Heritage Problems, Causes and Solutions

Calogero Bellanca and Susana Mora Alonso-Muñoyerro

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3

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Esperienze di Studio e Restauro in Europa – 3

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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

ACKNOWLEDGEMENTS

We express our thanks to Eugenio Gaudio, Former Magnificent Rector of Sapienza University of Rome, for his constant support and interest at every stage of the European project (SURE) and during the preparation of these volumes and all the professors of it, and to the ETSAM Director, DCTA directors, AIPA research group and a special remember to Luis de Villanueva and Fernando Ripolles.

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We feel is our duty to add our thanks to ICCROM and ICOMOS International.

Finally we want to express our thanks to the publisher, Sapienza University Press and specially to Eleonora Carletti and Roberto Di Iulio who with great ability and patience made it possible to print this work.

PART I

METHODOLOGICAL APPROACH TO CONSERVATION
PHYSICAL APPROACH

INTRODUCTION

The book provides the lecturer with an holistic approach to the understanding of the building an its physical appearance.
Thanks to this general overview, lecturers will acquire the methodology that will help them to obtain a diagnosis framework of the architectural element studied. It goes beyond methodology and furnishes general and sound criteria on the matter. It supports them to draw relations between all the phases of a restoration project, understanding the importance of finding and having general guidelines that are appropiate to the building, element or site, and its values.

> "The material used in a work of art carries the message of the image and it does so in two ways which can be defined as structure and appearance. Separating out these fundamentals is like exploring the verso and recto of a medal or coin. Whether appearance prevails or structure, together they represent the two functions of material in a work of art and normally one does not contradict the other, although conflict is still possible. Such conflict is usually in the contrast between the aesthetic case and the historical case, and in the end appearance will override structure, where they cannot otherwise be reconciled" (1).

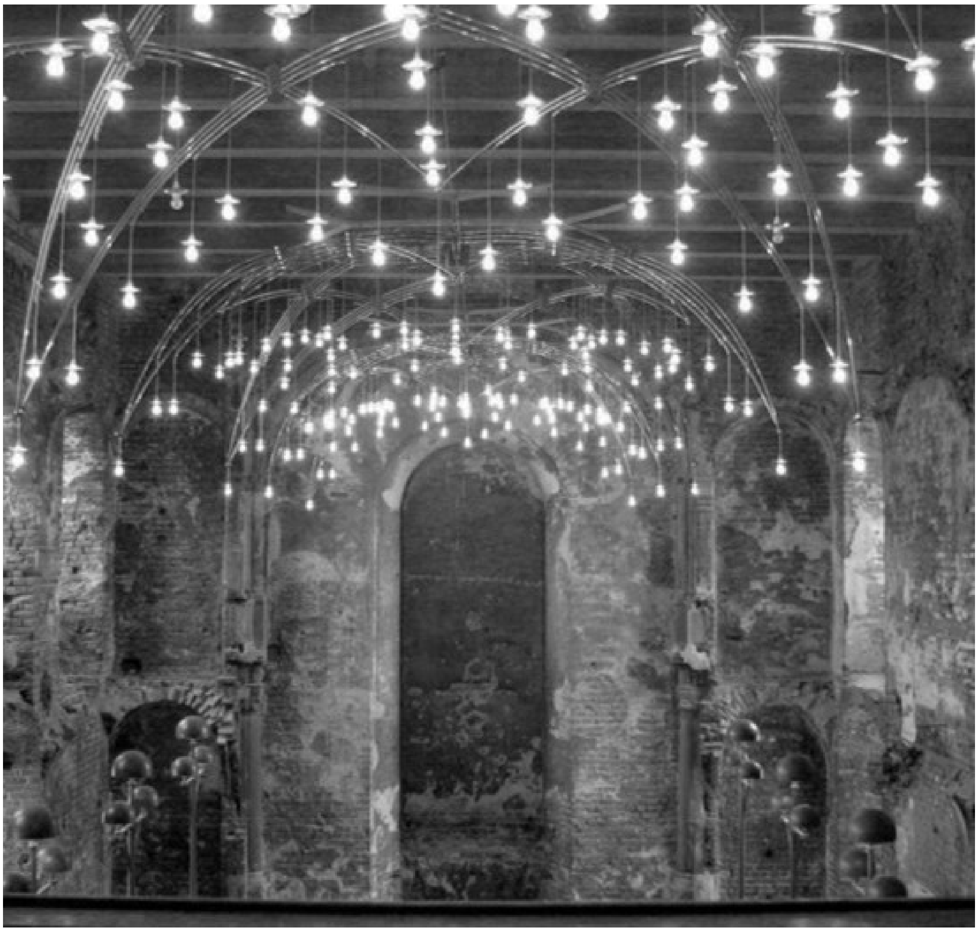


Fig. 1. Kolding Castle (Denmark). Inger & Johannes Exner. From *www.usefultravel articles.com.*

ASSESSMENT OF THE VALUES AND SIGNIFICANCE OF THE BUILDING (theoretical approach)

This aspect is focused on the study of the history and the composition of the building. The memory will be completed with bibliographical research, while the compositive description can be studied in comparison with similar buildings.

Fig. 3. *Colosseo*. Diagnose of the construction (physical approach). Photo by Susana Mora, 2010.

DIAGNOSIS OF THE CONSTRUCTION (physical approach)

This aspect includes an assessment in terms of heritage values, considering historical and artistic values. This evaluation requires knowledge of restoration history and criteria and will conclude in the statement of certain premises that would act as guidelines for the corresponding intervention.

Fig. 4. *Martinetto singolo*. From G. Doglioni, G. Mirabella, *Venezia: forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, 2011, p. 208.

CRITERIA

The main issues in the intervention on historical buildings are:

- TO CONNECT (compromise): to achieve a compromise between the conservation of the documentary and historical values of the building, and the contemporary values of the historical construction. The conservation and use of the building may require architectural solutions to stability, security, comfort and aesthetic criteria.

- TOLERANCE (respect): every intervention on a historical building is different from others. There needs to be an assessment of the main values that the building holds. The architectural project should respect and embrace those values, privileging the conservation of the built heritage.

TO CONNECT (compromise)

The intervention in the Palladian Basilica allows the conservation of the building stratifications to meet the inclusion illumination systems, security features and uses. The rooms in the building can host exhibitions and different events respecting its history.

Fig. 5. Basilica Palladiana in Vicenza (Italy). Internal view. Photos by Susana Mora, 2015.

Fig. 6. Basilica Palladiana in Vicenza (Italy). External view. Photo by Susana Mora, 2015.

TOLERANCE (respect)

To respect and not to annul the pre-existence.

To give value to the constructive systems and to the surfaces of the envelope.

The restoration offers to the viewer the clue for a previously existing window over the main entrance. This is done with the use of colour and texture.

Fig. 7. Trajan's Market. Rome (Italy). Stratification with loggia. Cavalieri di Rodi. Photo by Susana Mora, 2015.

Fig. 8. Villa Saraceno in Agugliano, Vicenza (Italy). Photo by Susana Mora, 2015.

DATA GATHERING

WORKING PROCESS

- To know about the building. -> This subject will provide the methodology corresponding to the study of the physical and technical aspects of the building.

- To diagnose.

- To delimit premises.

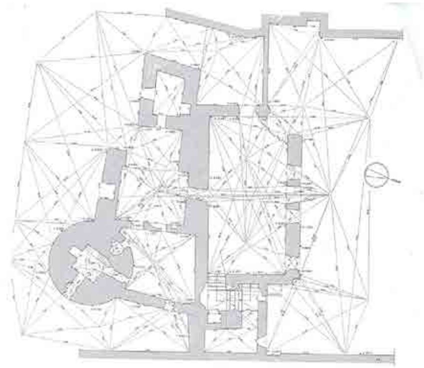
- To provide solutions.

- To respect and not to annul.

- To give value to the constructive systems and to the surfaces of the envelope.

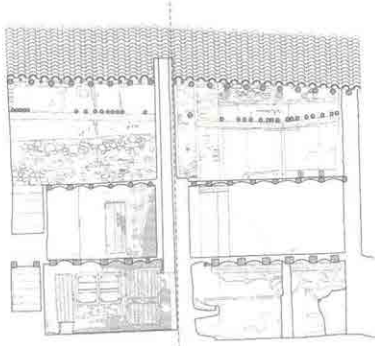
- The restoration offers to the viewer the clue for a previously exciting window over the main entrance, this is done with the use of colour and texture.

The data gathering consists of the following activities:



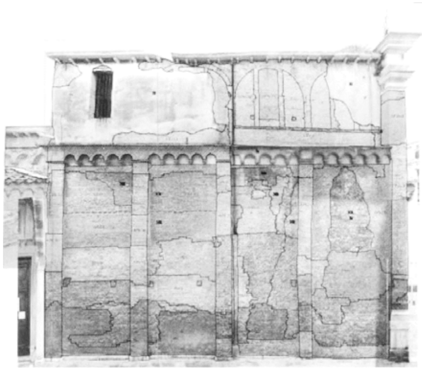
Geometrical survey
(*rilievo geometrico*)

Fig. 9. G. Carbonara (2)



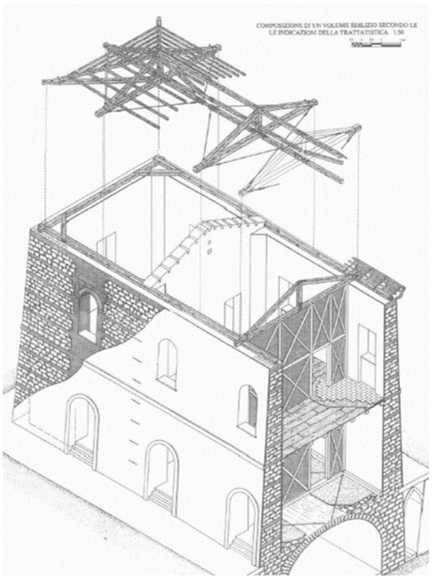
Constructive systems survey
(*rilievo architettonico*)

Fig. 10. F. Vegas and C. Mileto (3)



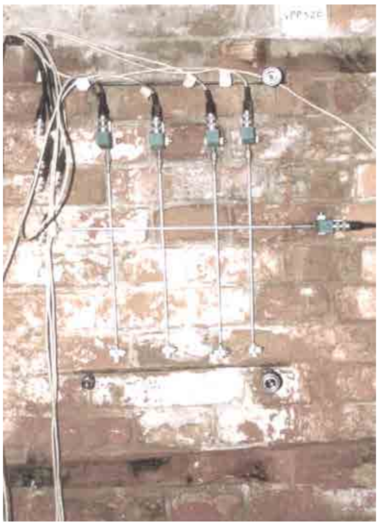
Stratigraphy. Phases.
Archaeology

Fig. 11. F. Doglioni (4)



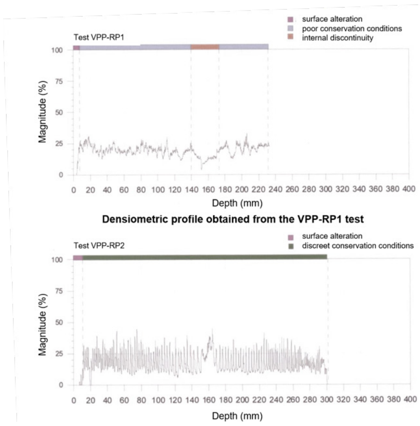
Mechanical and constructive
survey

Fig. 12. F. Doglioni (5)



Damages. Monitoring

Fig. 13. *Doppio martinetto.* F.
Doglioni (6)



Damage monitoring

Fig. 14. F. Doglioni (7)

NOTES

1) From BRANDI C., *Theory of restoration*, english edition, Firenze 2005, p. 51;

2) CARBONARA G., *Restauro dei monumenti*, guida agli elaborati grafici, Napoli 1990; BELLANCA C., (a cura di) *Una didattica per il restauro*, Roma 2008, and BELLANCA C., (edited by), *Methodical approach to the restoration of Historic Architecture*, Firenze 2011, pp. 181-271;

3) VEGAS F., MILETO C., *Aprendiendo a restaurar*, in “PH”, “Boletin del Instituto Andaluz del Patrimonio Historico”, 2018, 26, n. 93, pp. 196-197;

4) DOGLIONI F., MIRABELLA G., *Venezia: forma della costruzione, forme del dissesto*, Venezia 2011, p. 71;

5) DOGLIONI F., MIRABELLA G., *Ibidem*…, pp. 203-210;

6) Ibidem, 203-210;

7) Ibidem, 203-210.

CHAPTER 1. GEOMETRICAL SURVEY: TRADITIONAL METHOD, NEW TOOLS

GEOMETRICAL SURVEY

rilievo in Italian,
levantamiento in Spanish
relevé in French,
survey in English,
Bauforshungen in German.

DEFINITION:

According to the most advanced interpretations architectural survey (should be understood to mean) the primal form of knowledge of preexisting architecture and therefore, the set of operations, measurements and analysis necessary to understand and document the architectural good in its complete configuration, including the urban and territorial context, in its dimensional and metric characteristics, in its historical complexity, in its structural and constructive characteristics, as well as in the formal and functional features.

In short, survey can be a tool to portray the state of a monument in a certain time of its constructive history. Therefore, the study of successive surveys allows us to determine and understand the constructive and projectual stratification of the historical building.

In addition to the practical purpose of the conservation of Architectonic Property, the survey must also be considered a necessary and significant contribution to the knowledge of the historical-artistic heritage itself. That is, to consider the survey as an end and not only as a means to a subsequent restoration.

Architectural survey charter. Before we must remember:

for the methodical study of the architectural organism, see the masters of the Roman School of Architecture, from Gustavo Giovannoni to Vincenzo Fasolo, though we should mention, as a summary:

DE ANGELIS d'OSSAT G., *Guide to the methodical study of monuments and causes of their deterioration*, ICCROM and Faculty of Architecture, University of Rome, Roma 1972; CARBONARA G., *Restauro dei Monumenti*, guida agli elaborati grafici, Napoli 1990; ZANDER G., *Scritti sul restauro dei monumenti architettonici*, Roma 1993.

Also to be noted are the surveys conducted by CURUNI S.A., DONATI L., *Creta Bizantina, rilievi e note critiche su ventisei edifici di culto in relazione all'opera di Giuseppe Gerola*, Roma, 1987. Lastly on some didactic lines, BELLANCA C., *Ascoli Piceno e i suoi monumenti, primi avicinamenti e riflessioni attraverso lo studio e le proposte di restauro*, Roma-Ascoli Piceno 2000.

AIM OF THE SURVEY

A good general survey carried out on an architectural cultural asset, should essentially allow for:

1. **Geometric definition:** The knowledge, accurate, reliable and critically purified, of the morphological and dimensional configuration of the object, in its current physical state.
2. **Technical definition:** The technical, technological and material knowledge of the object, which helps understand both their constructive modalities and their current conditions of alteration and degradation.
3. **Thematic survey:** The possibility of an agile thematic edition of the surveying planimetry, to deepen the historical knowledge of the object as the first document of itself, which can only be deciphered thanks to careful survey and direct observation task.
4. **Historical observations** coming from both a preliminary approximation documented and planned on the object (prior critical understanding), indispensable for conducting a good survey, such as unpublished observations, resulting from direct and frequent contact with the monument.

Architectural survey is a discipline that uses all the sciences and all the techniques that can contribute to the reading, measurement and analysis of architecture in morphological, material, and structural aspects, visible or hidden.

Fig. 1. Tempio di Romolo al Foro Romano, Roma. Approach to detail. From G. Carbonara, *Restauro dei monumenti. Guida agli elaborati grafici*, Liguori Editore, Napoli 1990, XXXVIII.

Every architectural organism is in relation with the environment.

What is any architectural body living in a constant relationship with the environmental context. This relationship must be taken into account. Approach from the distant to the close context:

To approach: designing the context.
The method is important; not so much the technology used.

Fig. 2. Aerophotogrammetry. From C. Bellanca (a cura), *Una didattica per il restauro*, Alinea Editrice, Firenze 1987, p. 154.

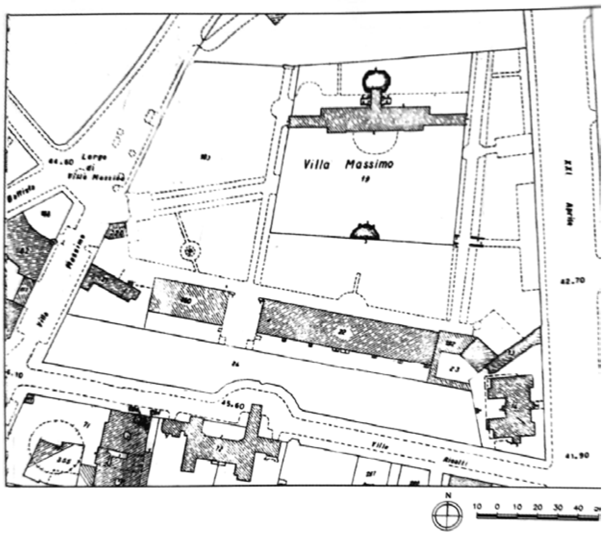


Fig. 3. Cadastral excerpt. Villa Massimo, Roma. From C. Bellanca (a cura), *Una didattica per il restauro*, Alinea Editrice, Firenze 1987, p. 154.

