Heritage Problems, Causes and Solutions

Calogero Bellanca and Susana Mora Alonso-Muñoyerro

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Esperienze di Studio e Restauro in Europa – 3

Heritage Problems, Causes and Solutions

Calogero Bellanca and Susana Mora Alonso-Muñoyerro

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This material is didactic, to be used in education. The graphic material although fundamentally is made by the authors, includes photographs and drawings compiled from material used by the authors in their lessons in ETSAM (UPM) (*Construction and Heritage Courses*), Sapienza University of Rome (*Course of Theory and Practice of Conservation* and *Laboratorio di Restauro*) and other european university.

In this volume have collaborated specially these architects:
Ignacio Mora Moreno, Alejandro Iniesta Munoz, Magdalena Prieto de la Lastra

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In copertina | *Cover image*: *Colosseum*, detail. Photo by Susana Mora and Calogero Bellanca.

Dedicated to our parents

Maria and Antonino
Consuelo and Justo

Index

PART III – CONSTRUCTION APPLIED TO HERITAGE

CHAPTER 8. WALLS: CONSTRUCTIVE SYSTEMS, PROBLEMS, CAUSES AND SOLUTIONS

"Walls, piers and columns all form part of the same system of enclosure of space and support of the roof. Stone and brick masonry are considered together as they are so similar, but mud brick has special problems of its own, so it is studied in a separate chapter. Timber walls must not be forgotten, but here the problems are not so much structural as the decay of the material itself… Each geographical region and period in history has had its own characteristic way of building walls. Therefore, each type of wall has different preservation and repair problems dependent upon its construction and strength of the primary and secondary materials; for example, unbaked brick laid in mud mortar, unboned stone blocks, closely fitted polygonal masonry laid dry and random rubble in lime mortar will age differently from say, bonded masonry laid in mortar or Roman mass concrete walls. Ruins can often be informative about the nature of structural systems, as the collapse pattern of a wall may show how it ultimately failed and thus how a similar type of wall should be reconstituted and strengthened."

From FEILDEN B.M., *Conservation of Historic Buildings*, Butterworths, London 1982, p. 61.

TYPES OF WALLS

- Homogeneous / Heterogeneous
- Cladding
- According to composition
- One or several leaves

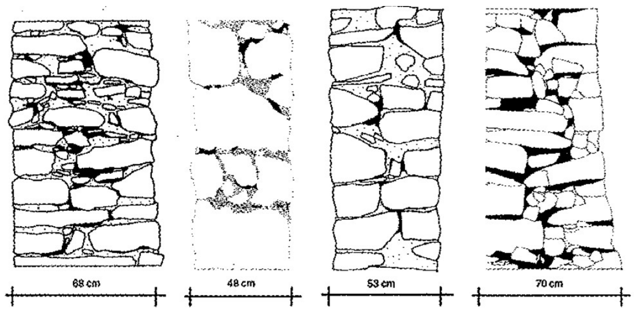


Fig. 1. From J. Ashurst, *Conservation of Ruins,* Routledge, Oxford 2006, p. 109.

PROBLEMS

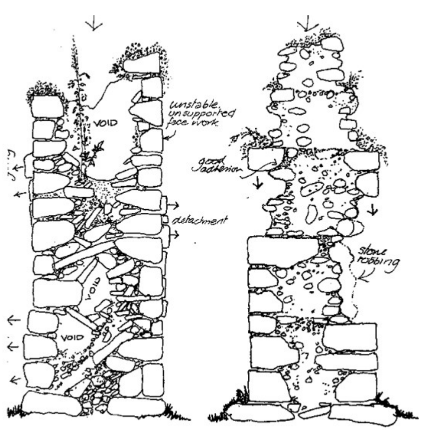


Fig. 2. From J. Ashurst, *Conservation of Ruins,* Routledge, Oxford 2006, p. 109.

STONE MASONRY

ASHLAR MASONRY:

Ashlar masonry consists of carefully dressed stones with accurate bedding and fine joints of 3 mm thick. This is the best type of stone construction. It is ensured that the sizes of individual stones are in conformity with the general proportions of the wall in which they are placed. It is further divided into the following types:

1. Ashlar Fine
In this type of masonry, stones are well dressed on all bed and side joints and the faces are rendered perfectly true to the desired pattern. The stones are laid in regular courses not less than 30 cm height. Almost all the courses are of same thickness. The face stones are laid headers and stretchers alternately. The height of stones used are never less than their breadth and their length never less than twice their height.

2. Ashlar Rough Tooled
In this type of masonry, the exposed faces of stones have a fine dressed chisel drafting all around the edges. This may be about 25 cm in width. The portions in between the drafts are roughly tooled. The thickness of joints allowed in this case is 6 mm. In all other respects it conforms to the specifications of Ashlar fine masonry.

3. Ashlar Rock Quarry Faced
In this type of masonry, the exposed face between the draft is not tooled but is left unfinished. The projections in the space enclosed by chisel drafts should not exceed 8 cm to 10 cm.

4. Ashlar Chamfered
In this case the edges round the exposed face of each stone are beveled off at an angle 45° for a depth of 25 mm or more.

5. Ashlar Facing
In this type of masonry, the faces of stones are rough tooled, rustic or chamfered and are provided in face work only but the backing may be made in brick work, concrete or rubble masonry. The stones are not less than 20 cm in height and 1 1/2 times the height in width. One third of the length of each course should be of headers. The bed joints of all the stones are dressed perfectly true and square. Bond stones should run through the backing when the wall is less than 80 cm in thickness. For greater thickness the bond stones should overlap each other by 15 cm.

6. Ashlar Block in Course
It is similar to ashlar rough tooled with the only difference that in this case the height of the course is lesser but not less than 20 cm.

Fig. 3. From J. Ashurst, *Conservation of Ruins,* Routledge, Oxford 2006, p. 80.

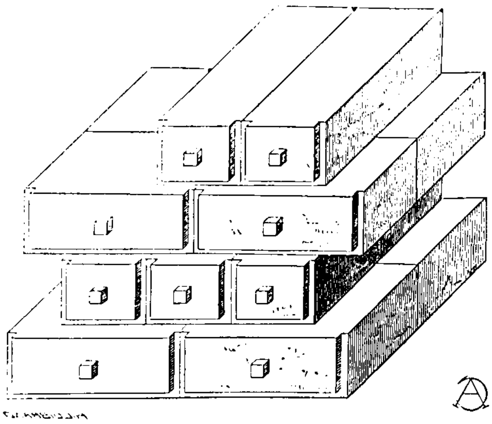


Fig. 4. From J. Ashurst, *Conservation of Ruins,* Routledge, Oxford 2006, p. 81.

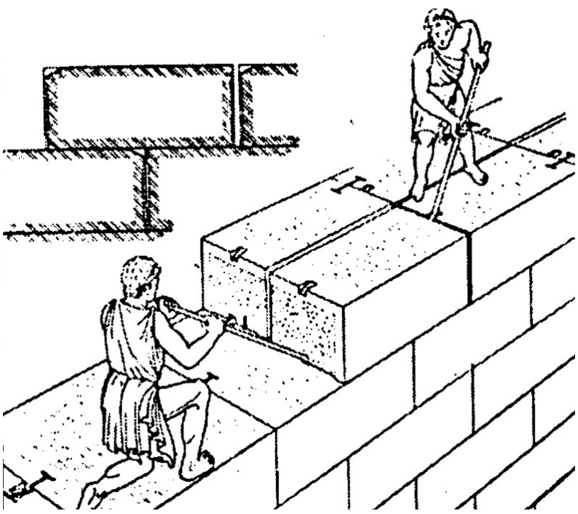


Fig. 5. From J. Ashurst, *Conservation of Ruins,* Routledge, Oxford 2006, p. 82.

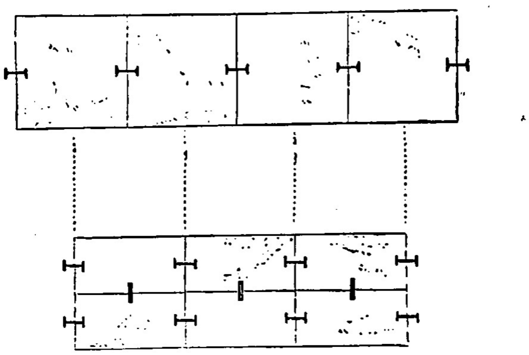


Fig. 6. From J. Ashurst, *Conservation of Ruins,* Routledge, Oxford 2006, p. 82.

RUBBLE MASONRY

(1) In rubble masonry the stones are not of uniform size and shape and are not finely finished while constructing rubble masonry the following points should be taken in mind:

1. Width of the face stone should not be less than the height of the course.

2. All the stones should be wetted before laying and stones from opposite faces should bond with each other.

3. The backing should have sufficient bond with the facing. The stones on the face should have full joints for a specified distance from the face.

4. Sufficient headers should be used in each course.

5. The height of stone should not exceed its smallest horizontal dimension.

6. The stones should be placed on their widest side so that they may not act as edges. Further edged stones with in sufficient tails should not be used.

