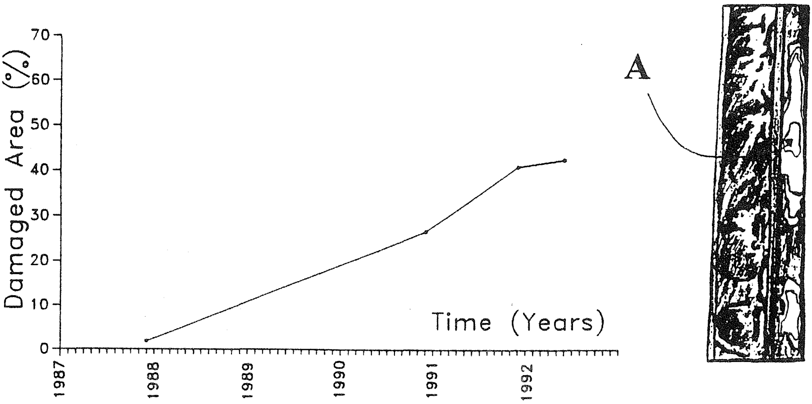


Fig. 16 -Milan Cathedral, Italy, facade: rate of physical and chemical damage of a detail

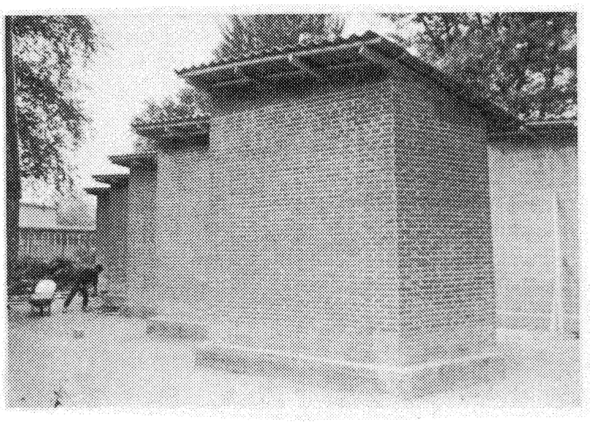


Fig. 17 - Full-scale models built in an outdoor laboratory in Milan.

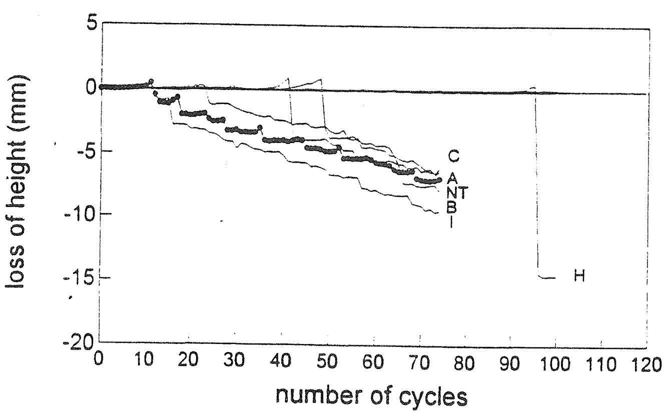


Fig. 18 - Damage curves for treated and untreated stones; thickness of lost material vs. number of aging cycles.

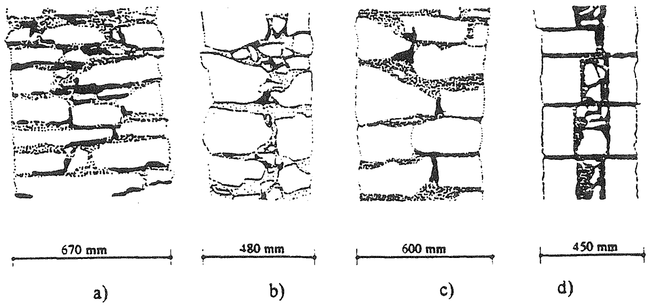


Fig. 19 - Classification of multiple-leaf stonewalls.