REGULATORY CRITERIA FOR THE SURVEY

In the programming and realization of the architectural survey, the following criteria must be taken into account:

a. Foresee the general scope, which can often require a project, a direction of the works and a final evaluation, according to the level of difficulty of the building.

b. Contextually consider both metric and technical research, as well as bibliographic, archival and iconographic research.

c. It is necessary to describe the location of the architectural body with respect to the National Cartographic System and the local reference adopted for the 1: 500 scale survey, if any, of the historical center to which it belongs.

d. The information obtained in the surveys can be considered as a partial component of a broader territorial database, so the surveys must be done in a computerized format.

e. The measurement systems and methods, as well as their tolerance, will be appropriate to the scale of representation and the expected contents.

f. The content of the representation must be related to the scale planned or adopted for the rendering and for the purpose of the investigation.

g. Consistent procedures should be established, as clearly as possible, for the realization of the direct, topographic and photogrammetric survey. The use of methods and techniques of various types should be referred to the general project of the investigation.

THE SURVEY AS AN OPEN SYSTEM OF KNOWLEDGE.

In general it is necessary to foresee:

– The realization of the general, or basic, and of the thematic survey, covering the totality of the architectural organism and its significant themes, in everything concerning its value and its conservation; as well as the survey, differentiated by types, of decorative elements and permanent furniture.

– The development of a sufficiently extensive measurements campaign to properly define the geometric model of the architectural body and represent it in all its parts.

– The reference of all measurements to a single system, conveniently preselected.

– Representations in variable scales, according to the dimension of the object, its characteristics and the objectives of the survey.

– That all the graphic elaborations are provided with a graphic scale.

– Ensure that the measures have a general accuracy compatible, on the one hand, with the error of the graphics and with the purpose of the survey and, on the other, with the possibilities offered by computer tools.

– Adopt all the necessary precautions to guarantee the metric stability of graphic representations.

– To carry out an exhaustive and scientifically adequate photographic documentation, in addition to bibliographic, archival and iconographic investigations that are suitable for the purpose sought.

THEMATIC SURVEY

The survey may vary from one building to another, depending on its characteristics; however, the general scheme can be the following:

a. Architectural survey, including dedication to different uses.

b. Survey of the structure and the corresponding table.

c. Survey of the architectural elements of value and typological relevance, with creation of the corresponding inventory.

d. Survey of pavements and roofs.

e. Survey of the walls and the coverings, with their constituent materials, as well as their states and degrees of conservation.

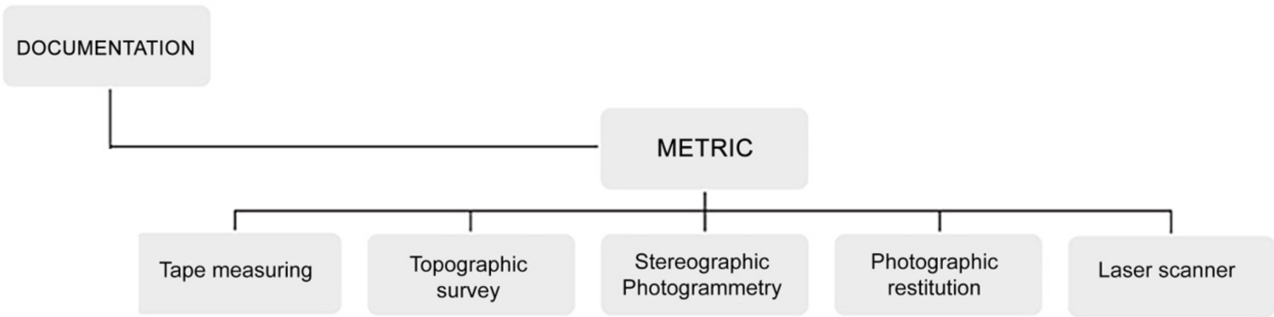
f. Table and inventory of constituent elements.

g. Survey of the facilities with the inventory of their utility. and on the basis of the contributions of the documentary investigation.

h. The chronology of the construction phases, as far as possible.

GEOMETRICAL SURVEY: MEASSURE METHODS

A. Direct or simple methods
B. Topographic methods
C. Photographic methods
D. Photogrammetric methods



The measurement systems can be grouped according to the complexity of the instruments used.

GEOMETRICAL SURVEY: TRADITIONAL METHOD

A. DIRECT OR SIMPLE METHOD. TRADITIONAL SURVEY

Measurement systems can be grouped according to the complexity of the instruments used. In the first place we have the simplest instruments and among them the tape measure, the plumb line and the level.

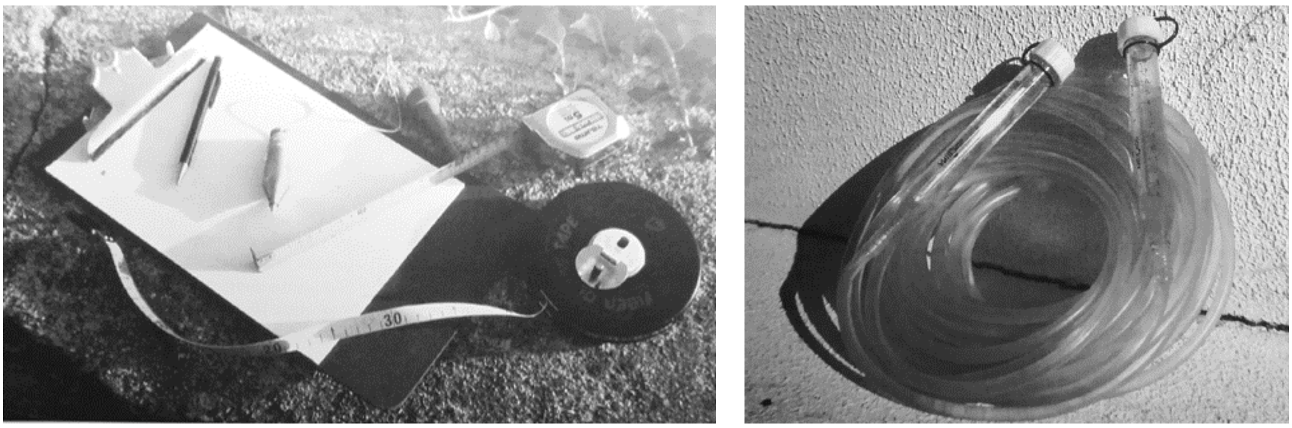


Fig. 4. On the left: paper, pencil and measuring tape. On the right: water level. Photos by Susana Mora.

SIMPLE METHOD: DIRECT AND DEFFERED METHOD

In the simple surveys there are two types:

• Direct survey
The direct survey is carried out in situ and does not require further elaboration than in any case the cleaning up of the drawing.
It usually requires the placement of auxiliary elements of reference, such as strings arranged in grids for the drawing of the plants or plumb lines with marks at fixed intervals for the elevations.

• Deferred survey.

In most of the architectural survey work carried out with simple instruments, the deferred survey method is used. That is to say, the necessary data are collected in the place with which later, in the office or study, the drawings are elaborated; therefore, far from the building or object.

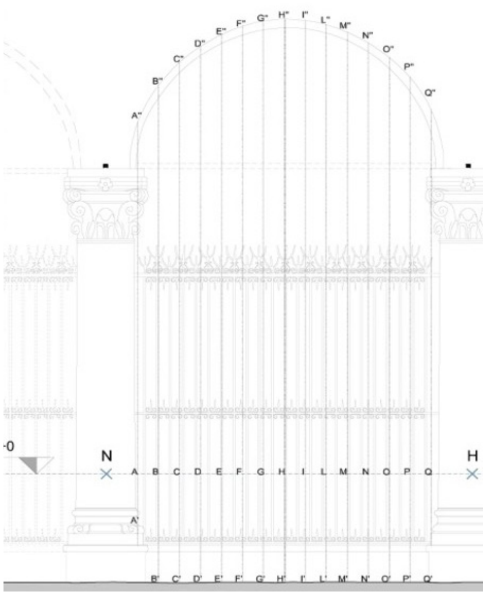
Figs. 5, 6. Direct measuring work in Martorana (Palermo) Church. Data collection by C. Bellanca, 1986. Photos by A. Bellanca.

SIMPLE METHOD: MEASURE RULES

Golden rules of all measurement with tape. The trilateration.

1. Every linear measurement that we take must always correspond to the side of a triangle from which we will have to measure three sides. The other more complex geometric shapes must be broken down into triangular shapes.
2. The triangles must be arranged so that their dimensions are the maximum possible, as long as they can be measured with the instrument which we have. At the same time, they should approximate equilateral triangles, since triangles with very unequal sides generate higher position errors of their vertices.
3. Although it is always convenient that there is redundancy in the measurements, it is also not advisable to multiply the number of triangles, as this produces a greater complication in the realization of the drawing.
4. The measurement by triangulation makes it possible to establish respect for the irregularity of the object, for which reason we must reject any presupposition of regularity, orthogonality or symmetry.
5. Special care must be taken that the vertices are always measured in the same place, since the existence of small shifts may cause errors.

Another rule to apply in this method is that all the measures to be taken in the same direction must be taken from a common origin and never as the sum of several partial measurements. In this way, the accumulation of small errors in the reading of the tape is avoided, as well as the fact that a partial measurement with a gross error influences the determination of all the elements that follow.



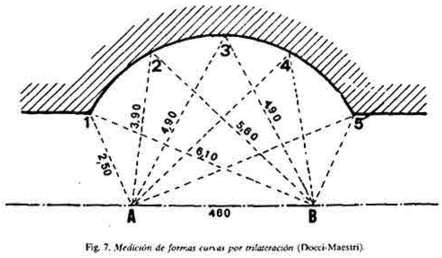


Fig. 7. On the left: Elevation measurements. From M. Docci, *Il rilevamento architettonico*, Laterza grandi opere, I edizione 1984, p. 203.

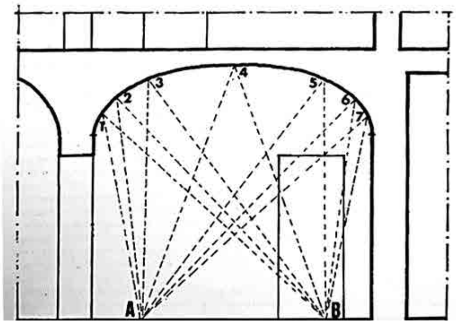


Fig. 8. On the right: Elevation measures. From M. Docci, *Il rilevamento architettonico*, Laterza grandi opere, I edizione 1984, p. 212.

SIMPLE METHOD: TRILATERATION

The basis of this method is always the trilateration or measurement of the sides of triangles. This method starts from the principle that the triangle is the only flat figure geometrically definable univocally with the simple measurement of its sides and without needing to know the measure of its angles. If we know the three sides of a triangle, the solution is unique; there is only one correct solution.

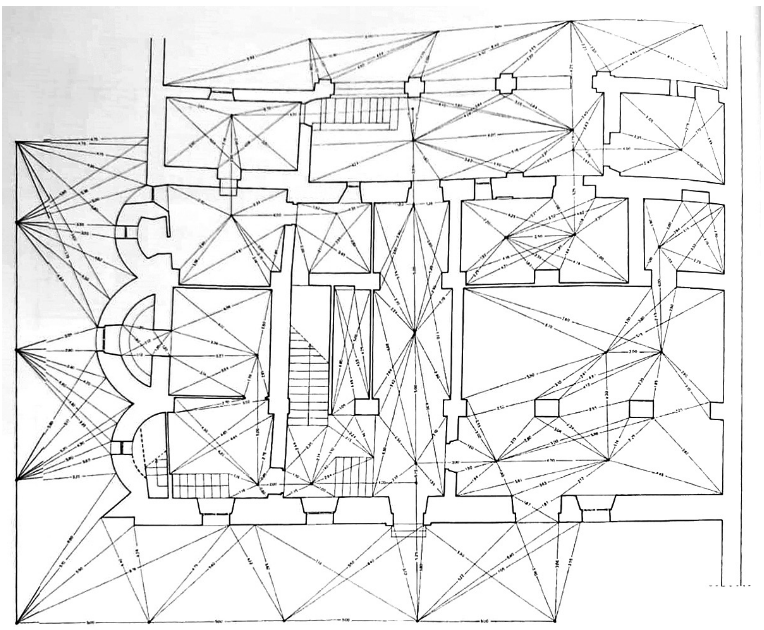


Fig. 9. Pieve di San Basso. From C. Bellanca (a cura), *Una didattica per il restauro*, Atena Editrice, Roma 2008, p. 162.

Chain Trilateration:

Set the control points
Triangulation of the plan
Establish control measures
Taking system measurements
Elaboration of sketches

SIMPLE METHOD: SKETCHES

The importance of good sketches must not be forgotten in this method, since much of the building's information will also be reflected in them.

The sketch must be an anticipation of the final drawing, which although it does not need to be on a precise scale, must contain all the information that will later appear on the final map. The sketches will be drawn to the largest possible size and will be labeled and marked clearly.

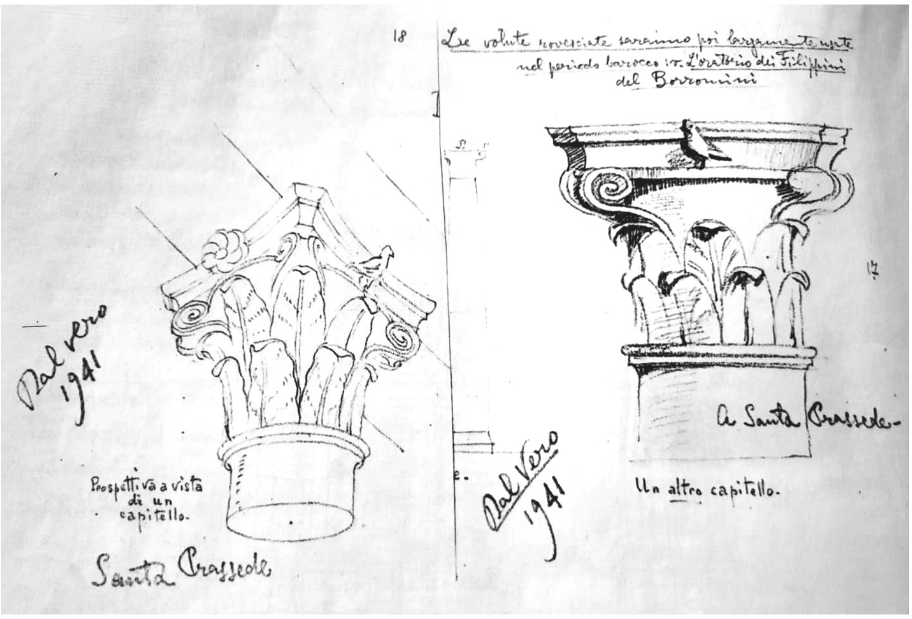


Fig. 10. Chapter sketches by G. Zander (left) and (right). From G. Zander, *Scritti sul Restauro dei monumenti architettonici,* Bonsignori editore, Roma 1993, p. 104.

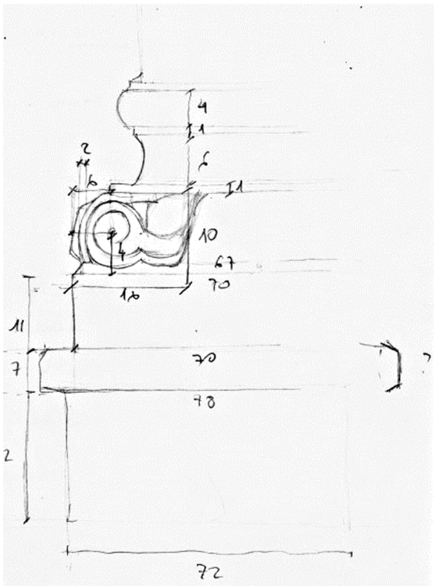


Fig. 11. Sketch by Susana Mora.

SIMPLE METHOD: DETAILS

When necessary, extended partial sketches should be made, so that no dimension or detail is omitted. In any case, we must consider that the time spent on making a good sketch will always be a saving in the long run by avoiding mistakes, lack of definition and, finally, the need to redo some of the work.

SIMPLE METHOD: SURVEY EXAMPLES

Geometrical survey. External and internal polygonal lines.