7. Chips should not be used in bed joints for setting the stones.

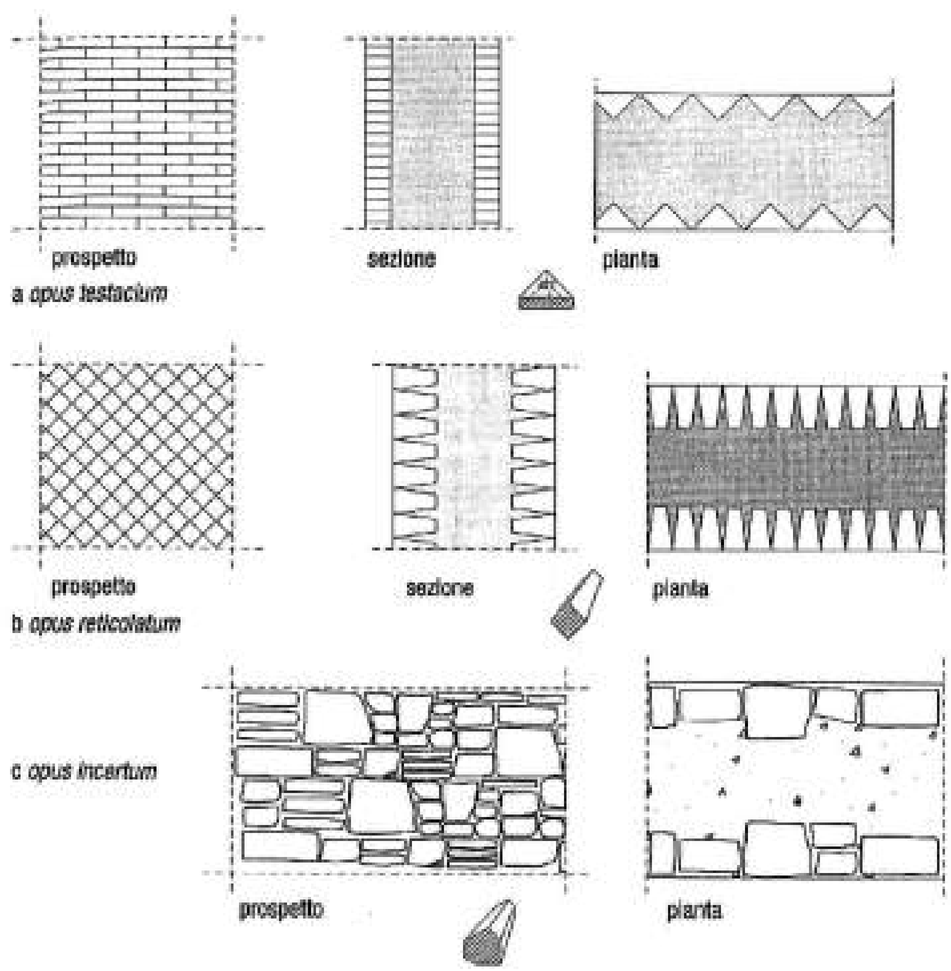


Fig. 7. Three types of opus cementicium: opus testacium, opus reticolatum, opus incertum. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011, p. 19.

The rubble masonry is further classified into the following types:

1. Un-coursed Rubble Masonry
This type of masonry is built practically without any dressing. This is the poorest form of stone masonry. The stones used are taken directly from quarry. Larger stones are laid on flat beds. In this vertical joints are not formed to plumbness. The stones to be used for the face should have uniform color and greater size. One stone is used for every square meter of face work. Bond stones provided to interlock the two faces should extend up to the full thickness of the wall if the wall is less than 60 cm in thickness. A line of headers overlapping each other for a length of at least 15 cm is laid right through the wall for more than 60 cm thick walls. In this case the thickness of the joints should not exceed 12 mm.

2. Random Rubble Masonry
Random rubble masonry is slightly superior to un-coursed rubbled masonry. The stones to be used in this type are hammer or chisel dressed. The stones in each course need not be of the same height. All the courses should be of the same height. Not more than two stones, one above the others should be used in each course. The face of stones is of uniform color and approximately equal in size. The height of stones should not be more than their breadth or length of tail into the work. Small chips should be used when the joints are very thick. At least one fourth of the stones should tail back into the hearting to ensure proper strength to the work.

3. Coursed Rubble Masonry
This type of masonry is further divided into 1st class, 2nd class and 3rd class masonry. It is commonly used in various types of residential and public buildings, piers and abutments of bridges. In the 1st class coursed rubble masonry all the courses are built to the same height with the minimum height being 15 cm. The beds of face stone are hammer or chisel dressed. In good work, about one third of the face stones tail back into the hearting for a distance of two times their height for normal walls and three times for thicker walls. The thickness of the joints should not exceed 10 mm.

4. Dry Rubble Masonry
In this type of masonry mortar is not used. It is constructed in same manner as ordinary rubble masonry.

Fig. 8. Photo by Susana Mora.

Fig. 9. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 106.

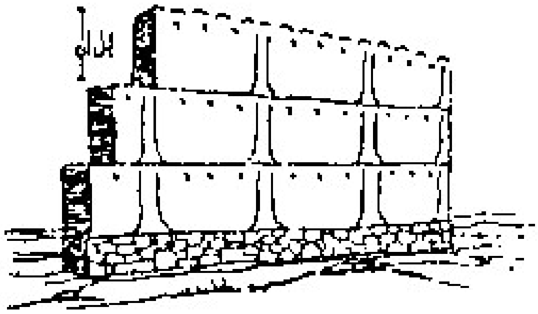
BRICK MASONRY

(2)

Fig. 10. Palatino, Rome. Photos by Susana Mora, 2010.

RAMMED EARTH WALL

– USE OF NATURAL RAW MATERIALS
– NON-COMBUSTIBLE
– THERMALLY MASSIVE
– STRONG
– DURABLE



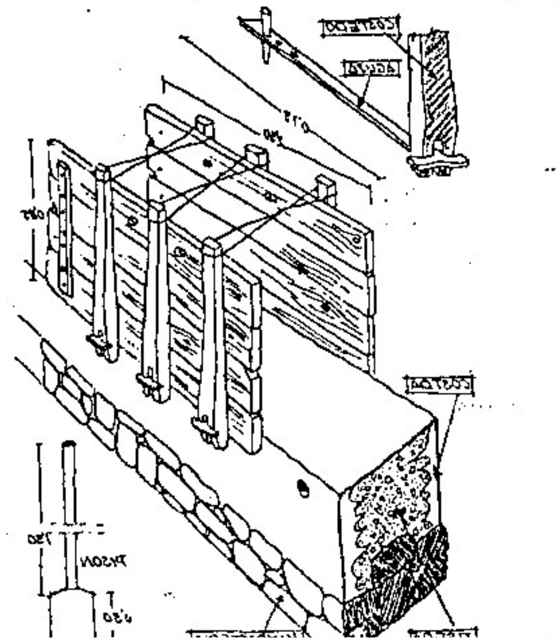


Fig. 11. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 115. (3)

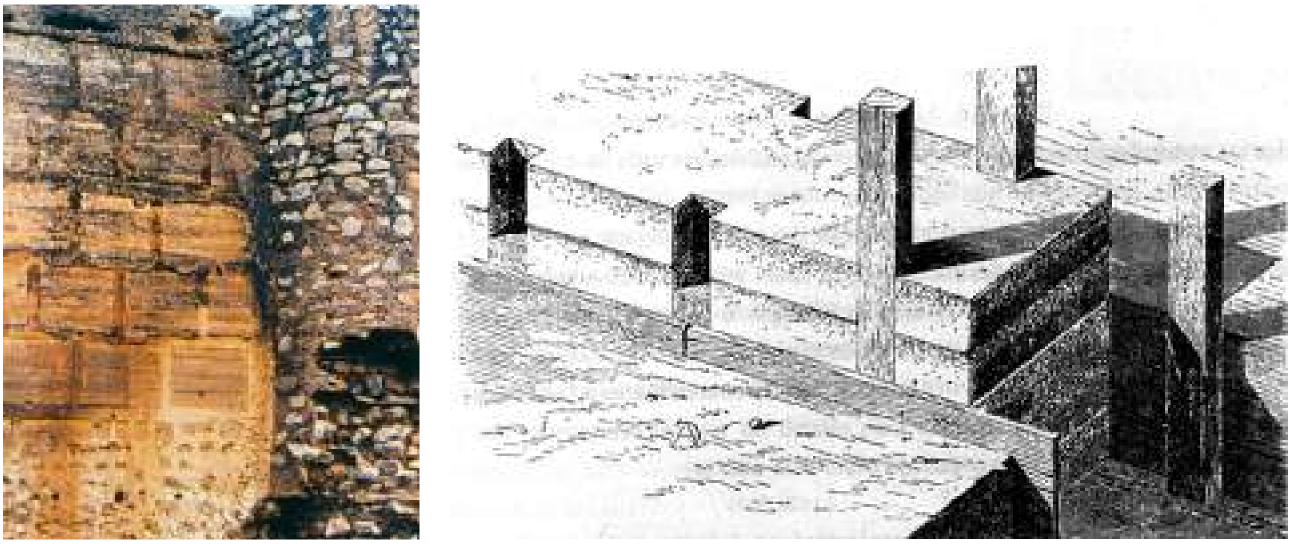


Fig. 12. Alcázar, Guadalajara. Photo by Susana Mora.

WOODEN FRAME WALL

– ADOBE (MUD BRICK)
– BRICK

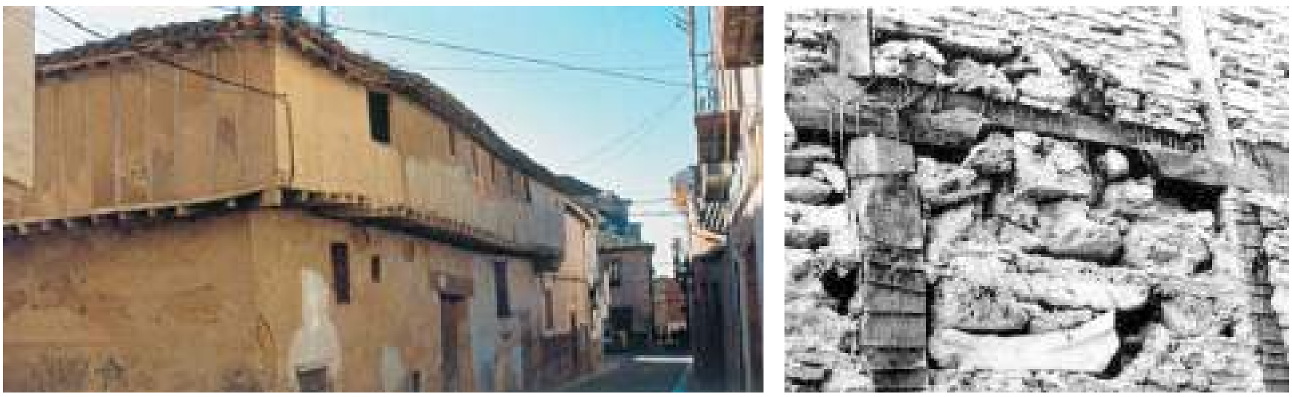


Fig. 13. Alhondiga, Torrelaguna, Madrid. Photos by Susana Mora, 1991.