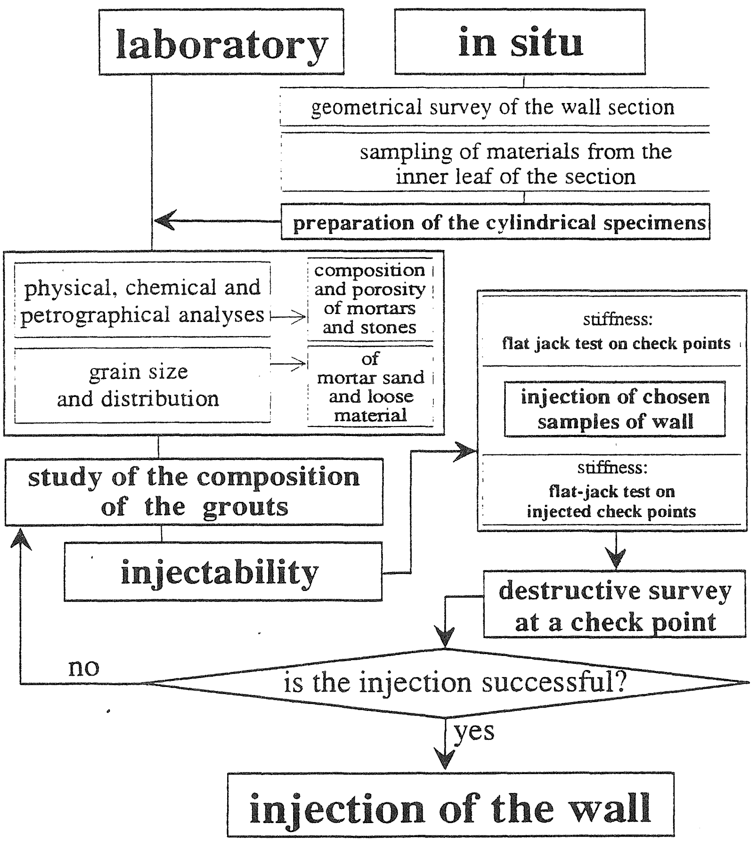


Fig. 20 - Procedure for the investigation on the effectiveness of grouting by injection.

CODES AND RECOMMENDATIONS

There is a great difficulty in stating strict rules for the restoration of existing buildings, first of all due to the differences between buildings and structures and to the many technologies of construction and materials. Codes of practice nevertheless are necessary to give guidelines for the choice of adequate modeling of the structural behaviour and of successful repair and retrofit techniques, so as standards for the use of new or traditional materials in restoration.
Several recommendations and codes have been set up in different countries: Uniform Code for Building Conservation in USA is an example of how some common rules can be proposed even in the case of existing buildings.
Recommendation for testing of materials cored from existing buildings (NORMAL) and materials used for the repair and restoration have been prepared in Italy by Committees nominated by the Ministry of Cultural Properties. These tests are certainly very important for the choice of the right materials and techniques for restoration. Other mentioned recommendations have been proposed by the GNDT in accordance with the Ministry for the strengthening of monumental buildings. Nevertheless a more updated code of practice is still lacking.
Other countries are certainly working on a national level, but European Committees should be also set up within the frame of CEN/TC125 Masonry.
A RILEM Committee, the 127MS still ongoing is dealing with destructive and nondestructive testing of masonry and with durability tests; drafts on flatjack, shove, sonic and ultrasonic tests have already been prepared and will be proposed in a near future for publication. CIBW23 is a Committee dealing also with testing and modeling for repair and strengthening of masonry structures.

CONCLUSIONS

An attempt was made in these few pages to summarize the state of the art of the research and philosophy of safety. Of course, due to lack of space and also uncompleted information for which the author apologizes, this report is not exhaustive and important contributions may have been missed.
Restoration has to be intended as far as possible as conservation of the building materials and structure, even in seismic areas. In some cases as it was shown by the results of research carried on in Italy, Slovenia, Germany and other countries, by the application of Los Angeles law in US, by some interventions done in Italy and Greece even dwellings can be saved with a friendly retrofitting.
The positive aspect of the present situation is that more and more researchers, organizations and professional people are working within the frame of a deep respect for the existing buildings no matter if they are simple dwellings or monumental constructions. Of course modest and costly techniques should be applied with sensible choices taking into account not only new but also traditional materials and methods.
More efforts are needed in calibration of investigation procedures, mathematical modeling and codification.

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