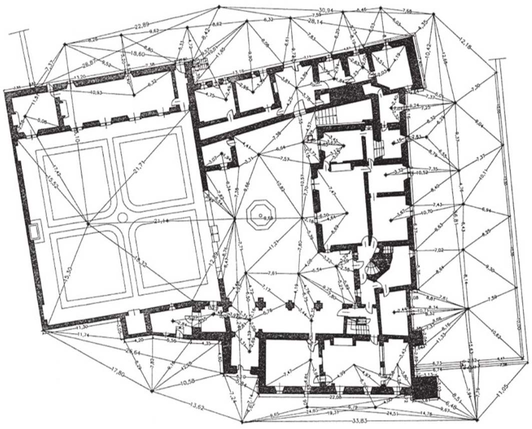


Fig. 12. Castello di Issogne, Val d’Aosta. Ground floor. From F. Vella, E. Viganò, “Final Degree Project”, *Manuale del restauro achitettonico*, Mancosu, Roma 2001, Section H. Approcci metodologici, rilievo geometrico, 12.

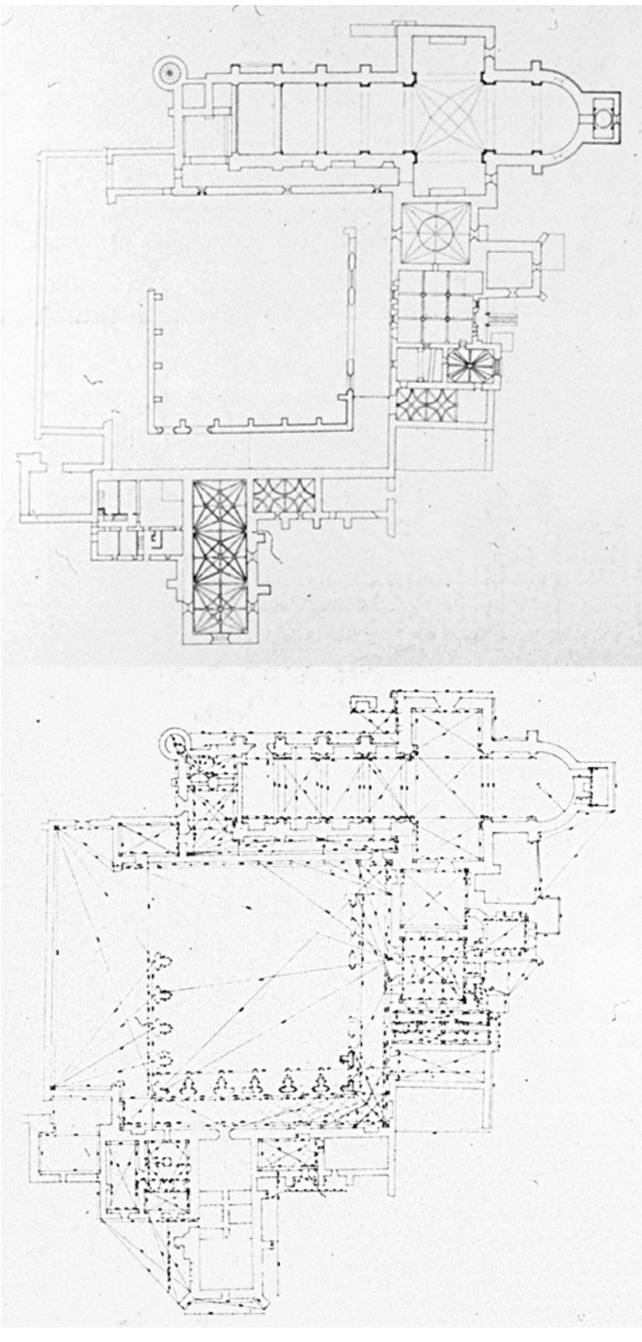


Fig. 13. Ground plan survey facing downwards and facing the vaults. Santa María de Carracedo Monastry.
Plans by Salvador Pérez Arroyo and Susana Mora, 1990.

SIMPLE METHOD: ELEVATIONS

Operations on elevations:

1. Internal levels referring to external envelope.

2. Sizes to be taken from the section.

3. Identification and determination of the off-axis areas.

4. Dimensions to be taken for the relative positions of the openings.

5. Windows positioning on the ground floor: dimensions measured on the axis.

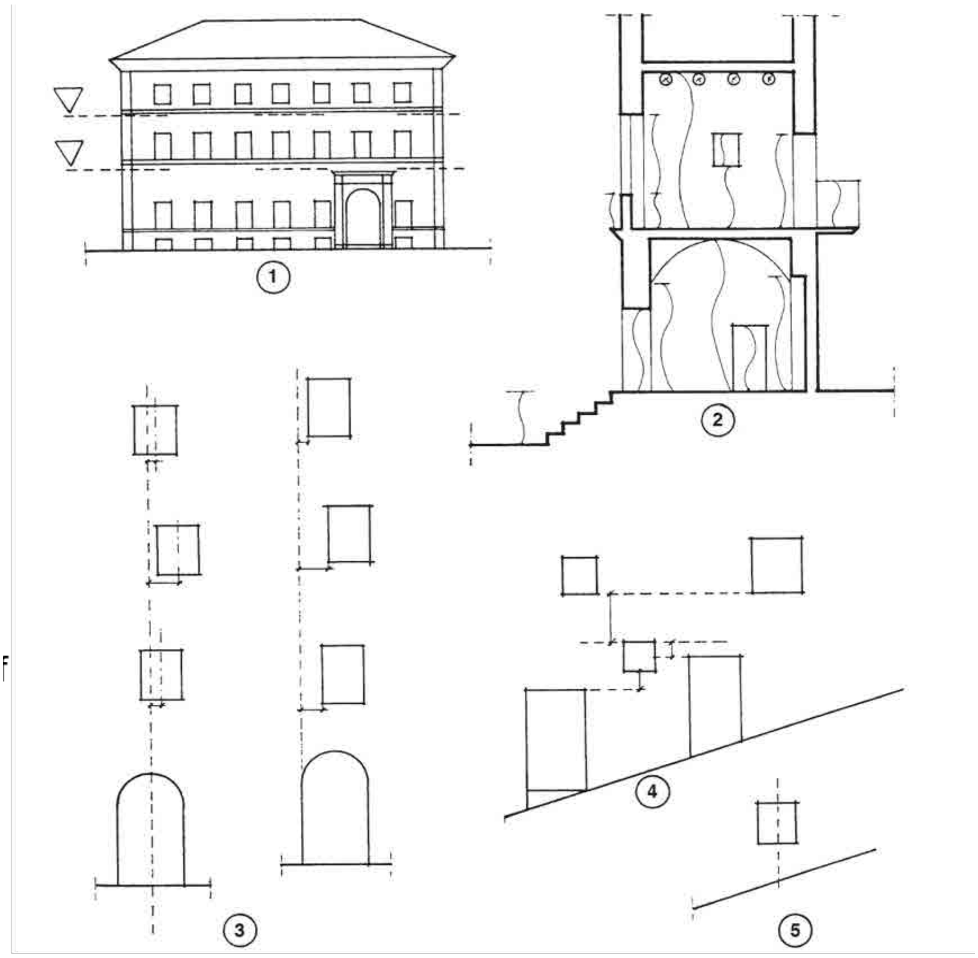
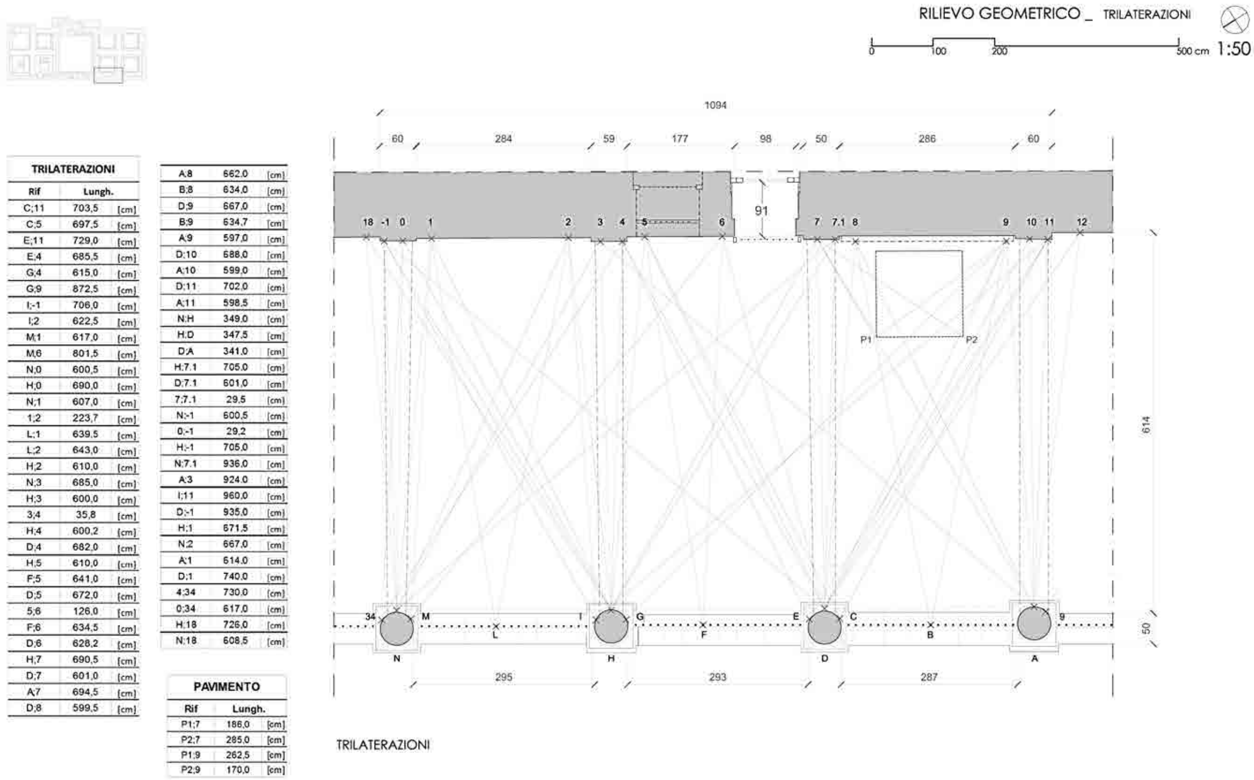


Fig. 14. From Carlo Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001, Section E. Indagini preliminari e diagnostica, metodologie di rilievo, 23.



TRILATERAZIONI		
Rif	Lungh.	
C;11	703,5	[cm]
C;5	697,5	[cm]
E;11	729,0	[cm]
E;4	685,5	[cm]
G;4	615,0	[cm]
G;9	872,5	[cm]
I;-1	706,0	[cm]
I;2	622,5	[cm]
M;1	617,0	[cm]
M;6	801,5	[cm]
N;0	600,5	[cm]
H;0	690,0	[cm]
N;1	607,0	[cm]
1;2	223,7	[cm]
L;1	639,5	[cm]
L;2	643,0	[cm]
H;2	610,0	[cm]
N;3	685,0	[cm]
H;3	600,0	[cm]
3;4	35,8	[cm]
H;4	600,2	[cm]
D;4	682,0	[cm]
H;5	610,0	[cm]
F;5	641,0	[cm]
D;5	672,0	[cm]
5;6	126,0	[cm]
F;6	634,5	[cm]
D;6	628,2	[cm]
H;7	690,5	[cm]
D;7	601,0	[cm]
A;7	694,5	[cm]
D;8	599,5	[cm]

A;8	662,0	[cm]
B;8	634,0	[cm]
D;9	667,0	[cm]
B;9	634,7	[cm]
A;9	597,0	[cm]
D;10	688,0	[cm]
A;10	599,0	[cm]
D;11	702,0	[cm]
A;11	598,5	[cm]
N;H	349,0	[cm]
H;D	347,5	[cm]
D;A	341,0	[cm]
H;7.1	705,0	[cm]
D;7.1	601,0	[cm]
7;7.1	29,5	[cm]
N;-1	600,5	[cm]
0;-1	29,2	[cm]
H;-1	705,0	[cm]
N;7.1	936,0	[cm]
A;3	924,0	[cm]
I;11	960,0	[cm]
D;-1	935,0	[cm]
H;1	671,5	[cm]
N;2	667,0	[cm]
A;1	614,0	[cm]
D;1	740,0	[cm]
4;34	730,0	[cm]
0;34	617,0	[cm]
H;18	726,0	[cm]
N;18	608,5	[cm]

PAVIMENTO		
Rif	Lungh.	
P1;7	186,0	[cm]
P2;7	285,0	[cm]
P1;9	262,5	[cm]
P2;9	170,0	[cm]

Fig. 15. Detail of triangulation. Internal polygonal lines. Ospedale Maggiore, Milan (Italy). Design by Pablo F. Cueto, 2012.

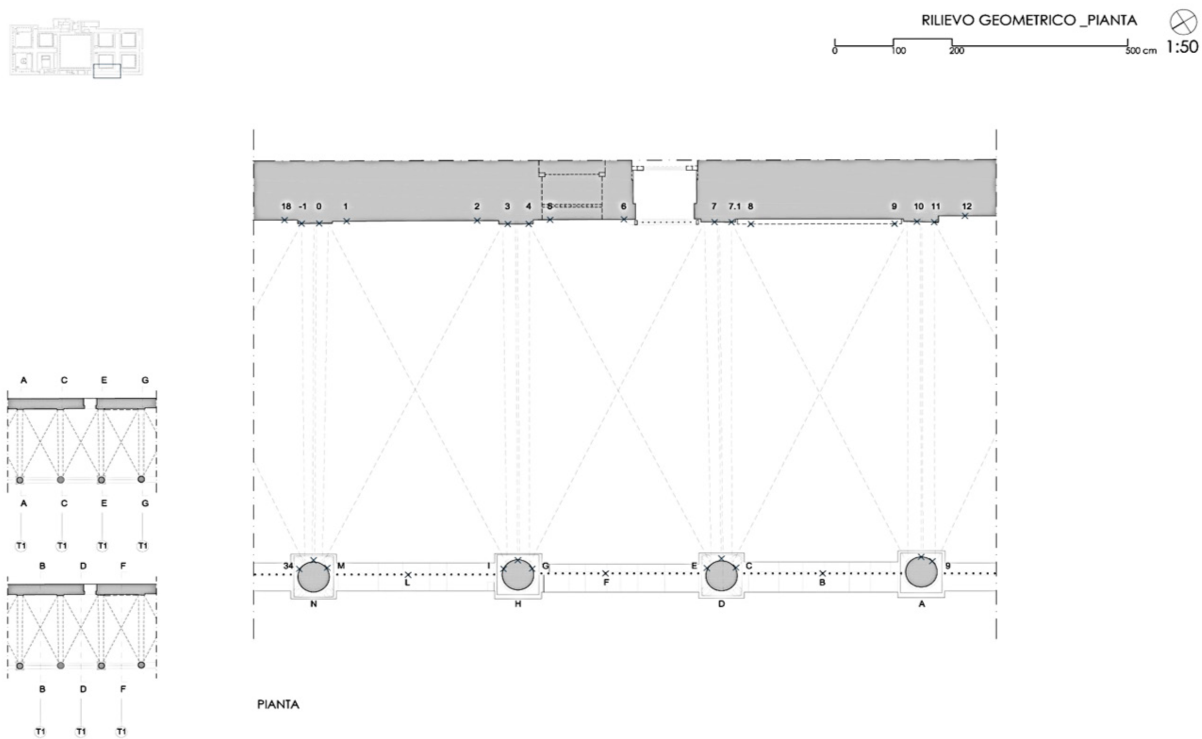


Fig. 16. Detail of triangulation. Floor plan. Ospedale Maggiore, Milan (Italy). Design by Pablo F. Cueto, 2012.

Fig. 17. Approach to detail. Cross Section. Ospedale Maggiore, Milan (Italy). Design by Pablo F. Cueto, 2010.