METHODOLOGICAL APPROACH

1. Damages and background
2. Analysis of observed pathology
3. Verification of the hypotheses
4. Selection of repair solutions
5. Execution of the works

1. DAMAGES AND BACKGROUND

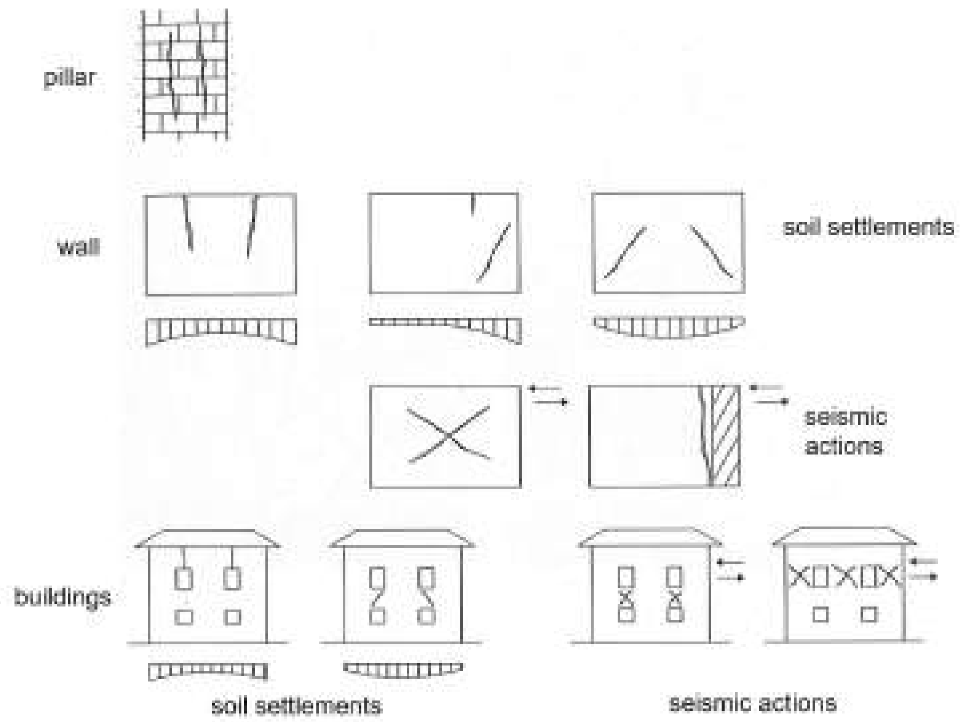
- Historical references:
  - · Photographs, documents, testimonies
- Existence of previous buildings
- Structural or architectural modifications
- Damages: earthquakes, flooding…
- Modifications of the environment:
  - · Excavations, paving, sanitation, wells, cellars…

2. ANALYSIS OF OBSERVED PATHOLOGY

- Verify the origin of damages
- Typology of wall problems:
  - · Fissures
  - · Cracks
  - · Deformation
  - · Inclination
  - · Deterioration
  - · Loss of material
  - · Patina, color change, vegetation, salts, efflorescences

DAMAGES AND DEFORMATIONS IN A WALL STRUCTURE

We must remember:



(4)

Fig. 14. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011, p. 121.

POSSIBLE CRACKS IN MASONRY PILLARS SUBJECT TO CRUSHING PHENOMENA

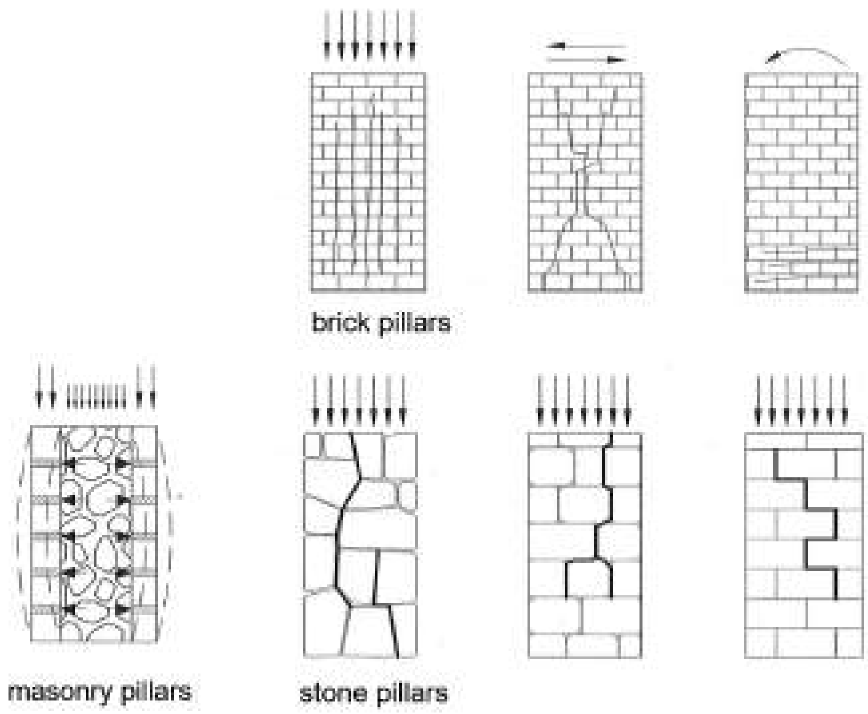
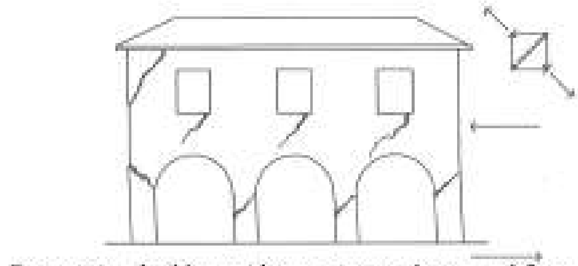
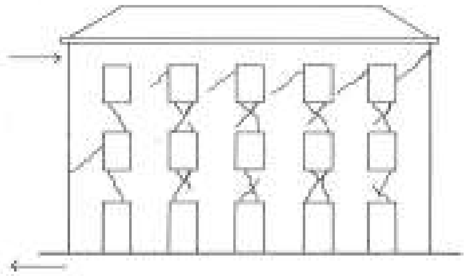


Fig. 15. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011, p. 123.



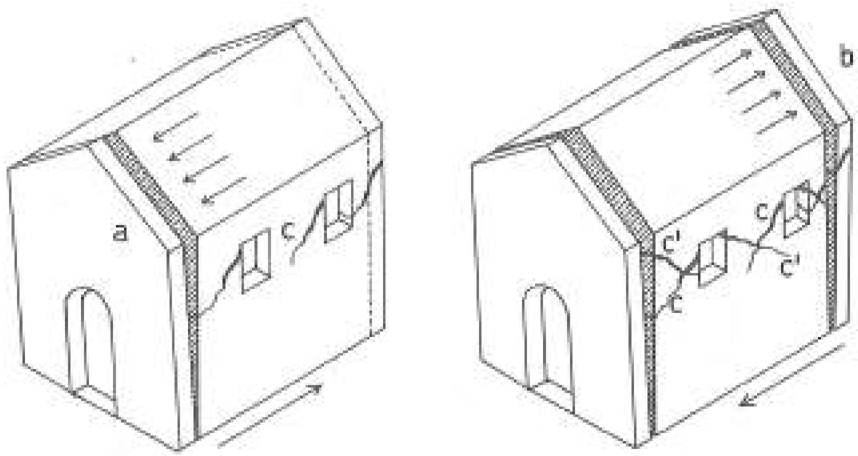
Damage in a building with a portico on the ground floor.



Characteristic fractures cross-shaped caused by cutting efforts in parapet-lintel areas in a facade wall subjected to parallel shockwaves

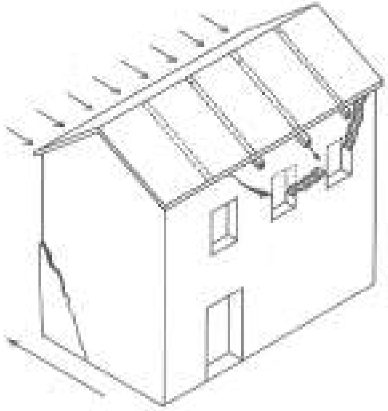
(5)

Fig. 16. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011.

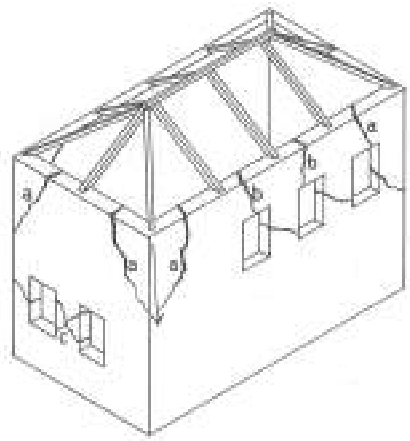


Thrust in one direction: detachment of the facade *a* and formation of fractures *c*.
Thrust in the opposite direction: detachment of the wall *b* and shear cracks *c'*.

Fig. 17. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011.



Detachment of a part of the façade due to puncture of the trusses. The corner areas can resist if the orthogonal walls are well connected to each other.



a) Corner damages caused by the action of the diagonal struts in a building with a spine wall; b) from the inertial forces of the wall and from the transverse struts of the roof; c) from the alternating shear actions.

Fig. 18. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011.

FOUNDATION AND GROUND DAMAGES

We must remember that some cracks are due to foundation and ground damages.

Edge Movements:

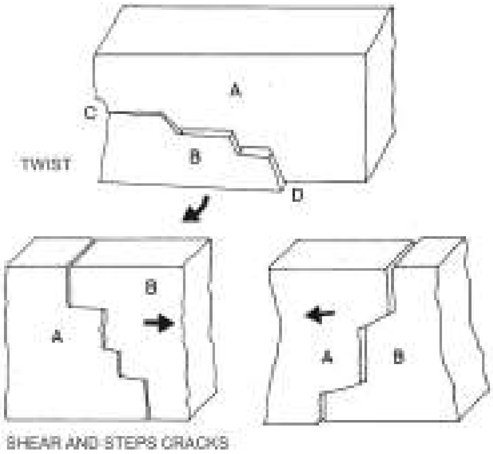


Fig. 19. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Madrid 1985, p. 54.

Edge Movements: Corner Settlement
Combination of movement in two orthogonal planes

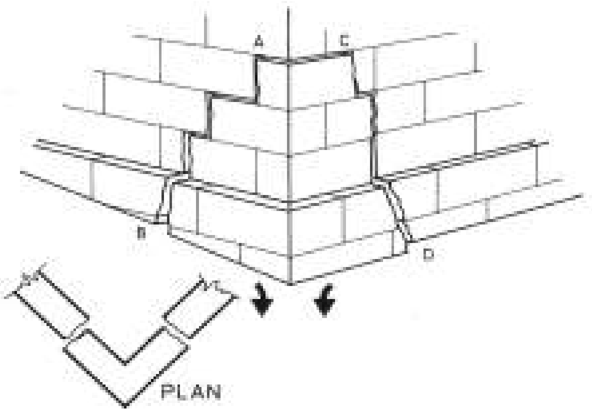


Fig. 20. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Madrid 1985, p. 63.

Edge Movements: Footing Settles and Leans
Combination of movement in two orthogonal planes with shear and step cracks.

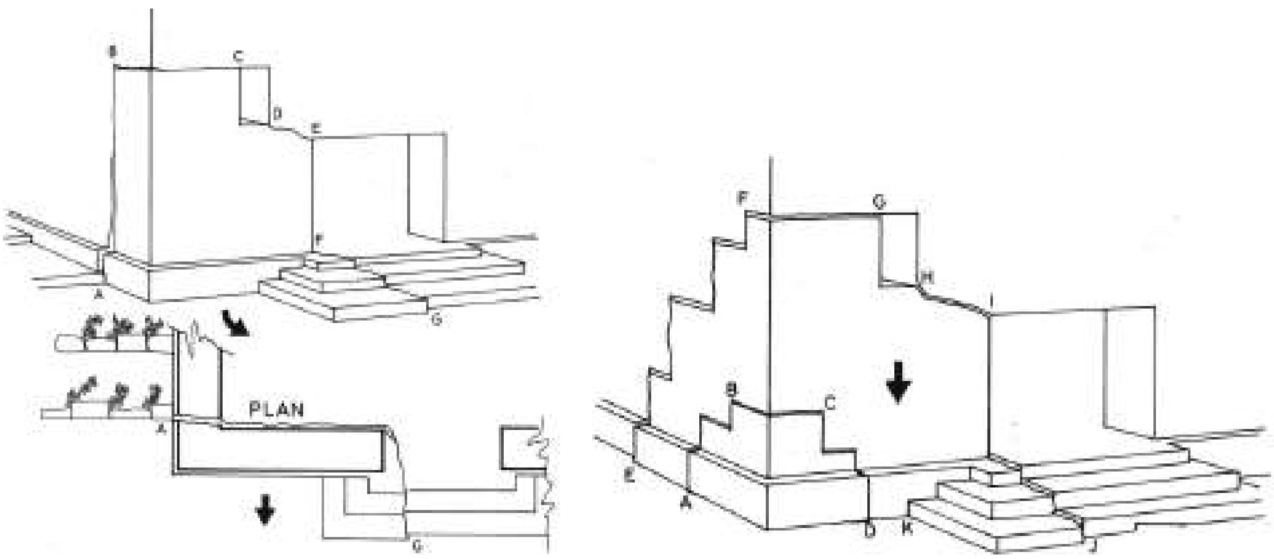


Fig. 21. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Madrid 1985, p. 66.

Internal Movements: Differential Settlement
Caused by weight and small differential settlement below load

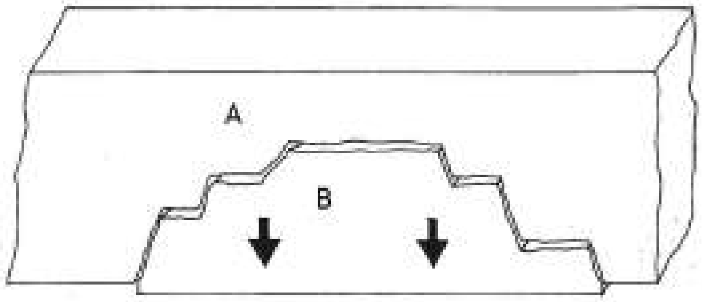


Fig. 22. From G. López Collado, *Las Ruinas en Construcciones Antiguas,* Miján, Artes, Gráficas, Madrid 1985, p. 54.

Internal Movements:
Wall is uniformly pushed and displaced with vertical shear cracks

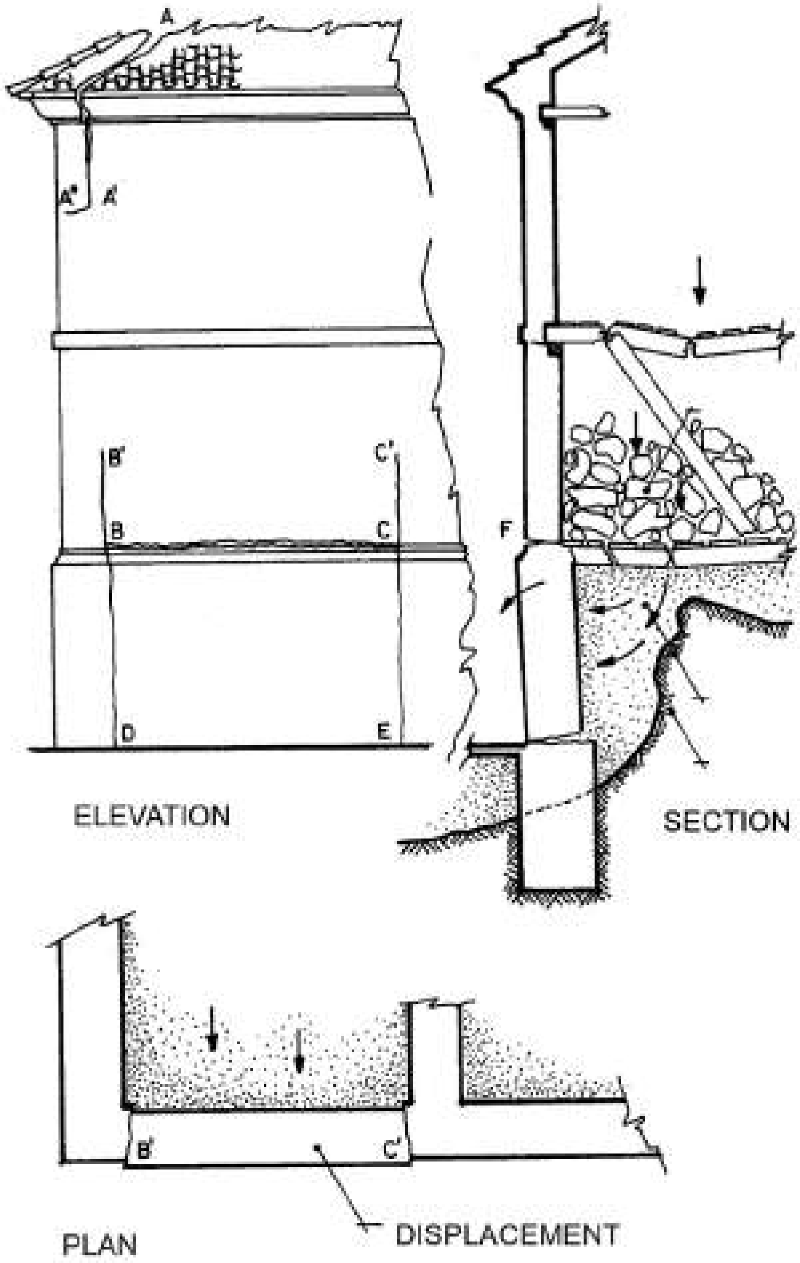


Fig. 23. From G. López Collado, *Las Ruinas en Construcciones Antiguas,* Miján, Artes, Gráficas, Madrid 1985, p. 56.