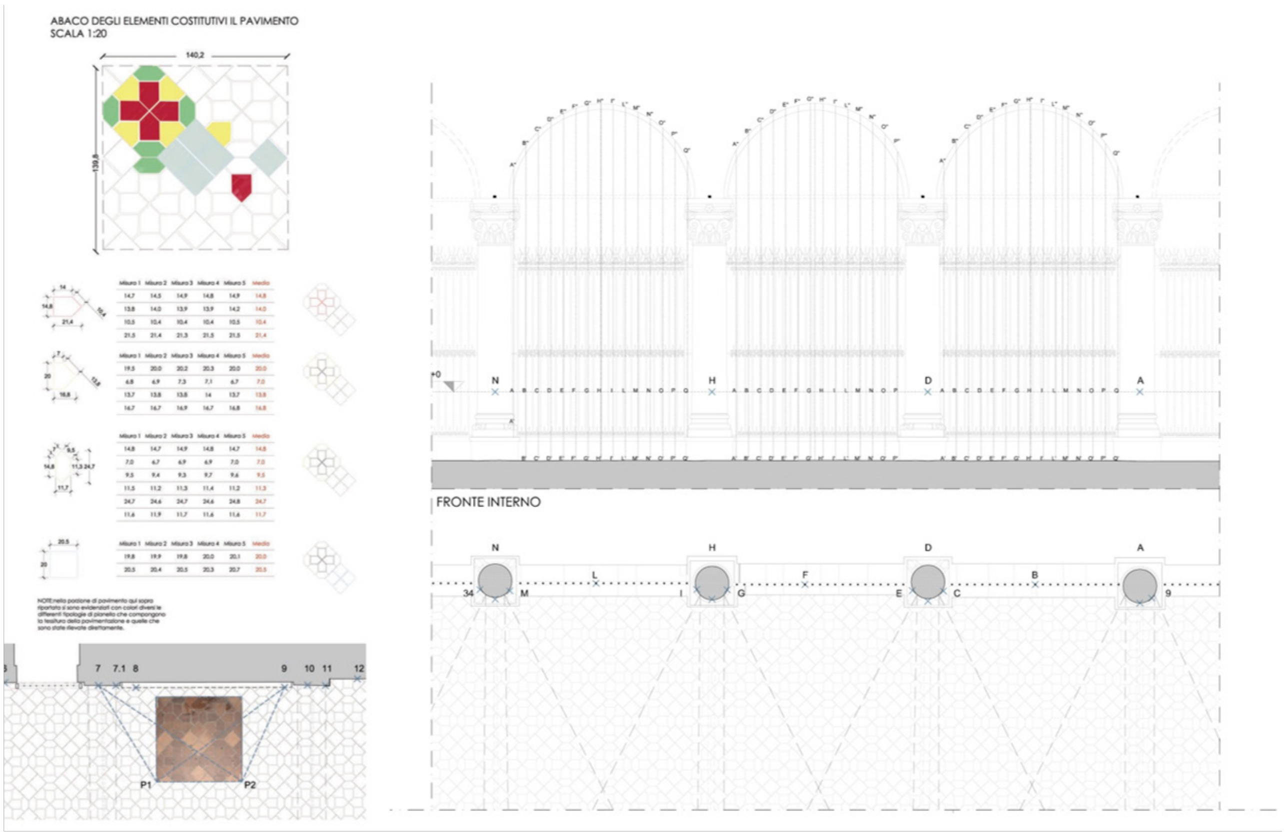


Fig. 18. Approach to detail. Elevation and pavement details. Ospedale Maggiore, Milan (Italy). Design by Pablo F. Cueto, 2010.

METROLOGY. PROPORTIONS.

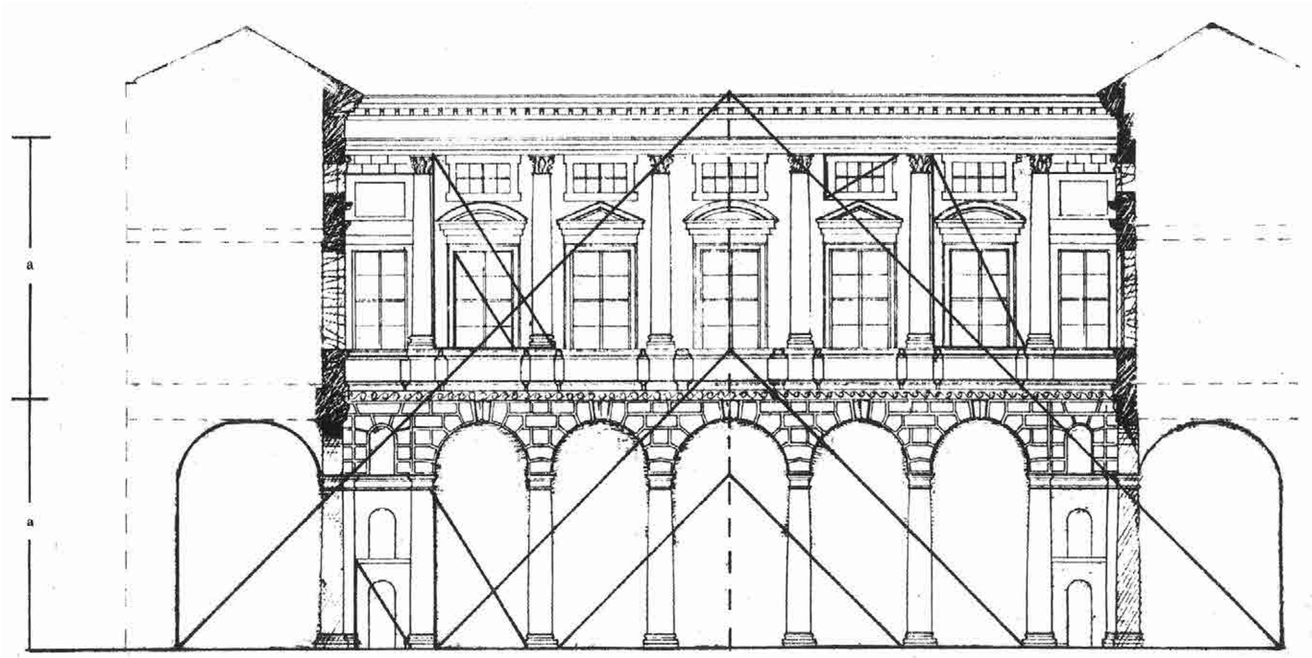


Fig. 19. Stadtresidenz Landshut. From C. Bellanca (a cura), *Una didattica per il restauro*, Atena Editrice, Roma 2008, p. 131.

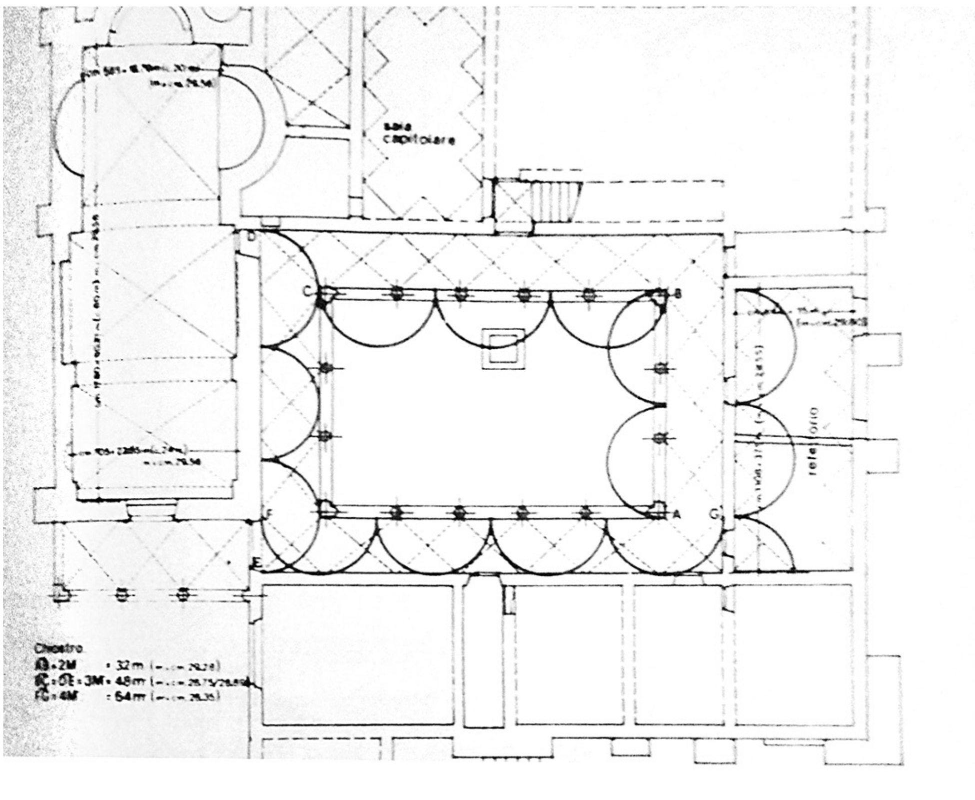


Fig. 20. San Francesco del Deserto, Venezia. From G. Carbonara, *Restauro dei monumenti. Guida agli elaborati grafici*, Liguori Editore, Napoli 1990, XLVII.

GEOMETRICAL SURVEY: NEW TOOLS

B. TOPOGRAPHIC SURVEY. NEW TOOLS

(1) In general, an adequate analysis of an architectural work requires us to always consider it as a three-dimensional object and to measure it by means of systems that provide us with the location in the space of its various elements. The measurement and survey of existing buildings and constructions using traditional methods (tape measuring) poses difficulties due to the inaccessibility of many parts, especially in spaces of great heights and dimensions.

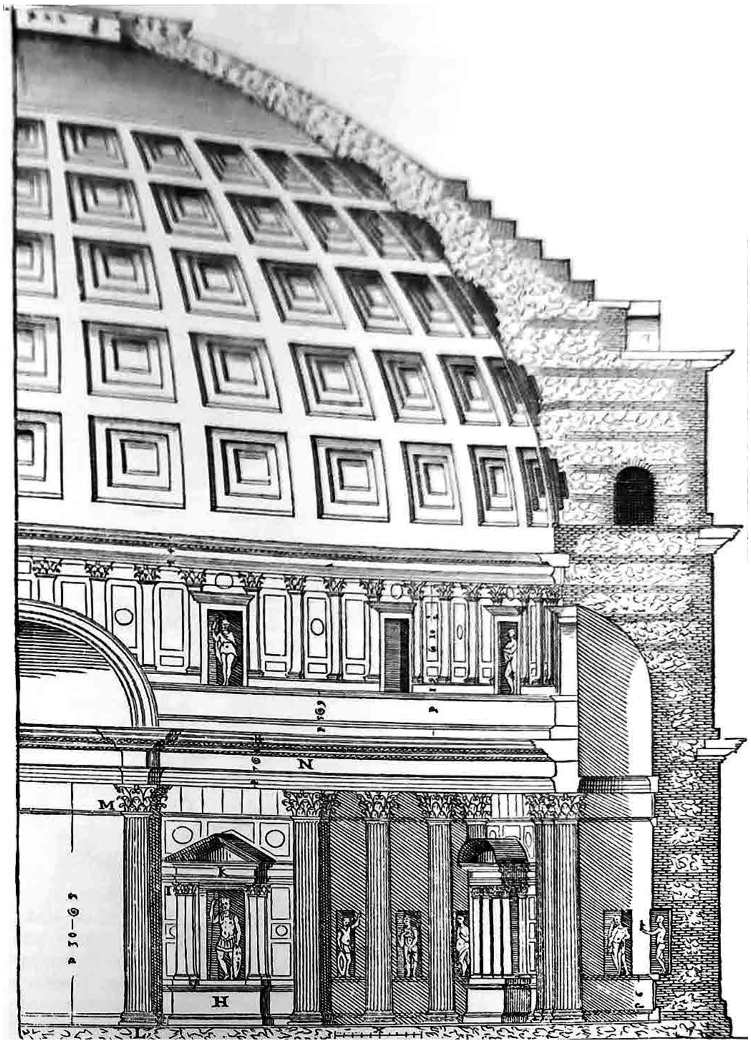


Fig. 21. Pantheon section. From M. Docci, *Il rilevamento architettonico*, Laterza grandi opere, I edizione, Roma 1984, p. 81.

Total station and point clouds:

These fixed points are the ones that allow sketched elements to be drawn on the screen, essentially through lines that connect these points. When working with optical devices (digital or analog) there can be some advantages in terms of accuracy, angle measurements, really horizontal and flat polygons, greater distances…) with respect to the measurements obtained with tape (traditional or laser).

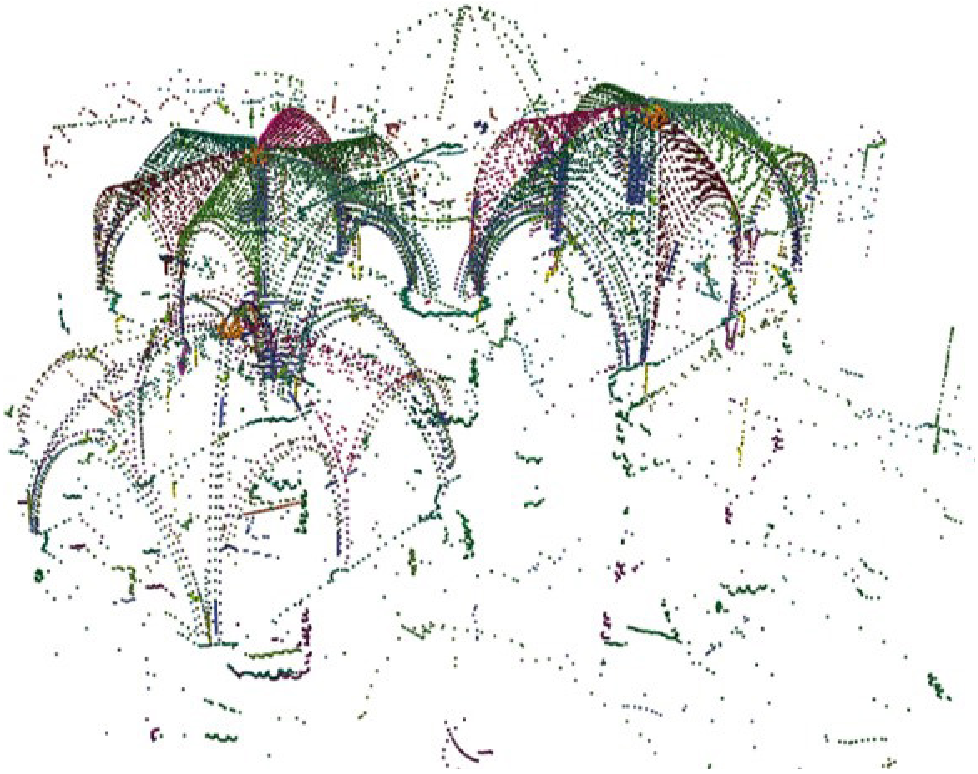


Fig. 22. Total station survey of the vaults sexpartitas of the presbytery and the cruising arm of the Cathedral of Santa María (Sigüenza). Rocío Maira Vidal, CSIC, 2016.

Polar and Cartesian coordinates:

The topographic survey allows us identify to significant points of the object, the more the better, and then determine its three coordinates, either directly or indirectly.

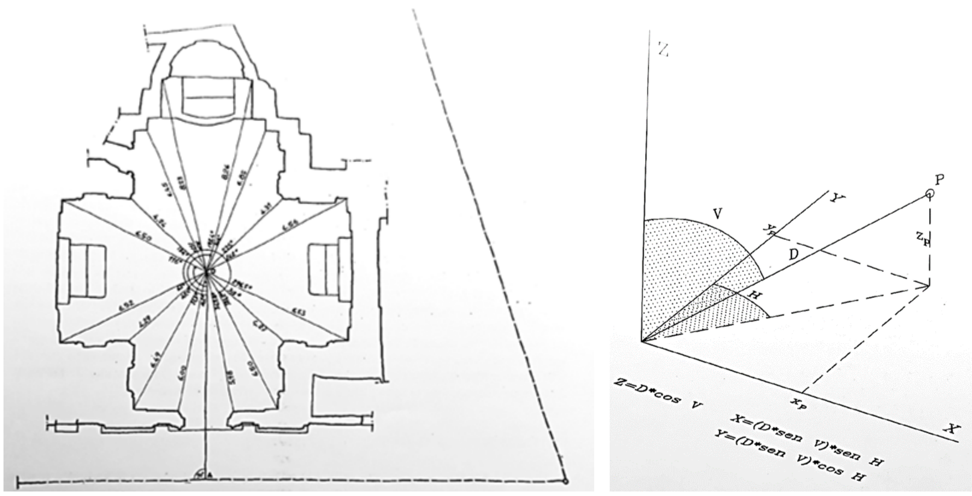


Fig. 23. Survey by polar coordinates of the Angelo Custode church in Bassano del Grappa, VI. From Cesare Feiffer, *Il progetto di conservazione*, FrancoAngeli, Milano 1989, p. 116.

Nowadays, topographic devices are used, called total stations, infrared-based apparatuses that, by means of a prism, allow us to obtain the three coordinates of the point where the prism is located and automatically collect them in an attached computer, with a capacity up to 8,000 points.

Fig. 24. Total station in the cloister of Santa María de Sasamón, Burgos. Photo by Susana Mora. (2)

Fig. 25. Technicians setting up the prisms. Santa María de Sasamón, Burgos. Photo by Susana Mora.

C. PHOTOGRAPHIC METHOD. NEW TOOLS

PHOTOGRAMMETRIC RESTITUTION

Photography provides a large amount of information about the geometry, decorations and textures of a building, but it is not a document that we can measure. In the case of photographs of flat surface objects, such as a facade, we can obtain, through photographic restoration, an image that preserves the angles and distances of the original object. In other words, this methodology allows us to eliminate the deformations that photography imposes on objects, provided that they are flat or decomposable elements in planes.