3. VERIFICATION OF THE HYPOTHESES

– Structural analysis (6)
– Surveys

DAMAGE DETECTION

– Surveys:

· Structural typologies
· Constructive survey
· Maps of damages
· Alteration and degradation
· Material deterioration
· Mechanical survey

– Examples:

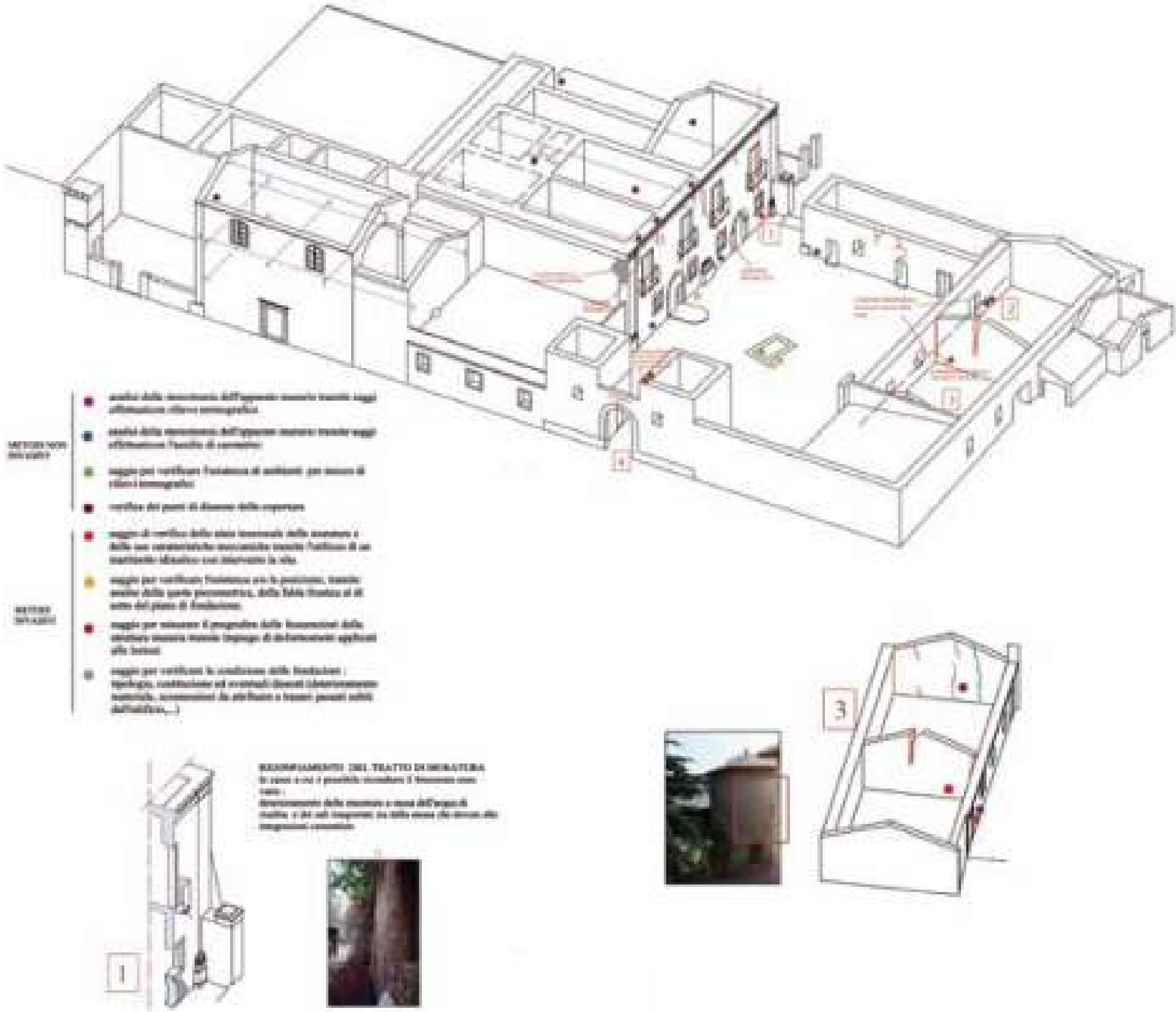


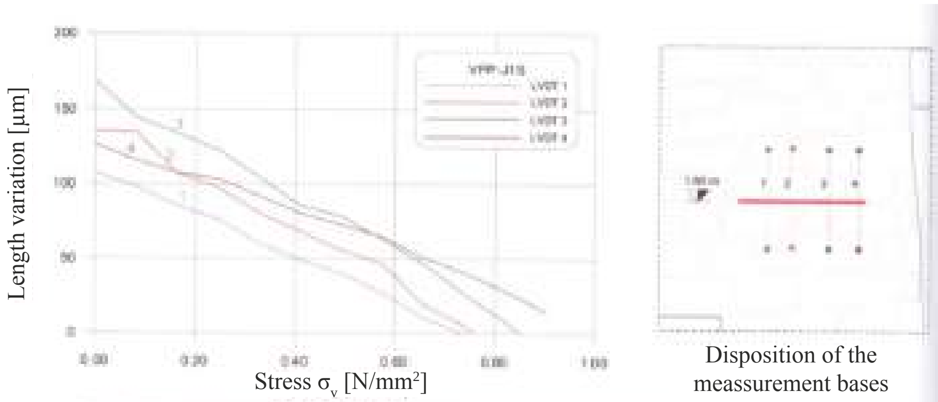
Fig. 24. Structural analysis of Palazzo Spadafora, Milazzo. From C. Bellanca, *Methodical Approach to the restoration of Historic Architecture*, Alinea Editrice, Firenze 2011, p. 249.

– Some essays:

· Simple Flat-Jack:

The vertical displacements are read with the flat jack inserted in the masonry. The hydraulic system is connected to a small tub inserted in the masonry.

Fig. 25. From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011, p. 208.



Test VPP-J1S. Trend of the distance between the mixture bases as a function of the applied effort.

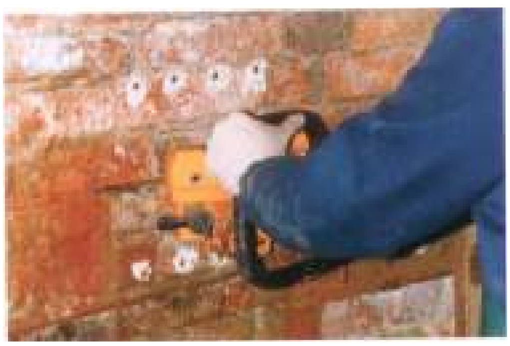
Fig. 26. From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011, p. 208.

Prova VPP-J1S	
Base di riferimento	SFORZO (N/mm²)
Base 1	0.74
Base 2	0.76
Base 3	0.85
Base 4	-
Stato di sforzo medio	0.78

Stress corresponding to the cancellation of the variation in length between the individual bases (interpolated values)

· Double Flat-Jack

Fig. 27. From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011, p. 209.



· Georadar

The execution of the surveys can be done via GPR with a 2 GHz dual polarity antenna, such as the one used in the survey made in Pisani Palace. A radar trace could be elaborated from the velocity analysis that was conducted on the diffraction produced by a fiuba. The processed data revealed three diffractions, and the position of the apex identified the distance and depth of the metal element that produced it.

– Instrumental Methods

· Endoscope

Fig. 28. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 71.

· Finite Element Analysis. Main Stresses

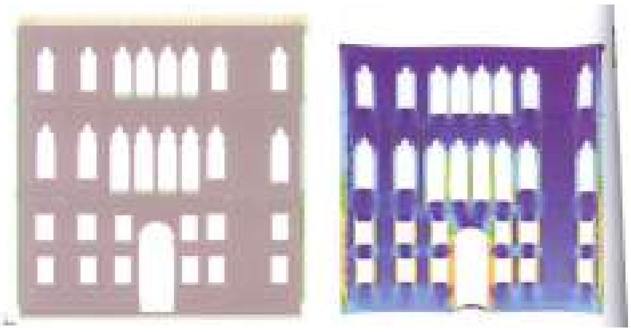


Fig. 29a. Stress in vertical direction. From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011.

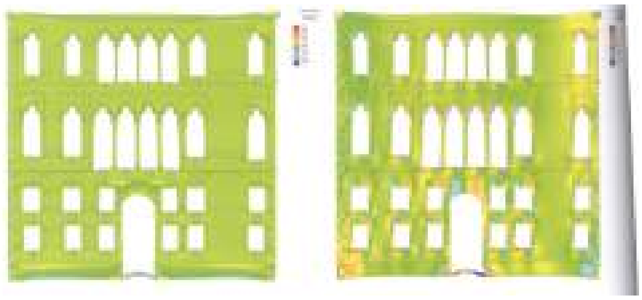


Fig. 29b. Stress in horizontal direction. From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011.

· Station Total Survey. Deformations

CAUSES

– Incompatibility (constructive)
– Water
  · Rain
  · Soil (capillarity)
  · Condensation
– Ground
  · Soil settlement
  · Earth pressure
  · Changes
– Structural
  · Originally
  · Joints
– Biological agents
– Contamination
– Human action
– Thermal
– Materials
  · Degradation
  · Oxidation

4. SELECTION OF REPAIR SOLUTIONS

(7) – Cleaning
– Surface consolidation
  · Protection
– Waterproofing
  · Drainage
  · Ventilation
  · Barriers
– Substitution
– Consolidation of joints
  · *Stuffed* and grouting
  · Sealing of cracks
– Edges consolidation
– Structural consolidation
  · External reinforcements
  · Injections
– Reintegration
– Shoring
– Anastylosis

Fig. 30. Santa María, Villalba del Rey, Cuenca. Photo by Susana Mora.

Fig. 31. *Stuffed.* San Gil, Atienza, Guadalajara. Photo by Susana Mora.

STUFFED **& GROUTING**

Fundamental solution to consolidate a wall. The joints must be cleaned where the masonry is fixed, eliminating the mortar in bad conditions. Generally we use a similar material or with similar characteristics of hardness, porosity, elasticity, etc. But it may be aesthetically very different looking for its formal differentiation. Sometimes it is delimited when it is carried out on a surface to be considered.

Fig. 32. Delimited *stuffed.* Antoni González. Barcelona. Photo by Susana Mora, 1993.

SEALING OF CRACKS

· Mortar
· Epoxy resins

Fig. 33. Defensive walls of Palazuelos, Guadalajara. Restoration by Susana Mora.

EDGES CONSOLIDATION

· Slope mortar
· Sacrificial layer
· Stone gabions

Fig. 34. Sacrifitial mortar, Clunia, Burgos. Photo by Susana Mora, 2011.

Fig. 35. (On the right, above) Stone gabions, Clunia, Burgos. Photo by Susana Mora, 2011.

Fig. 36. (On the right, below) Clunia, Burgos. Photo by Susana Mora, 2011.

STRUCTURAL CONSOLIDATION

– External reinforcements (8)
  · Buttress
  · Cladding
  · Cable-stayed
  · Bracing
  · Fibers
  · Anchoring
– Injections
  · By gravity
  · By pressure
  · Reinforced

BUTTRESS // EXTERNAL REINFORCEMENTS

Fig. 37. Colosseo, Stern consolidation, Roma. Photo by Susana Mora, 2015.