Fig. 26. Perspective Image of Hercules' Tower and it's restitution. By P. Latorre. (3)

In the restoration the vertical lines, which converge strongly in the photograph, recover their parallelism, while the frame of the photograph, which is presented as an orthogonal rectangle is transformed into a trapezoid.

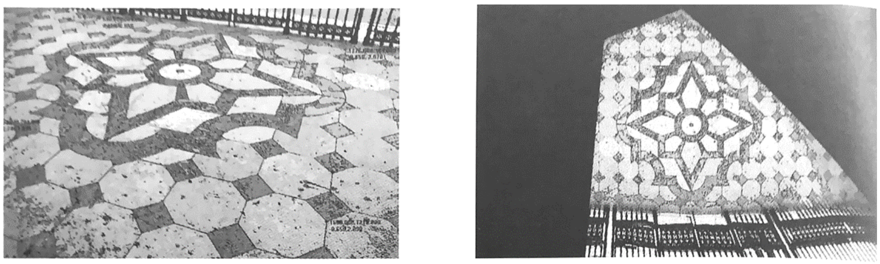


Fig. 27. Sevilla's Cathedral, Puerta de la Asunción floor, photogrammetric restitution. By J.M. Moreno, 2018.

In order to carry out the restitution of an image, it is necessary to clearly define the points of support (or rectification, control or calibration), at least four. The points must be clear and unequivocally locatable in the image as in reality. From these points we must know its exact position, either with measurements triangulated with a tape measure or with the support of a total station. They should also preferably be end points of the object, as far apart as possible, for greater accuracy.

With the help of the corresponding software (rectification programs or plugins) we will mark the support points on the photograph, assigning them the Cartesian coordinates that correspond to them in reality (x, y). The program will distort the image until a rectified photograph is obtained. There will be inaccuracies in the objects of the photograph that are delayed or advanced. With the help of CAD programs we can perform the survey of all the details gathered in the image: materiality, state of conservation, complex ornamentations, paintings, etc.

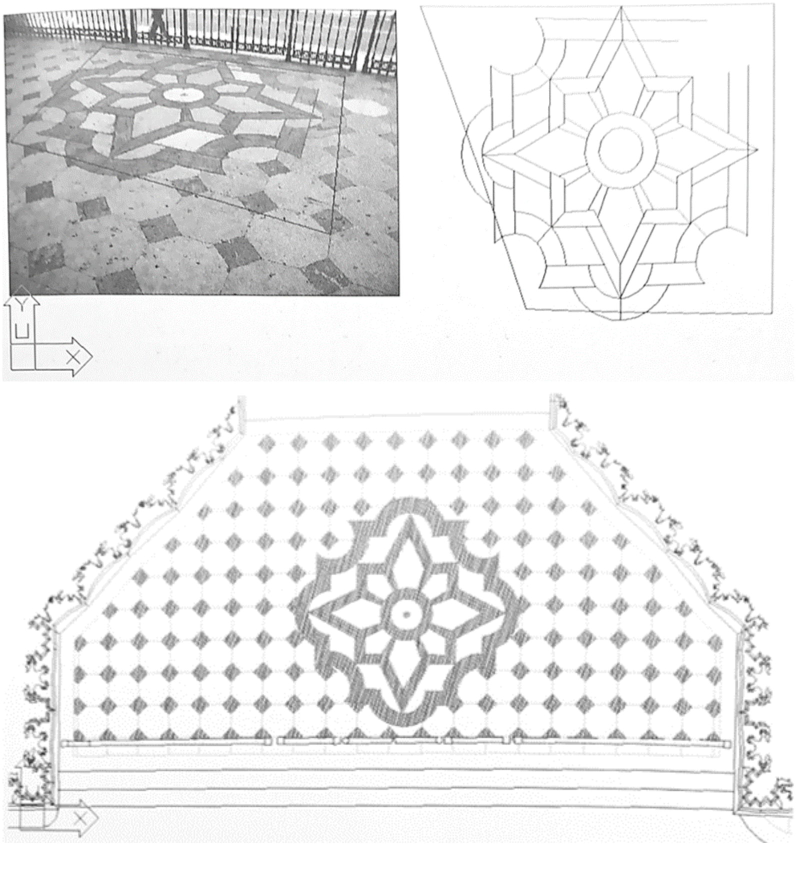


Fig. 28. Puerta de la Asunción, Sevilla Cathedral, Floor. Above: photograpy lines extracted to drawing. Below: final restitution.

C. STEREOGRAPHIC PHOTOGRAMMETRY METHOD. NEW TOOLS

Photogrammetry is that technique that allows us to measure objects, buildings or the terrestrial surface from perspective images obtained by photographic procedures. It is based on the principle of stereography, that is, the use of two images of the same object, but with different perspectives and, therefore, with two different projective beams. The intersection of these two beams will allow us to know the position of all those points that appear in both photographs. The result is a cloud of accurately situated points, which can be used as the base for the survey.

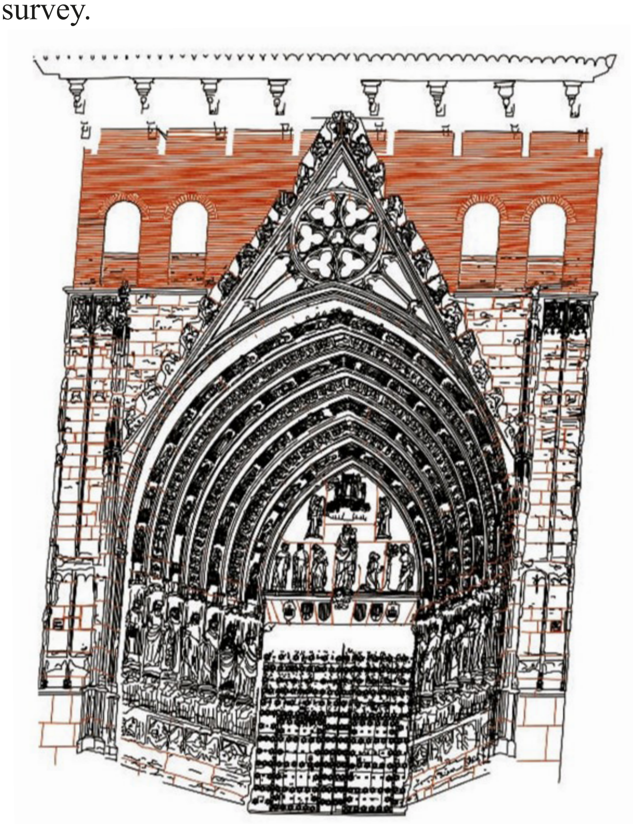


Fig. 29. Huesca Cathedral façade restitution. From IPCE-J.M. Lodeiro-Javier Laguna. (4)

Photography is an automatic system for recording perspective images. The perspective, as a centered projection representation system, is the result of the intersection with a projection plane or image plane, of the beam of directions generated by joining the points to be represented with the projection center. This means that if we have a photographic image and we know the relative position of its projection center (internal orientation), we can reconstruct the projective beam and with it the addresses of all the points that appear registered in the picture.

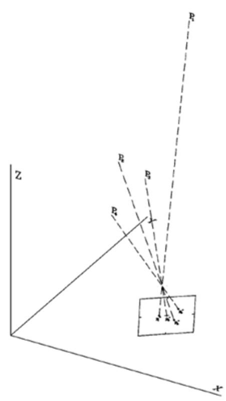


Fig. 30. From *Prescribing and restoring monuments and historic buildings*, Unesco, Paris 1972.

With a single image, that is, with a single beam of directions, we can not determine the position in space of any point, unless we know some other data, such as its belonging to the same plane perfectly defined in its situation and orientation. But if we use two perspectives, or two photographs, taken from two different points, we will have enough data to determine the spatial position of all those points that are visible in the two images. It will be sufficient to determine the intersections of the two projective beams as we do with theodolite measurements obtained from two stations.

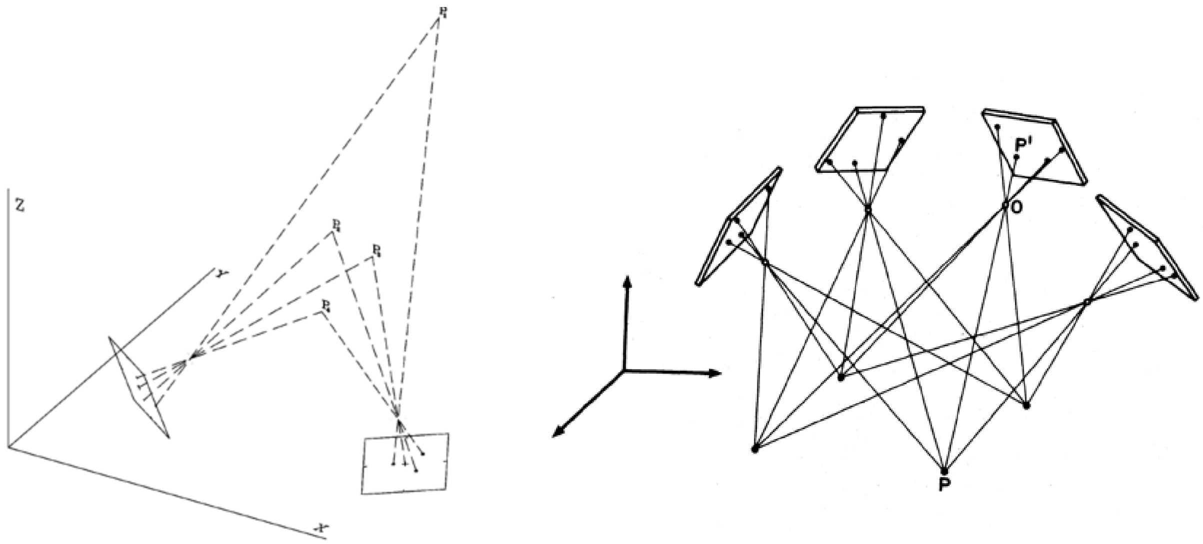


Fig. 31. From *Tecniche della conservazione* a cura di Amedeo Bellini, FrancoAngeli, Milano 1990, figs. 1, 2.

STEREOGRAPHIC PHOTOGRAMMETRY: PROCESS

Photogrammetric survey only requires a camera, a computer and measuring tape.

Previous tasks: calibrate the digital camera, use preferably a monofocal objective and write down the geometric characteristics of the lens.

1. Fieldwork. There are two different tasks involved:

– To take photographs. They should be taken as a series of overlapping pictures, correctly focused and well-contrasting. It is important to capture easily identifying points, such as marks, corners, angles, etc. An excessive deformation (convergence) of vertical or horizontal lines should be avoided.

– Anchor point. These should be easily identified and distant from each other. They should be set in a sketch as well as the distance between them following trilateration rules.

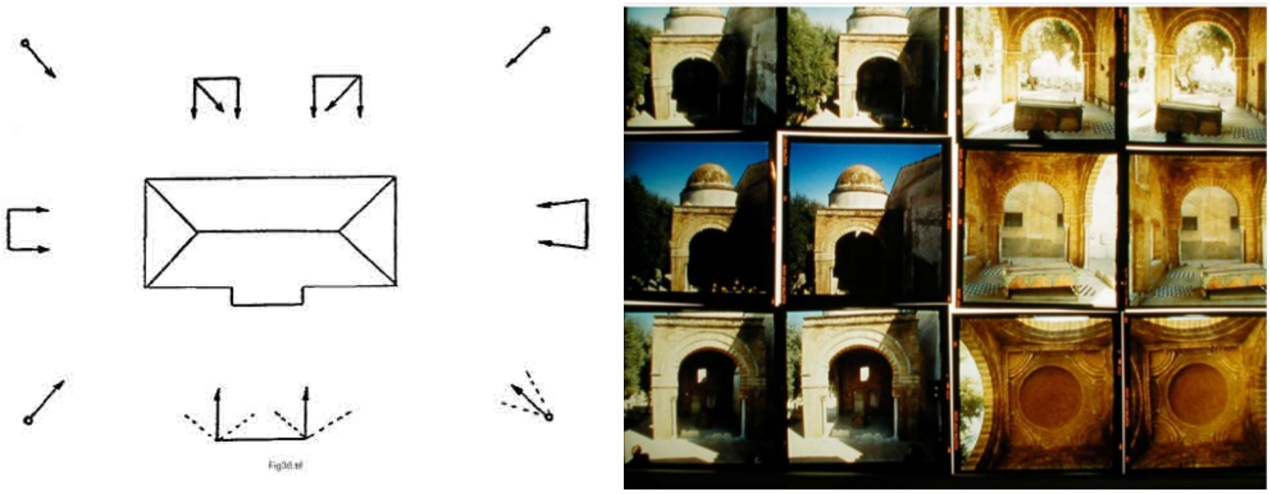


Fig. 32. Survey of the qubba-mausoleum of Sidi Bu-Jrisan (Tunisia).

2. Studio work.

We will use some restitution software, introducing the camera calibration and the photographs taken.

– Point selection. In order to set the 3D position of a certain point, we will identify it in every photograph where it appears. We will repeat this process with every point we need. There is some available software which can detect this point automatically.

– Identification of anchor point. Having selected these points, we will introduce their cartesian coordinates.

– Computer process. The program does the calculations to place the points. The result will be a cloud with the selected points. This method gives a precise information about the 3D geometry of the building. The outcome can be visualized as a point cloud, as a mesh, and as a texture mapped mesh, reproducing the aspect of the building.

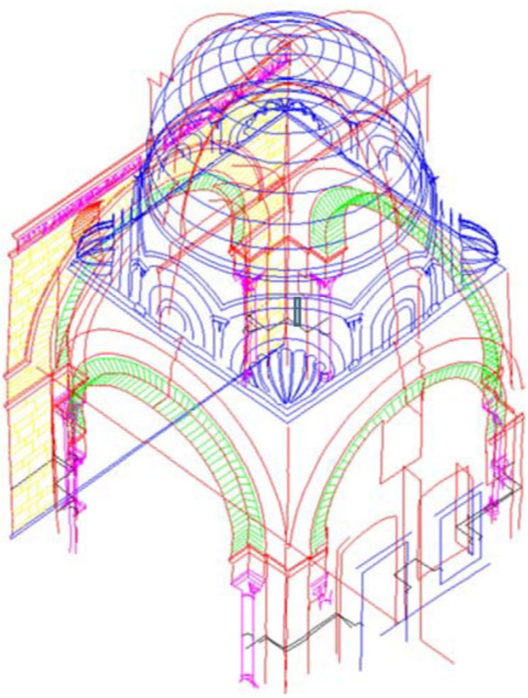


Fig. 33. 3D line drawing of the qubba-mausoleum of Sidi Bu-Jrisan (Tunisia) The outcoming information can be displayed in 3D or used for the drawing of 2D documentation. Survey by Laboratorio de Fotogrametría Arquitectónica de Valladolid. From Jesús Ignacio San José Alonso, *Levantamiento, tecnología y documentación de la arquitectura*, Universidad de Valladolid. (5)

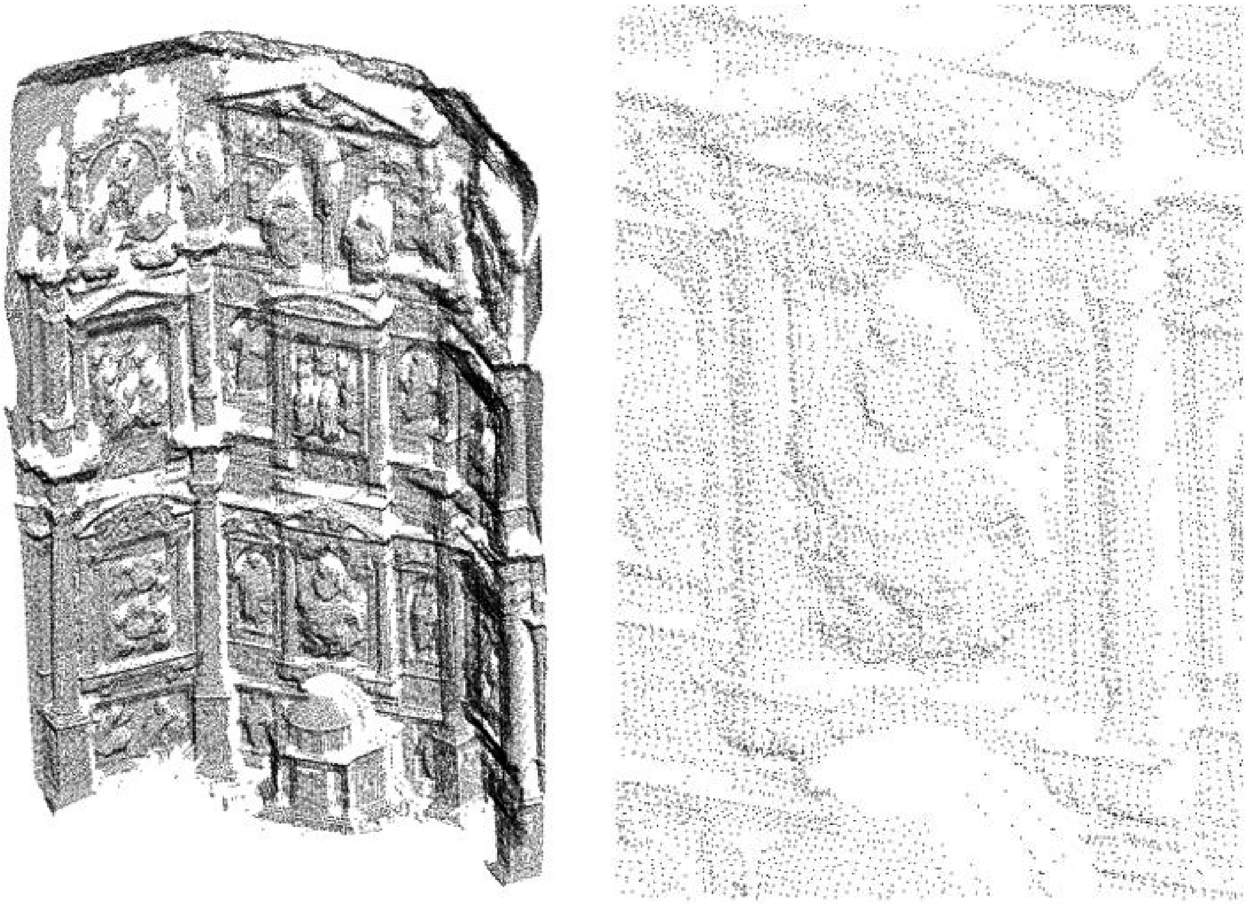


Fig. 34. Cloud point on the church of Santa María de Alaejos, Valladolid. General view on the left and detail on the right. Survey by Laboratorio de Fotogrametría Arquitectónica de Valladolid.

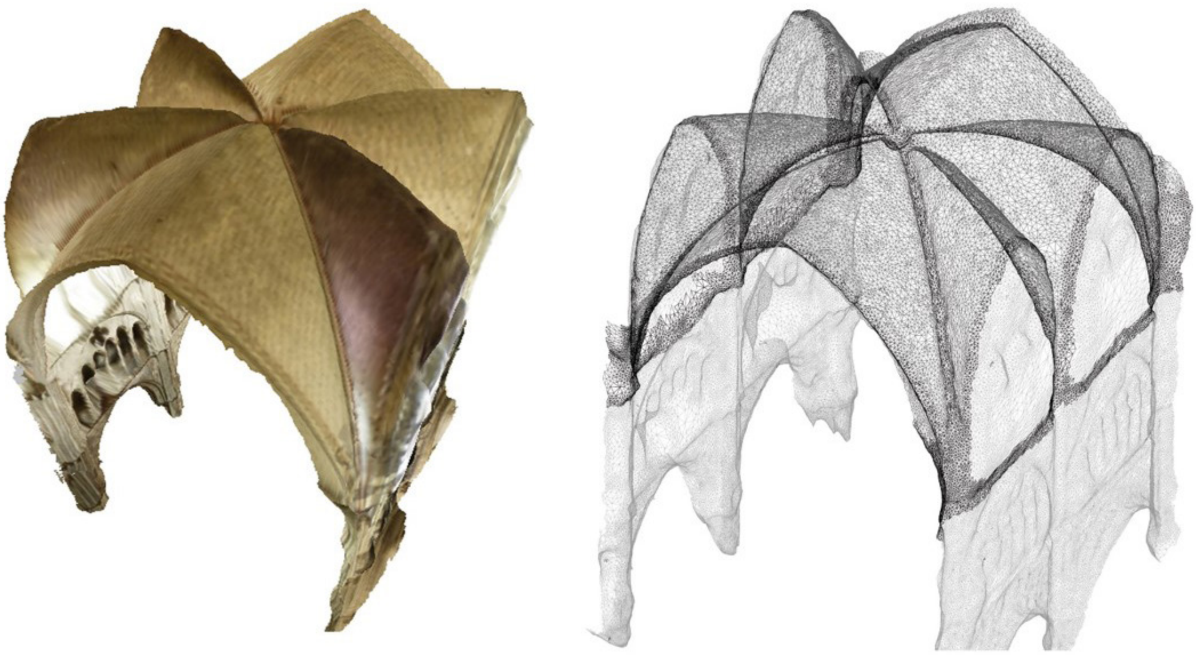


Fig. 35. Elevation of the sexpartite vaults of the Bourges Cathedral (France). On the left, photographic model, on the right triangulated mesh. Realization by Rocío Maira Vidal.

NOTES

1) DOCCI M., MAESTRI D., *Il rilevamento architettonico, Storia metodi e disegno*, Roma-Bari 1984, p. 212;

2) The survey was done during a workcamp, DIDA Firenze, /Etsam UPM, on 2015 and 2016;

3) Work done by P. Latorre from 1990;

4) Instituto del Patrimonio Cultural de Espana;

5) Made with Autodesk 123D Catch from convergent or multi-image photogrammetry.

BAHR H.P., *The use of photogrammetry in the analysis of deformation* in Stable – Unstable? Structural consolidation of ancient buildings, editors R.M. Lemaire, K. Van Balen, Leuven University Press, 1988, pp. 157-166.

DE JONGE K., VAN BALEN K. (editors), *Preparatory architectural investigation in the restoration of historical buildings: papers of the international updating course held at the Raymond Lemaire International Centre for Conservation*, Leuven, May 25-June 1, 1996, published to mark the 20th anniversary of its creation, 2002.

MILETO C., VEGAS F., CRISTINI V., GARCIA L., *Architectural and archaeological heritage: management and new technologies*, online published e Göttingen 2020.

CHAPTER 2. MATERIAL SURVEY AND MECHANICAL SURVEY

> "The study and the restoration of architectural, archaeological environmental and landscape heritage are divided into three stages: the survey, the historical-critical analysis and the restoration project aimed at achieving concrete practical results. It is deemed essential, for didactic reasons, to make more illustrative the presentation of the sequence of graphic representations which the students will have to present in order to approach the discipline and, subsequently, sit the examinations. The question is one of continuing to verify, in the current Italian and European scene, a method for the study and the restoration of the existing through the diction proposed by Guglielmo De Angelis d'Ossat and further developed and added to by Giovanni Carbonara (survey, history, restoration), where every element of the triad justifies and completes itself by the antecedent and the consequent.
>
> The doctrinal direction merges with the operational, meaning to contribute to the production of the study and the restoration of the existing building."
>
> From BELLANCA C., *Architectural Conservation Studio*, with contributions by Susana Lopez Verdu and Alejandro Iniesta Munoz, Roma 2019.

The material survey is a description of the constructive systems and materials that make up the building subject to study. It is carried out through plans, sections, elevations on a scale of 1:50 (1:100 scale is suggested in case of very large complexes).

Those structures of particular importance should be highlighted, such as the vaults, the roofs, the floors, the fixed furniture, the masonry construction, the type of material used (stone, brick), its dimensions, the degree and type of surface finish, the thickness and treatment of joints, the thickness of the beds of mortar, etc.

(1) The material survey takes a previous geometrical drawing as a base. On top of it, further information is added to depict the constructive systems and materials of the building (stone and brick masonry, tile roofs, beams, mortars, etc.).

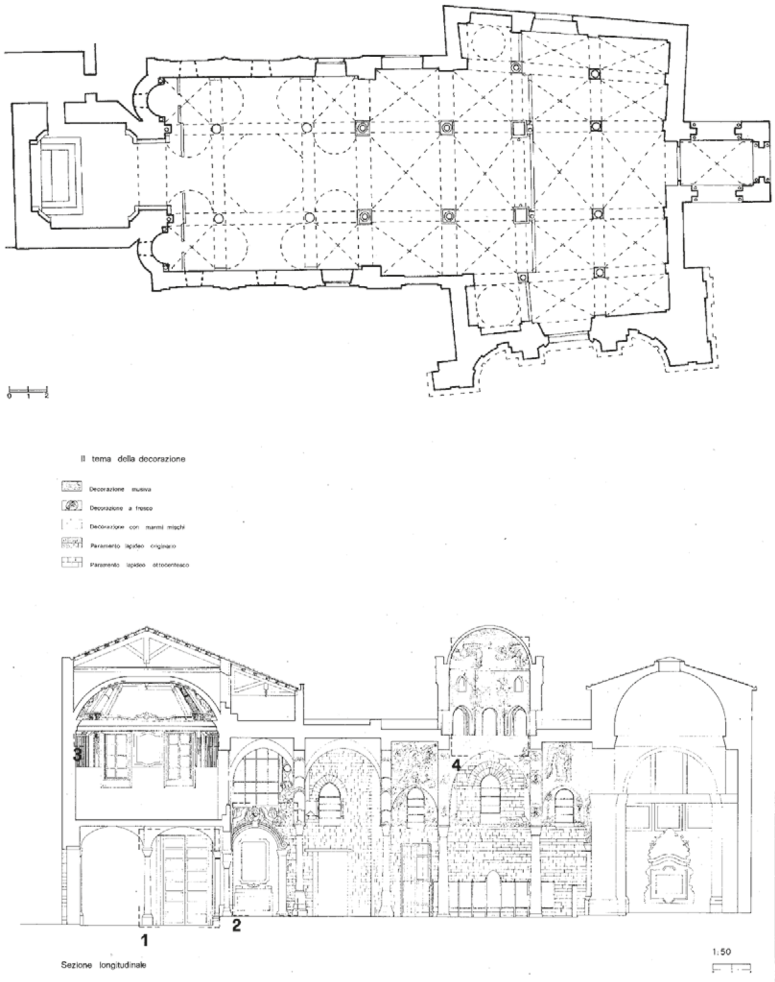


Fig. 1. Church of Martorana. From C. Bellanca, *Methodical Approach to the restoration of Historic Architecture*, Alinea Editrice, Firenze 2011, p. 103.

(2) This documentation is traditionally composed of orthogonal drawings: plans, elevations and section, but it can also include axonometric views of the building or of a certain constructive system.

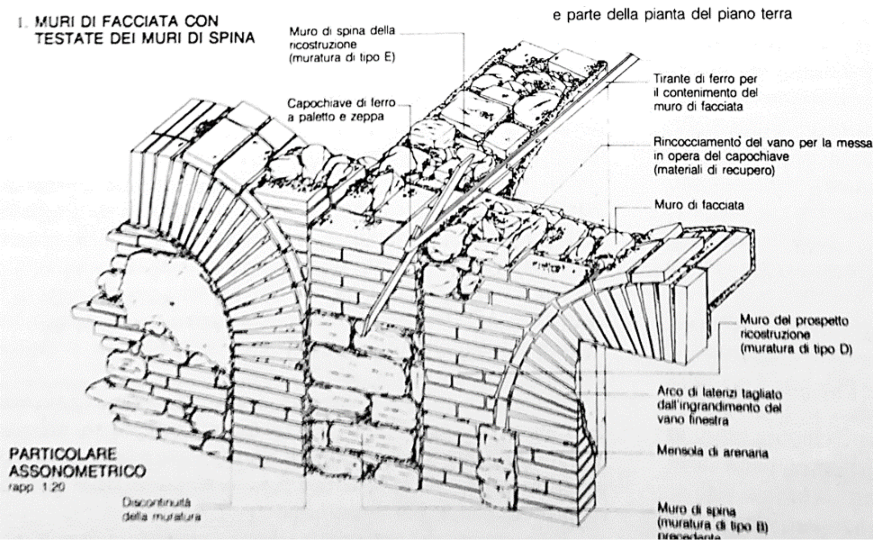


Fig. 2. Città di Castello, case in Via del Soccorso. *Manuale del recupero* (Città di Castello).

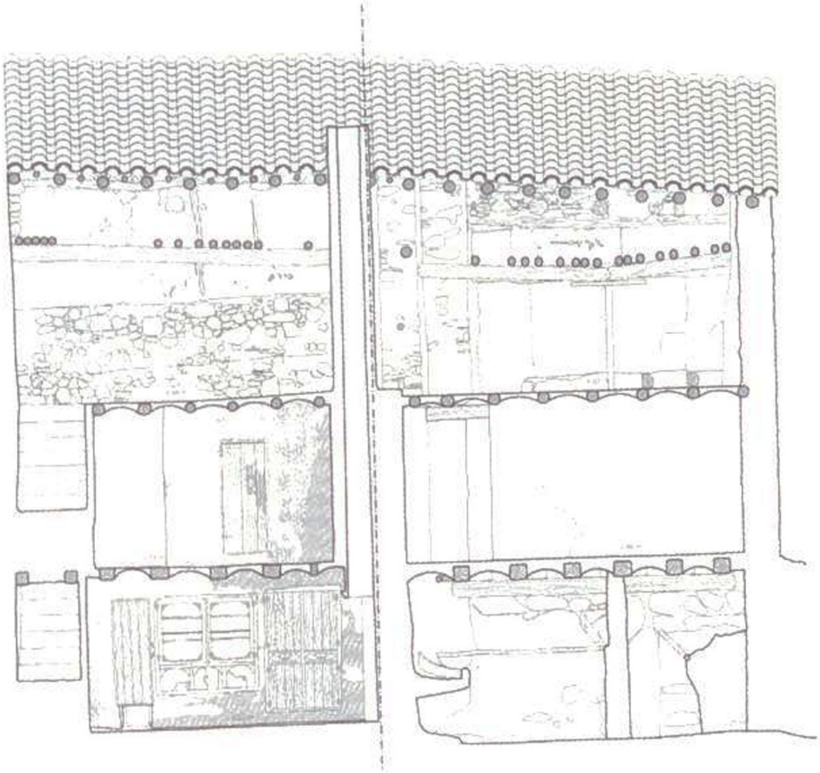


Fig. 3. Section.
From F. Vegas and C. Mileto, *Aprendiendo a restaurar*, in *PH: Boletín del Instituto Andaluz del Patrimonio Histórico*, year n. 26, n. 93, 2018. (3)

Fig. 4. Section.
From F. Vegas and C. Mileto, *Aprendiendo a restaurar*, in *PH: Boletín del Instituto Andaluz del Patrimonio Histórico*, year n. 26, n. 93, 2018. (4)

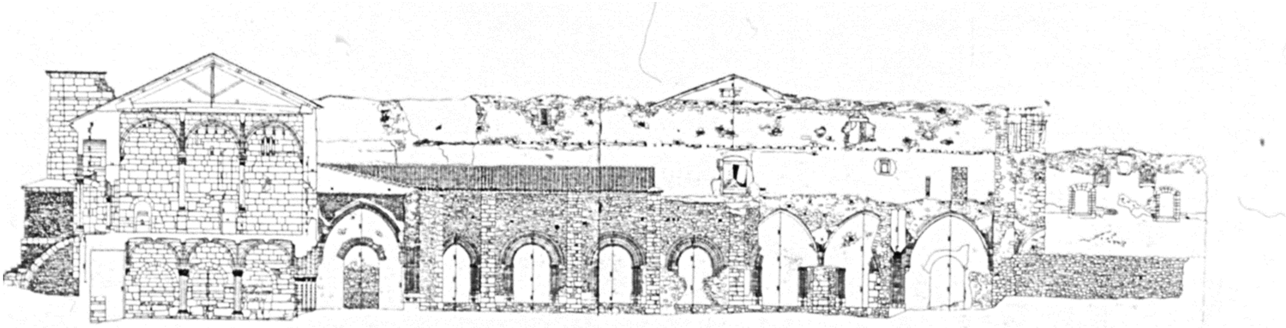


Fig. 5. Section survey. Longitudinal section along the cloister looking towards refectory of Santa María de Carracedo Monastry in Carracedo, León (Spain). Section by Salvador P. Arroyo and Susana Mora. (5)

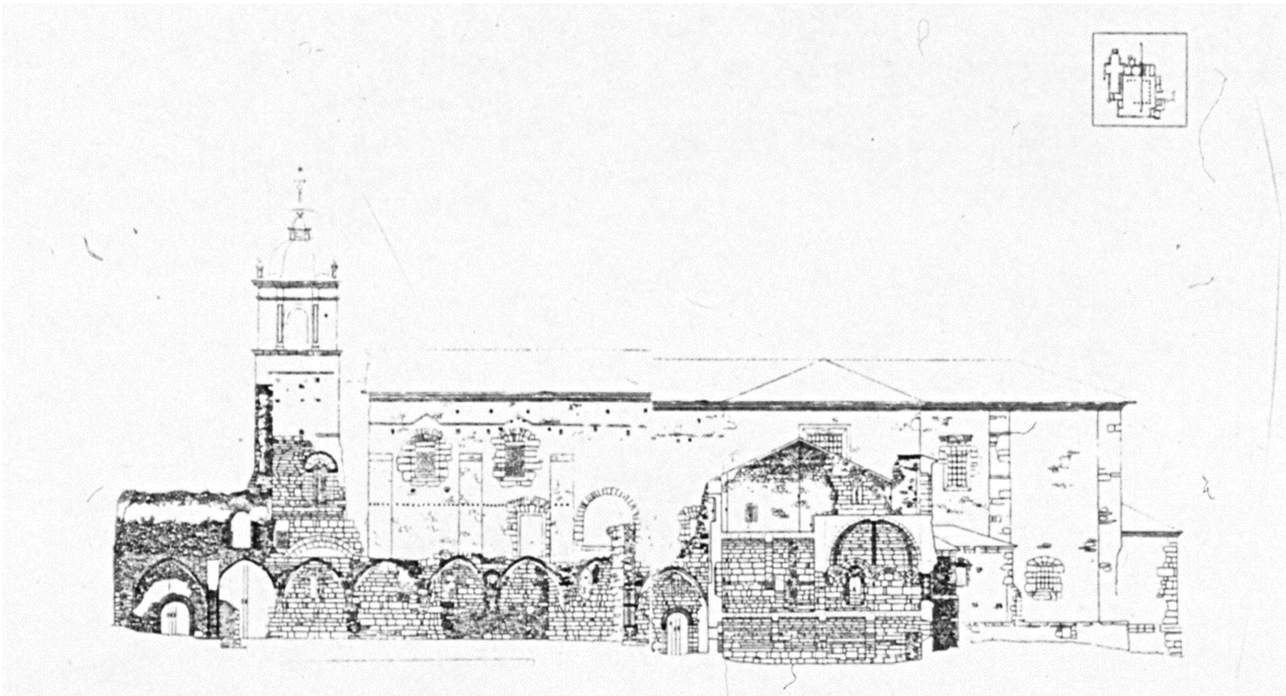


Fig. 6. Section survey. Longitudinal section along the corridor of Santa María de Carracedo Monastry in Carracedo, León (Spain). Section by Salvador P. Arroyo and Susana Mora.