Fig. 38. Buttress, Carracedo Monastry, León, 1990. Restoration by S.P. Arroyo and Susana Mora.

Fig. 39. Buttress, S.P. de Arlanza, Burgos, 1989. Restoration by S.P. Arroyo and Susana Mora.

Fig. 40. Colosseo Buttress. From S. Casiello, *Verso una storia del restauro*, Alinea Editrice, Firenze 2008.

Fig. 41. Colosseo Buttress, Rome. Photo by Susana Mora, 2015.

CLADDING

Fig. 42. Morella, Castellón, Spain. Photo by Susana Mora, 2016.

ANASTYLOSIS // BRACING

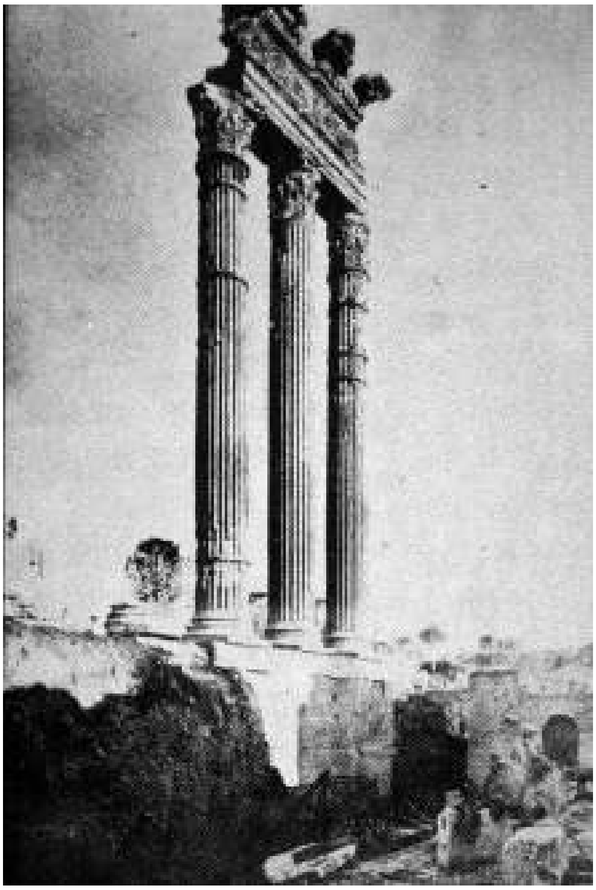


Fig. 43. Fori Imperiali, Roma. From C. Ceschi, *Teoria e storia del restauro,* Bulzoni, Roma 1970, p. 120.

HIDDEN REINFORCEMENTS // CABLE-STAYED

Restoration has insert reinforcements and still acts inside the columns.

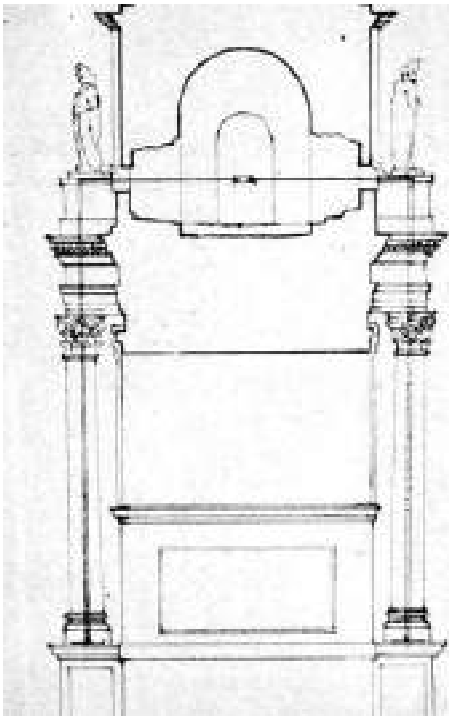


Fig. 44. Costantino Arch, Rome. From C. Ceschi, *Teoria e storia del restauro*, Bulzoni, Roma 1970, p. 129.

Fig. 45. Costantino Arch, Rome. From C. Ceschi, *Teoria e storia del restauro*, Bulzoni, Roma 1970, p. 129.

CLADDING

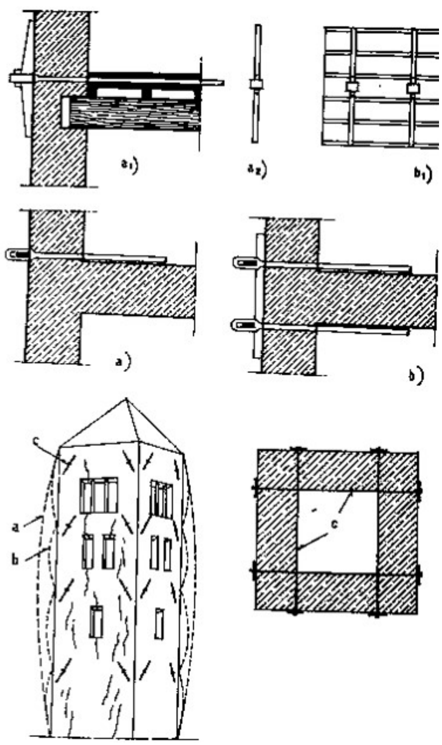


Fig. 46. From G. Cigni, *Il consolidamento murario*, Edizioni Kappa, Roma 1975.

AUXILIARY ELEMENTS // CABLE-STAYED

(9)

Fig. 47. On the left: Forte Fuentes, Colico, Lecco. L. Jurina. Photo by Susana Mora, 2015.

Fig. 48. On the right: Tail of the joinning elements in Forte Fuentes, Colico, Lecco. L. Jurina. Photo by Susana Mora, 2015.

Fig. 49. Castle of Trezzo d'Adda, Milan. Photo by Susana Mora, 2015.

CABLE-STAYED

Figs. 50-51. Massenzio Basilic, Rome. G. Croci. Photos by Susana Mora, 2017.

Fig. 52. Massenzio Basilic, Rome. G. Croci. Photo by Susana Mora, 2017.

BRACING


Figs. 53-54. Castle of Trezzo d'Adda, Milan. Lorenzo Jurina. Photos by Susana Mora, 2015.

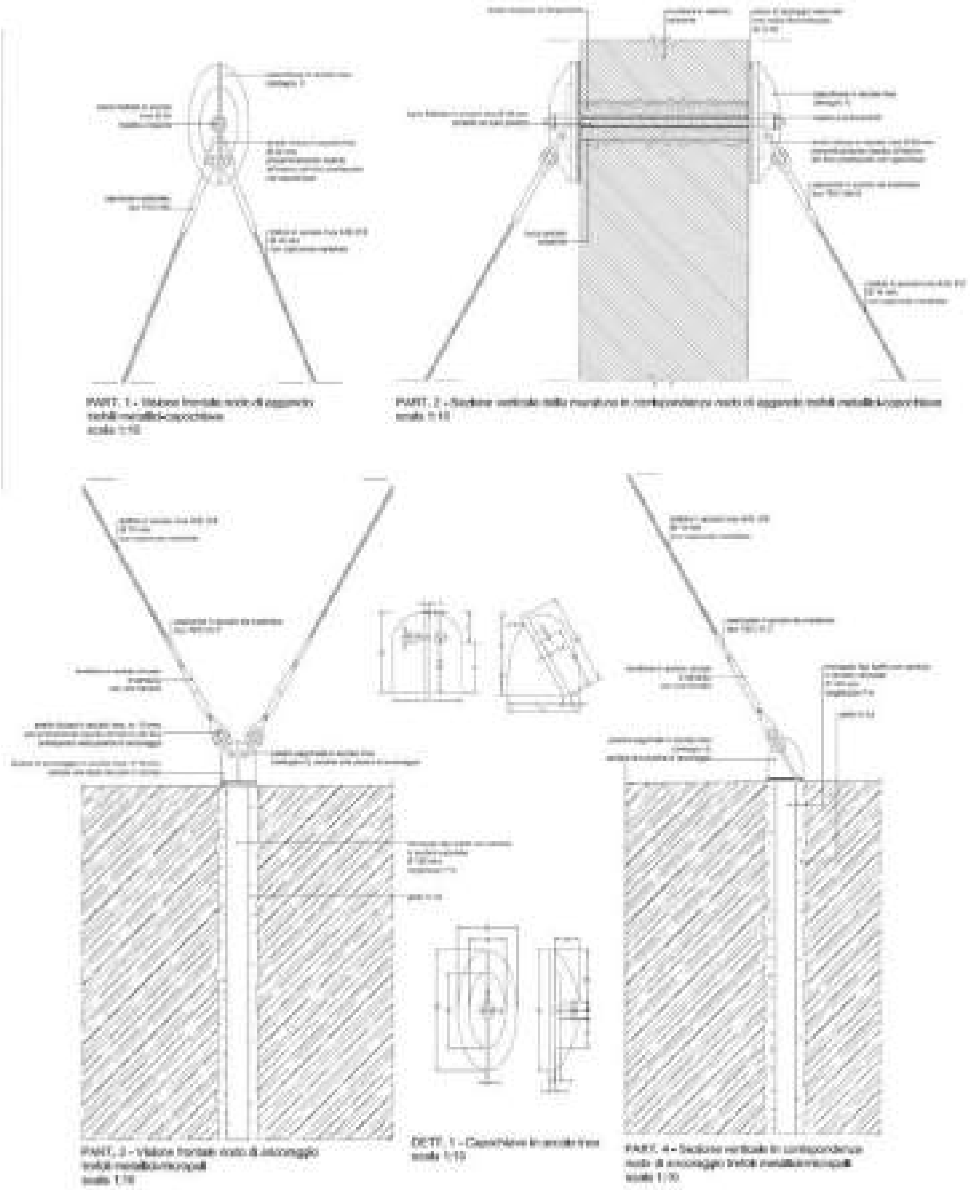


Fig. 55. Designs by Lorenzo Jurina.