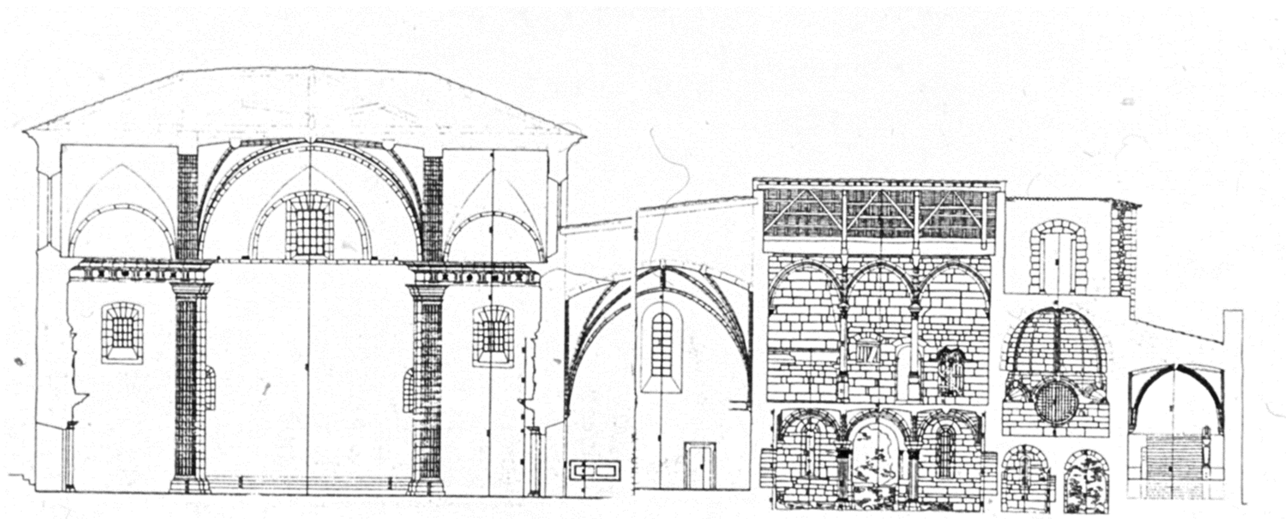


Fig. 7. Section survey. Transversal section of the church of Santa María de Carracedo Monastry in Carracedo, León (Spain). Section by Salvador P. Arroyo and Susana Mora.

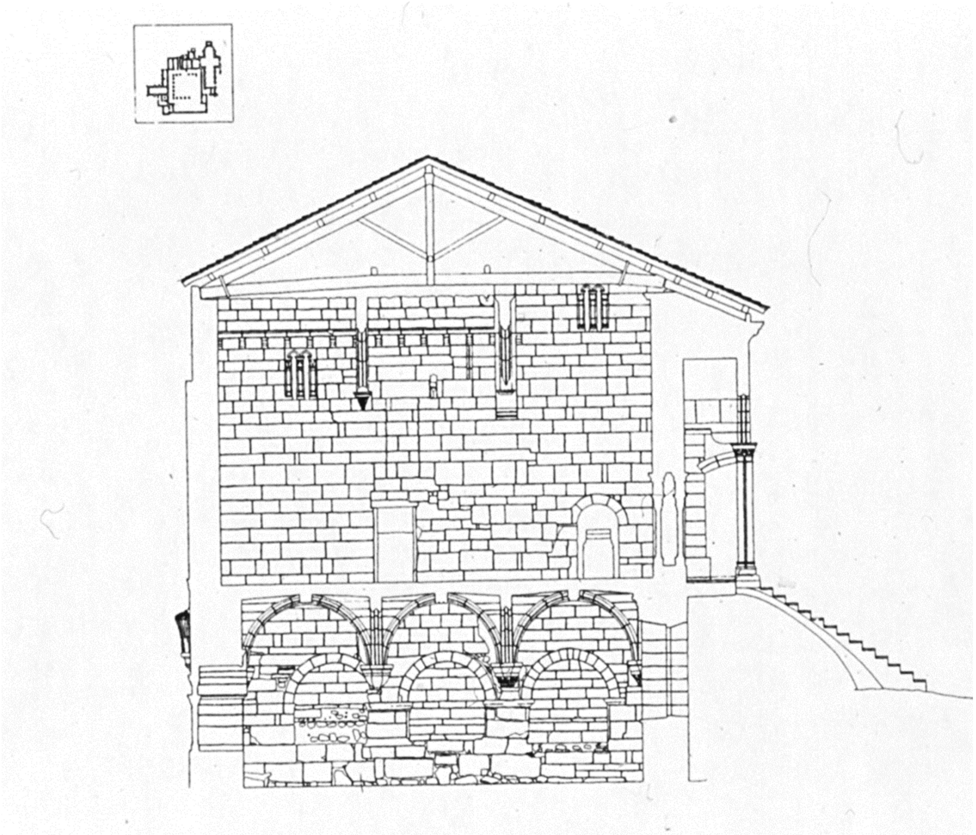


Fig. 8. Transversal section across “Capitulo” and “Cocina de la Reina” of Santa María de Carracedo Monastry in Carracedo, León (Spain). Section by Salvador P. Arroyo and Susana Mora.

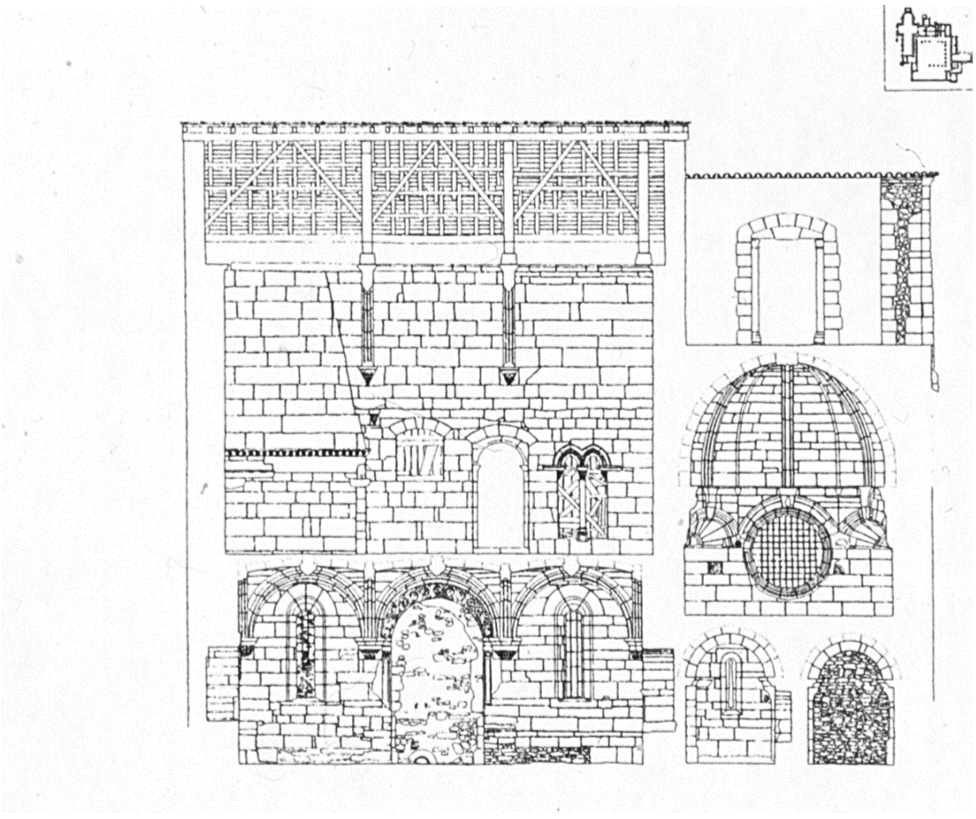


Fig. 9. Longitudinal section across “Capitulo”, “Cocina de la Reina” and “Locutory”, “Passage” and “Sala del Abad” of Santa María de Carracedo Monastry in Carracedo, León (Spain). Section by Salvador P. Arroyo and Susana Mora.[5]

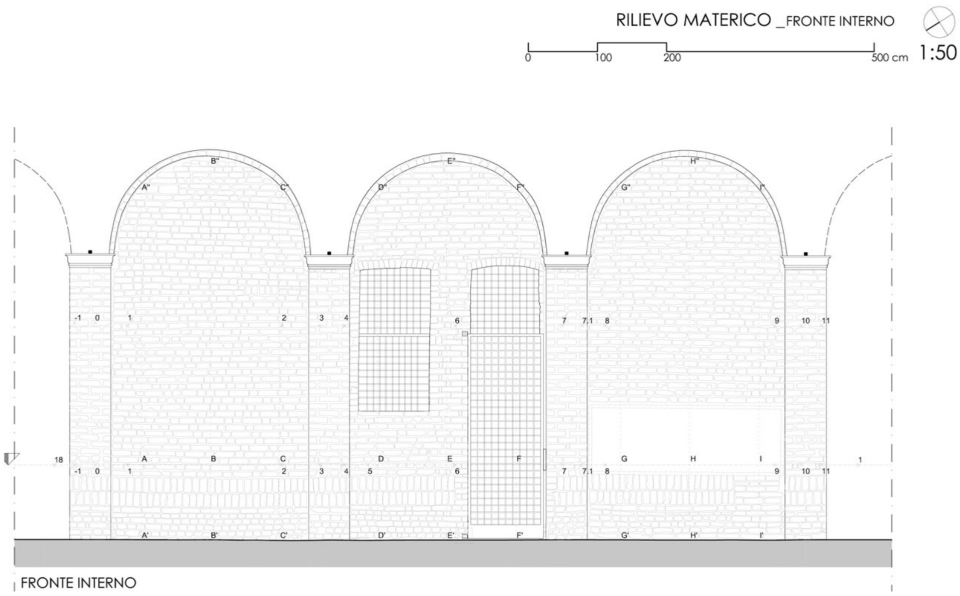


Fig. 10. Materials Survey. Internal elevation. Ospedale Maggiore, Milan (Italy). Elevation by Pablo F. Cueto, 2012.

Fig. 11. Approach to detail. Elevation. Ospedale Maggiore, Milan (Italy). Elevation by Pablo F. Cueto, 2012.

Fig. 12. Approach to detail. Elevation. Ospedale Maggiore, Milan (Italy). Elevation by Pablo F. Cueto, 2012.

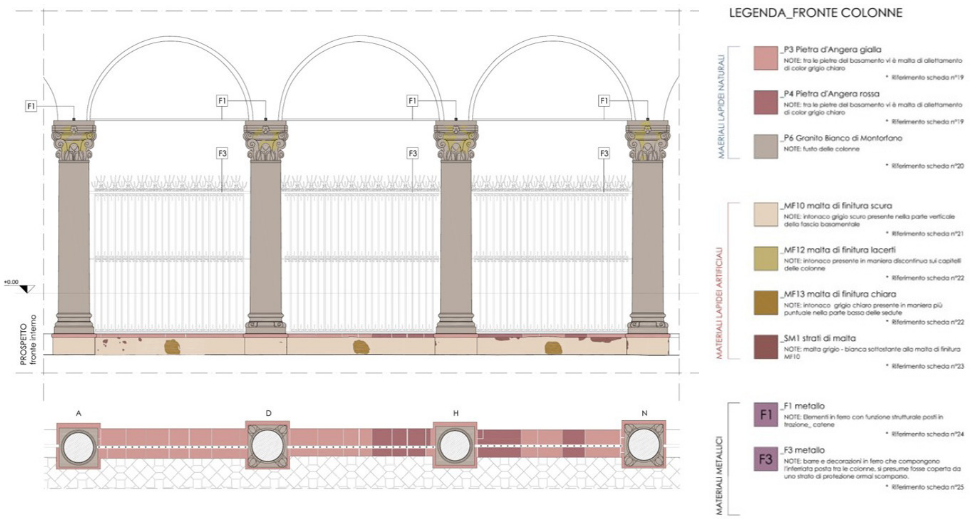


Fig. 13. Various materials and constructive systems. Ospedale Maggiore, Milan (Italy). Elevation by Pablo F. Cueto, 2012.

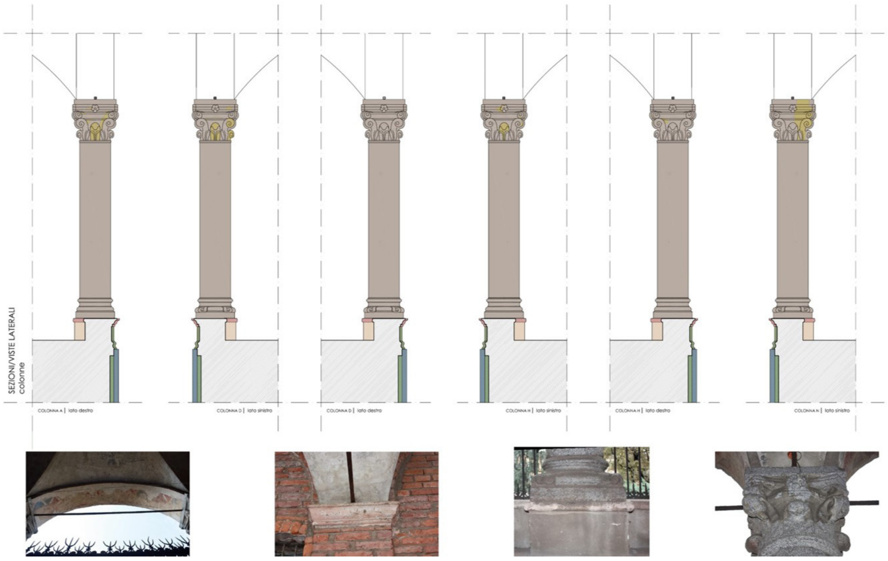


Fig. 14. Details. Ospedale Maggiore, Milan (Italy). Elevation by Pablo F. Cueto, 2012.