FIBERS

Use of carbon fiber as laminates in reinforcements for pillars and walls and aramidica fiber laminates in reinforcement of walls and pillars.


Figs. 56, 57. From F. De Cesaris, "Materiali e strutture", n. 12, 2017, p. 78.

Fig. 58. Basilica di Santa Maria di Collemaggio, L'Aquila. Photo by Susana Mora, 2012.

Fig. 59. Cathedral of Palestrina, Rome. From F. Marmo, *Materiali fibro-rinforzanti a matrice polimerica*, "Materiali e strutture", Anno 2, n. 34.

Reinforcement of beams and plates

Fig. 60. Palazzo Altemps, Rome. Photo by Calogero Bellanca, 2021.

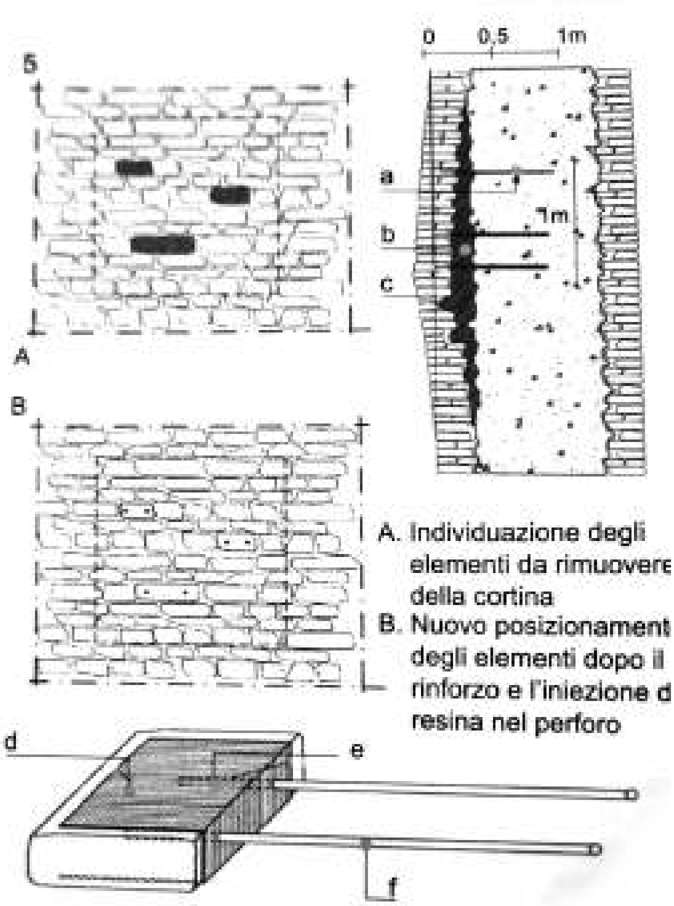


Fig. 61. Design by D. Fiorani. From G. Carbonara, *Atlante del restauro architettonico,* vol. II, Utet, Torino 2004, p. 530.

ANCHORING

Fig. 62. On the left: Traditional bracing reinforcement. From G. Carbonara, *Atlante del restauro architettonico,* vol. II, Utet, Torino 2004, p. 565.

Figs. 63, 64. On the right: From G. Carbonara, *Atlante del restauro architettonico*, vol. II, Utet, Torino 2004, p. 562.

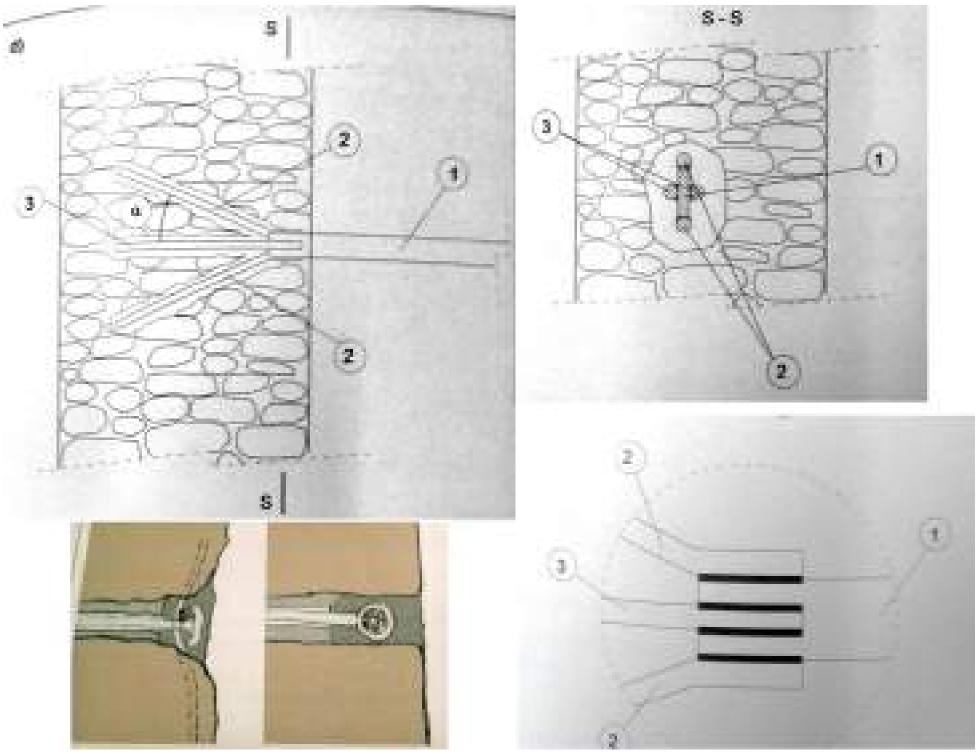


Fig. 65. Redesigned by Susana Mora.

INJECTIONS

The objective is to improve the properties in terms of continuity and resistance. The technique consists in the injection of a liquid consistency mortar, in order to fill gaps and fissures, restoring the mechanical capacity to the construction.

By Gravity:

- Injection control
- Grout density
- Washing inner leaf

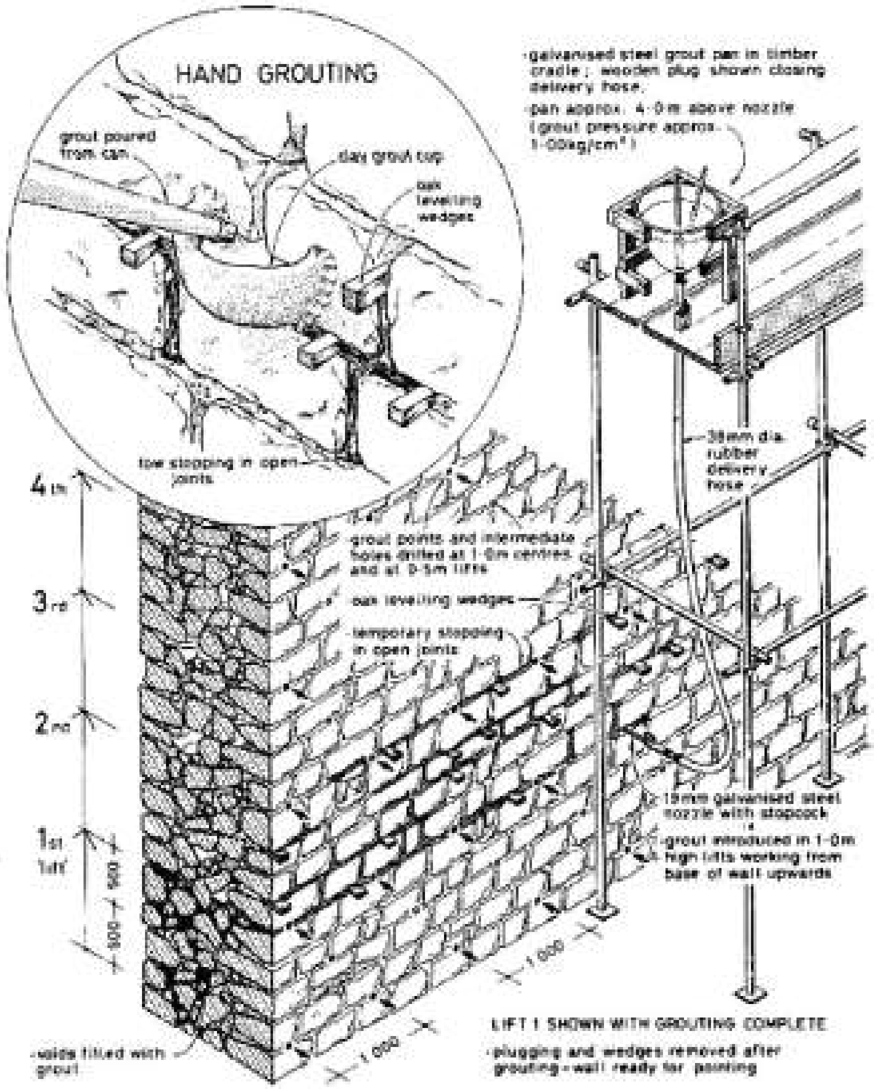
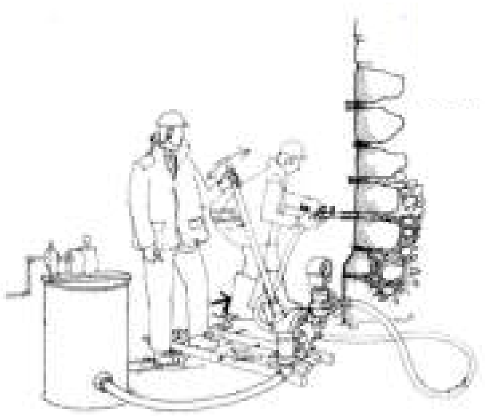


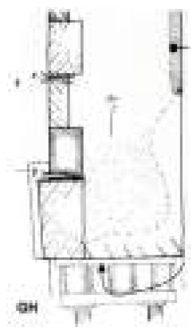
Fig. 66. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 175.

By Pressure:

- Constructive system
- Pressure
- Injection control
- Grout density
- Washing inner leaf



From the bottom



Upper holes

Fig. 67. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 187.

Reinforced.
Materials:

- Stainless steel
- Vitro / resin bars
- Synthetic resin bars
- Carbon fibers
- Polymeric fiber
- Synthetic ropes

Problems:

- Constructive system changes
- Static / Hyperstatic
- Expulsion of the bars
- Homogeneous systems
- Compatibility

Fig. 68. Reinforced. Problems in Paestum. From F. Lizzi, *The static restoration of monuments*, Sagep Publisher, Genova 1982.

REINTEGRATION

Technique that allows us to aesthetically integrate a work replacing its losses. To reduce the visual impact of damage and lacunae on a work, thus increasing its artistic and iconographic legibility. Should be clearly distinguishable when viewed at close proximity. Materials to be employed should be compatible with the original and reversible. A distinction is to be drawn between lacunae that can be reconstructed and those that cannot, as they require different methods of reintegration.

Fig. 69. Rome, example of external reinforcement. Photo by Susana Mora.

Similar Material

Fig. 70. Santa Maria Antiqua, Rome. Photo by Susana Mora, 2010.

Different Material

Fig. 71. Alhambra, Granada, Spain. Photo by Susana Mora, 2015.

Cuci-Scuci

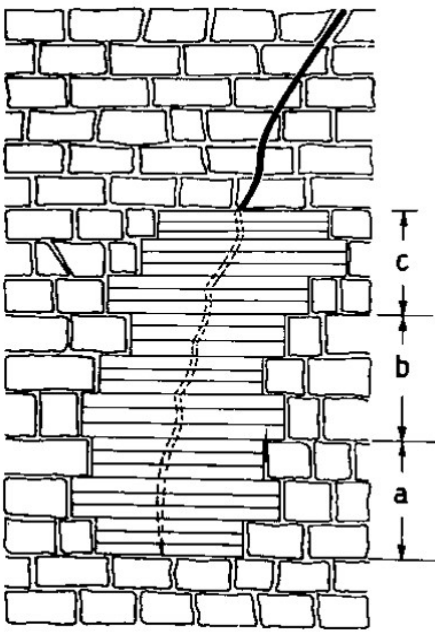


Fig. 72. Design by Susana Mora.

SHORING

Support constructions or parts of constructions in order to structurally stabilize and transfer loads to the ground.

Fig. 73. Colosseo, Rome. Photo by Susana Mora, 2016.

ANASTYLOSIS

Placement of pieces and/or elements demolished in the place that they originally occupied. Can help with metallic elements, buttress, etc. or from another neutral material to place them.

Fig. 74. Fori Imperiali, Rome. Photo by Susana Mora, 2010.

Fig. 75. Tempio di Vesta, Rome. Photo by Susana Mora, 2010.

Fig. 76. Tempio della Concordia, Agrigento. Photo by Susana Mora, 1985.

NOTES

Some historic contribution are:

ALBERTI L.B., *De re Aedificatoria*, 1485, tradotto in italiano 1546 da Cosimo Bartoli, *I dieci Libri di Architettura*, illustrati, 1550;
BLONDEL F., *Cours d'architecture enseigné dans l'academie royale d'architecture*, Paris 1675;
VIOLLET LE DUC E.E., *Architecture, in Dictionnaire Raisonné de l'Architecture Française*, Tome premier, Paris MDCCCLVIII, pp. 107-452; and ID., *Construction*, in *Dictionnaire Raisonné de l'Architecture Française du XI au XVIe siècle*, Tome quatrienne, Paris MDCCCLVIII, pp. 1-279;
LIZZI F., *The static restoration of monuments*, Sagep Publisher, Genova 1982;
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PICCARRETA F., *I meccanismi dell'equilibrio delle strutture murarie, lezioni di statica delle costruzioni in blocchi lapidei*, Roma 2000;
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Restauro e consolidamento, a cura di A. Aveta, S. Casiello, F. La Regina, R. Picone, Roma 2005;
BINDA L., (ed)., *Learning from failure: Long-term behaviour of Heavy masonry Structures*, Southampton 2008;
ICOMOS 2017, *Guidance on post trauma recovery and reconstruction for world heritage cultural properties*;
ROCA P., LOURENÇO P., GAETANI A., *Historic Construction and Conservation*, New York-London 2019;
MODENA C., *Criteria and Techniques for Repairing and Strengthening Architectural Heritage,* in *Conservation and Restoration of Brick Masonry Structures*, ed. by Tokio 2019, National Research Institute for Cultural Properties, pp. 47-63.

1) FIORANI D., *Strutture in elevato, Sezione C 2*, in *Atlante del restauro*, a cura di Carbonara G., Torino 2004, I pp. 176-183 e pp. 195-209;

2) "The load-bearing wall is probably the commonest type of building construction element. Loadbearing walls of masonry were used in buildings ranging from the palace of Versailles to the country villa or farmhouse, including churches and castles, mosques and monasteries. Such buildings may suffer damage because of thrust from defective roofs, but overall damage is more likely to result from defects in foundations and thermal stresses. Defects due yo disintegration of walls when the binding material of lime or cement deteriorates, and defects due to moisture, decay and aging or rotting of wood reinforcement, are also inherent in this form of construction". In FEILDEN B. M., 1982, p. 62; MARMO F., *L'innovazione nel Consolidamento*, si veda in particolare: chapter 2, *Metodi di rinforzo*, … Roma 2007, pp. 53-120;

3) "The merit of earhen construction, particulary in hot arid climates, is that it is comfortable due to its high thermal capacity and gives insulation, being cool bybdayband warm by night. Earth also has low capillary attraction. Low cost and ready availability of materials and the small amount of energy used in construction are also advantages which may convince builders that this material should not be despides. Even so, the ancients knew fully well that unless maintained regularly earth buildings could not be expected to last long. However, the material of an obsolete or a decayed building is readily recycled into a new building. Before re-use , a sample should be tested to see if it has lost any of its binding capacity, which can be improved by additives"… p. 73;

4) The methodology of all conservation depends upon making an inspection and report at regular intervals on all item of cultural property, recording the visible defects factually, in order to diagnose the causes of decay and propose an effective cure that involves only the

minimum intervention. This metoculous examination requires the ability to appreciate the messages in the cultural property and its values. The extend and nature of the historic buldingmust be included, as architecture cannot be divorced from its site-it is immovable cultural property which must be seen as a whole. The building must be looked at with a seeing and understanding eye, and allowed to speak to you. At the start, your mind should be cleared of preconception, and know that you know nothing" p. 203;

5) It is necessary to read GIUFFRÈ A., *Letture sulla meccanica delle murature storiche,* chapter 1, Roma 1990;

6) GIUFFRÈ A., *Leggendo il libro delle antiche architetture*, See in particular: *Procedura di analisi e progetto dell'intervento*, …, a cura di Carocci C., e Tocci C., Roma 2010, pp. 93-107;

7) LA REGINA F., *Sicurezza e conservazione*, … Napoli 1995, in particolare see: *Direttrici operative e tipologie d'intervento per il consolidamento strutturale delle opere murarie verticali*, … pp. 147-189;

8) We don't forget: DI STEFANO R. C., *Il consolidamento strutturale nel restauro architettonico,* Napoli 1990; FIORANI D., *Interventi sulle strutture in elevato,* in *Atlante di Restauro,* tomo secondo, sezione G 2 , a cura di Carbonara. G., Torino 2004, pp. 508-538;
DI PASQUALE S., *L'arte del Costruire, tra conoscenza e scienza*, Venezia 1996, pp. 397-470;

9) For cable solutions see JURINA L., *Vivere il monumento, conservazione e novità,* Milano 2006.

But don't forget the conservation of Stone: LAZZARINI L., TABASSO LAURENZI M., *Il restauro della Pietra*, Padova 1986, ristampa Torino 2010; CONTI C., TORRACA G., VEDOVELLO S., *Il consolidamento della Pietra nella dimensione del grande cantiere, metodi organici e inorganici su superfici marmoree,* in *Manutenzione e conservazione del costruito fra tradizione e innovazione*, Atti del Convegno di Studi (Bressanone) giugno, Padova 1986, pp. 765-776; TORRACA G., *La vulnerabilità e durabilità delle pietre, con particolare riferimento al caso dei templi di Paestum*, in "PACT", 1994, 32, pp. 157-168; ID., Tecnologia del Restauro delle superfici architettoniche in "Palladio", 1994, VII, 14, pp. 323-332; ID., *La pulitura delle facciate in Pietra: necessità della conservazione e immagine del monumento,* in *La pulitura delle superfici dell'architettura*, Atti del Convegno di studio (Bressanone luglio 1995), Padova 1995, pp. 1-7; CARBONARA G., *Dalla storia al restauro e viceversa, un caso significativo,* from *History to restoration and viceversa, a significant Case, in Basilica di San Pietro, restauro e conservazione*, Roma 1999, pp. 62-71; D'ELIA M., CAPPONI G., *Il cantiere di progetto per il restauro della Torre di Pisa,* in *La Torre Restituita*; "Bollettino d'Arte", 2005, numero speciale, III, pp. 461-486; D'ELIA M., CAPPONI G., SANTAMARIA U., TORRACA G., *Studi e interventi di avvicinamento al restauro* , in *La Torre Restituita,* "Bollettino d'Arte", 2005, volume speciale III, pp. 427-458; BELLANCA C., *Ascoli Piceno, Palazzo Roverella Preliminary reflections through study and the restoration of the surfaces*, in ID., *Methodical approach*, …, 2011, pp. 139-145.

HEYMAN J., Arches, *Vaults and Buttresses: Masonry Structures and their Engineering,* Cambridge University Press, 1996.

LYNCH G., ROUNDTREE S., *A guide to the repair of Historic Brickwork,* advice series, published by Stationery Office, Dublin, Ireland 2009.

THROOP D., KLINGNER R.E., *Masonry: opportunities for the 21st century*, ASTM International, Saltlake UTAM (USA) 2002.