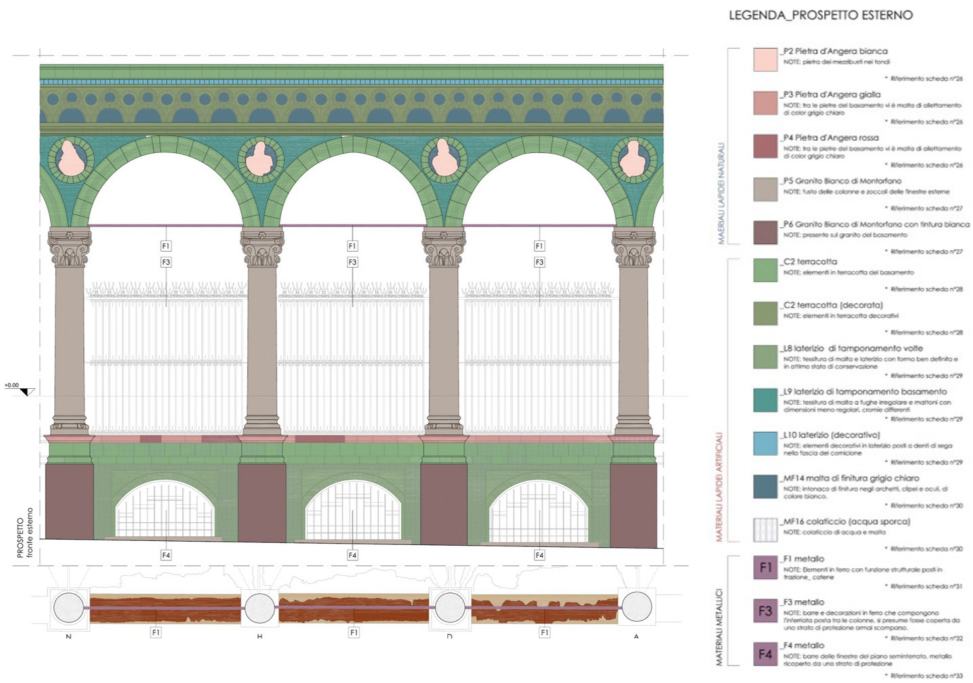


Fig. 15. Various materials and constructive systems. Ospedale Maggiore, Milan (Italy). Elevation by Pablo F. Cueto, 2012.

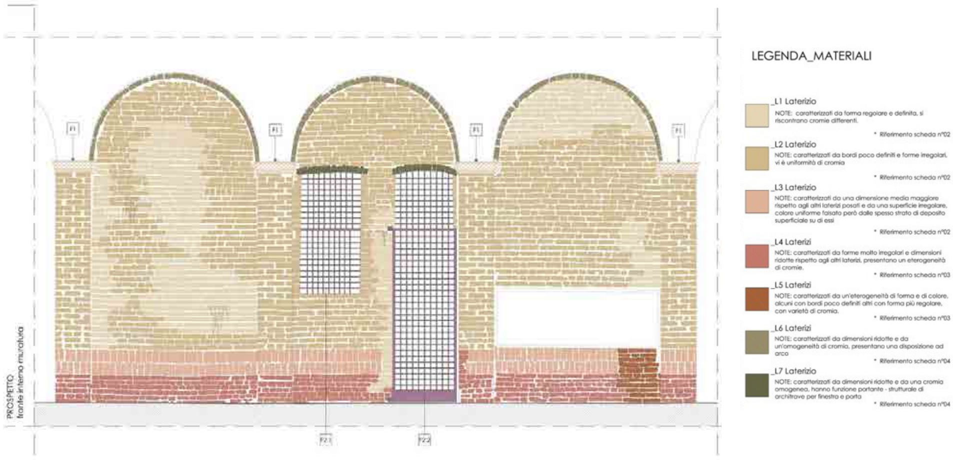


Fig. 16. Various materials and constructive systems. Ospedale Maggiore, Milan (Italy). Elevation by Pablo F. Cueto, 2012.

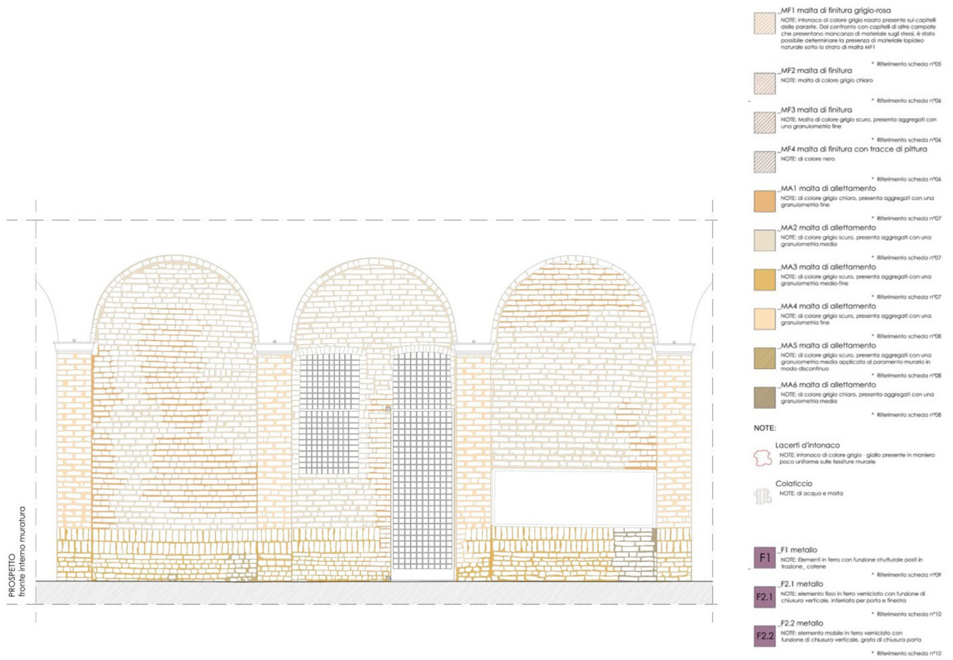


Fig. 17. Various materials and constructive systems. Ospedale Maggiore, Milan (Italy). Elevation by Pablo F. Cueto, 2012.

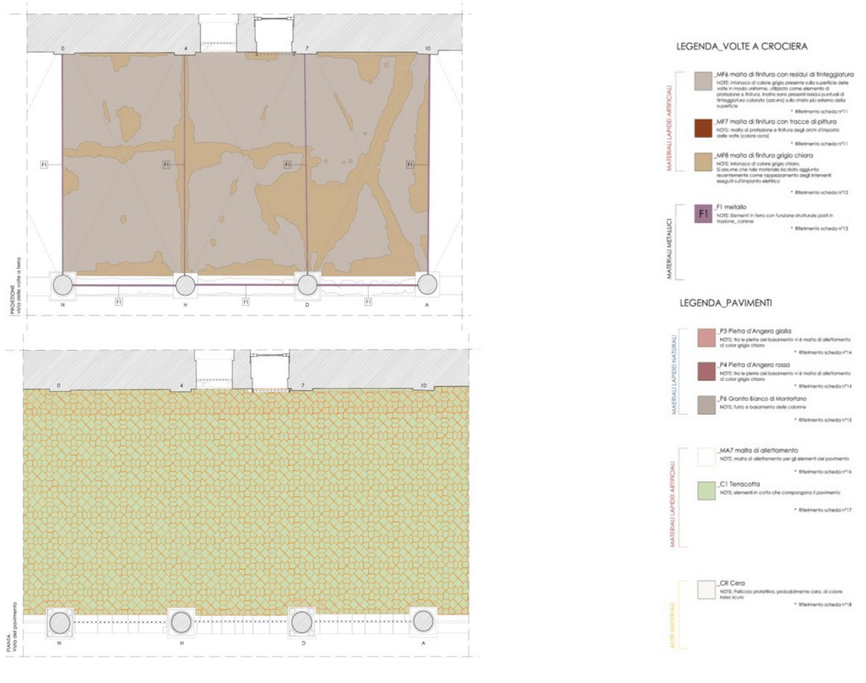


Fig. 18. Various materials and constructive systems. Ospedale Maggiore, Milan (Italy). Elevation by Pablo F. Cueto, 2012.

MATERIAL SURVEY: UNITS

It is sufficient to select the typical portions of the masonry wall, with dimensions of approximately 1 x 1 m; if the building contains different types of masonry, it is advisable to use two or more details for each type of masonry. The detection of the walls must be performed on site, after selecting the field to be detected; for greater precision, it is always advised to have a level and a plumb line, to check the verticality and the horizontality of the joints.

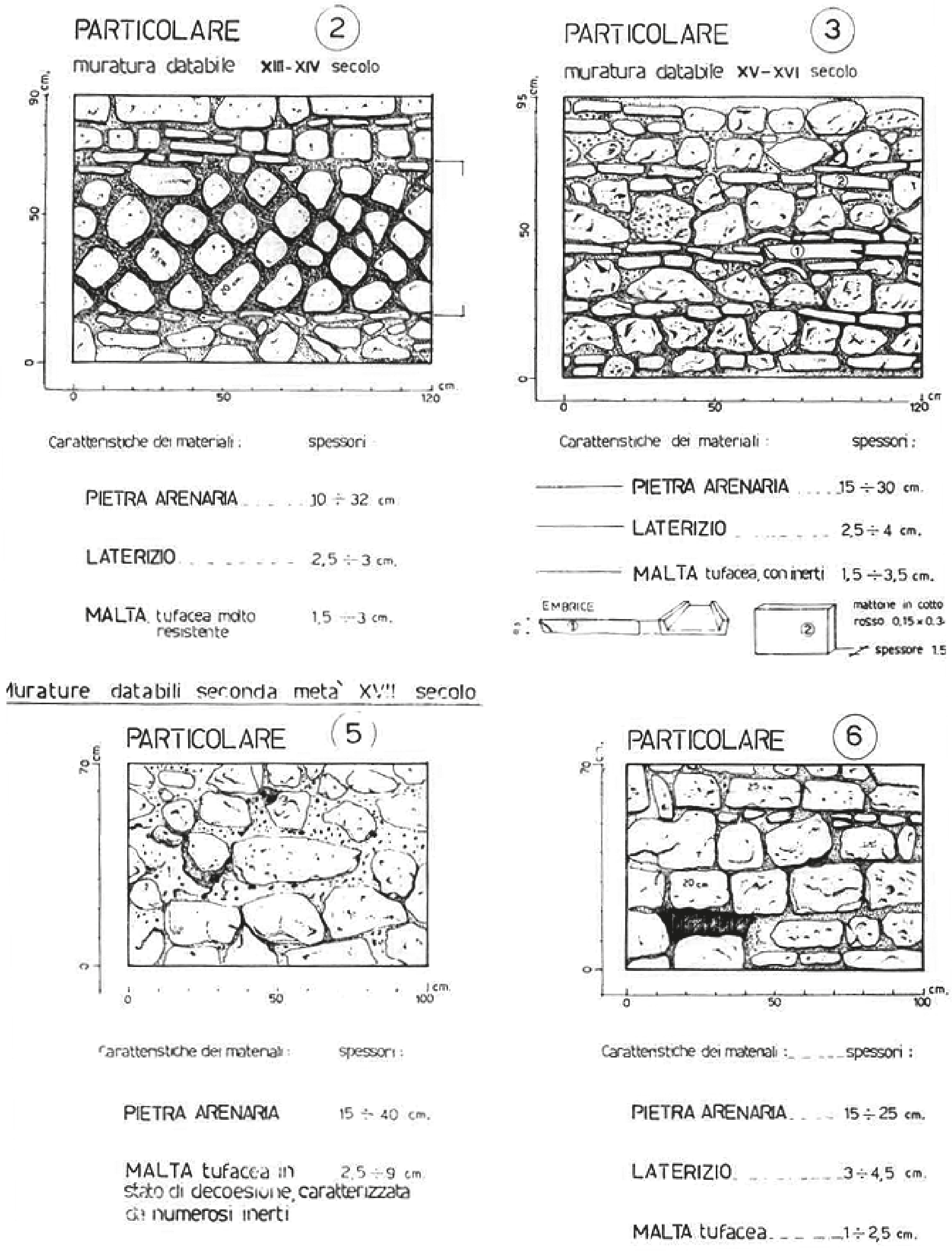


Fig. 19. Different units. Different materials and constructive systems. Example of a unit, Civitella San Paolo, Roma. From G. Carbonara, *Restauro dei monumenti. Guida agli elaborati grafici*, Liguori Editore, Napoli 1990, XLI.

It is essential that the representation of these details related to the masonry is always associated with other horizontal, in order to have immediately the perception of the dimensions of the modules. Given the use of very large scales, the representation must have a predominantly naturalistic character.

To facilitate direct detection and also to have a documentation of the state of the face, it is useful to take photographs of it, overlapping a square mesh lattice with sides of 10 cm. This documentation allows, if the photo is taken with the optical axis perpendicular to the wall, to print it in a set-point scale and thus have a measurable representation.

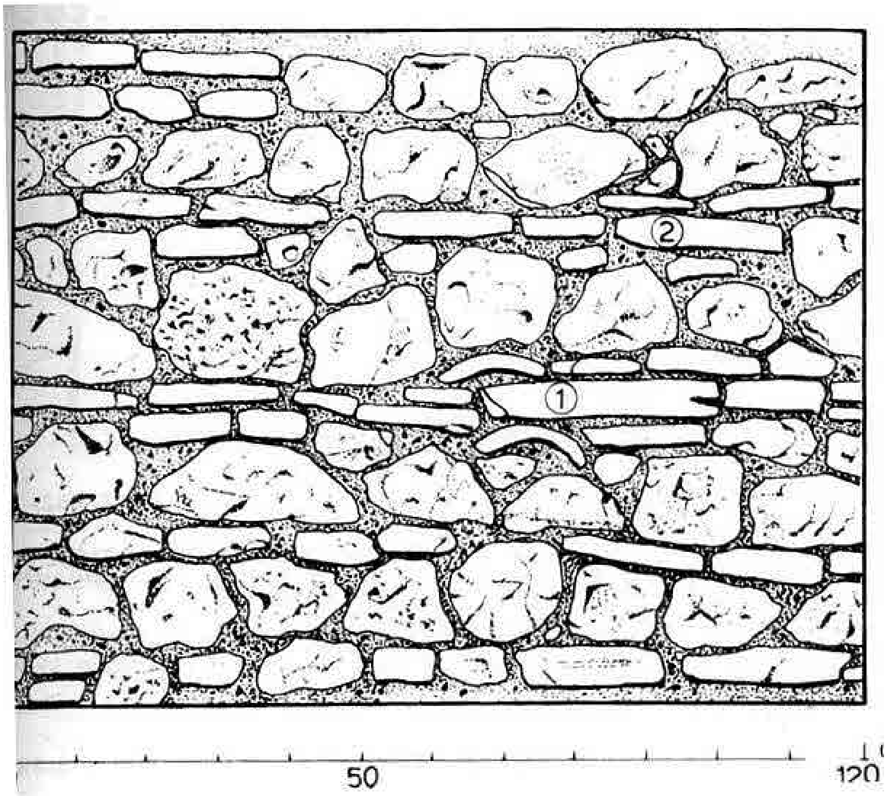


Fig. 20. Example of a unit. Particular units. Different materials and constructive systems. From G. Carbonara, *Restauro dei monumenti. Guida agli elaborati grafici*, Liguori Editore, Napoli 1990, XLI.

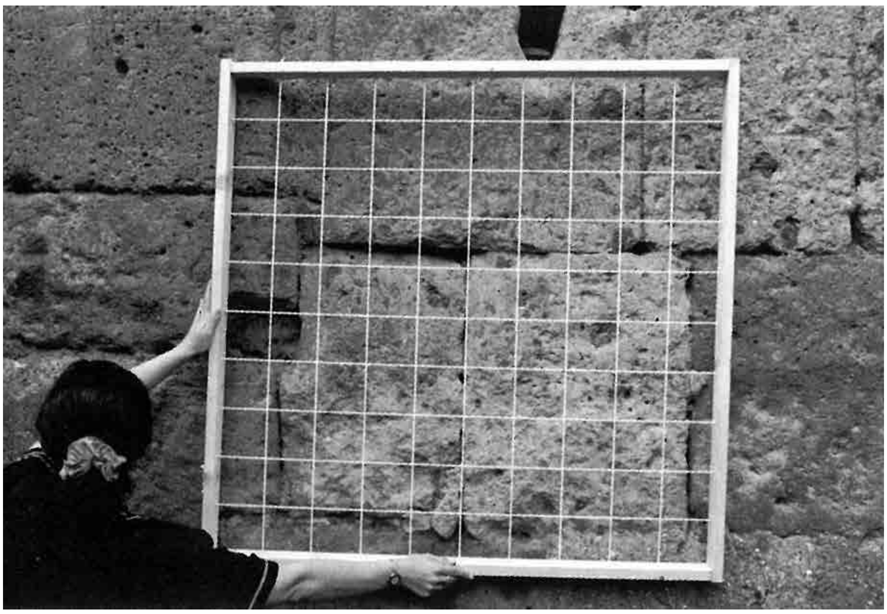


Fig. 21. Example of a unit. From G. Carbonara, *Trattato di restauro architettonico,* V. 2, Utet, Torino 2005, p. 493.

MECHANICAL SURVEY

Composition of a building volume according to the indications of the treatises. General idea for the construction of a building with reference to a group of buildings as an «aggregate».

Fig. 22. General idea of an «aggregate». Bollettino ufficiale della regione Marche, anno XXXI n. ed. S. 15.

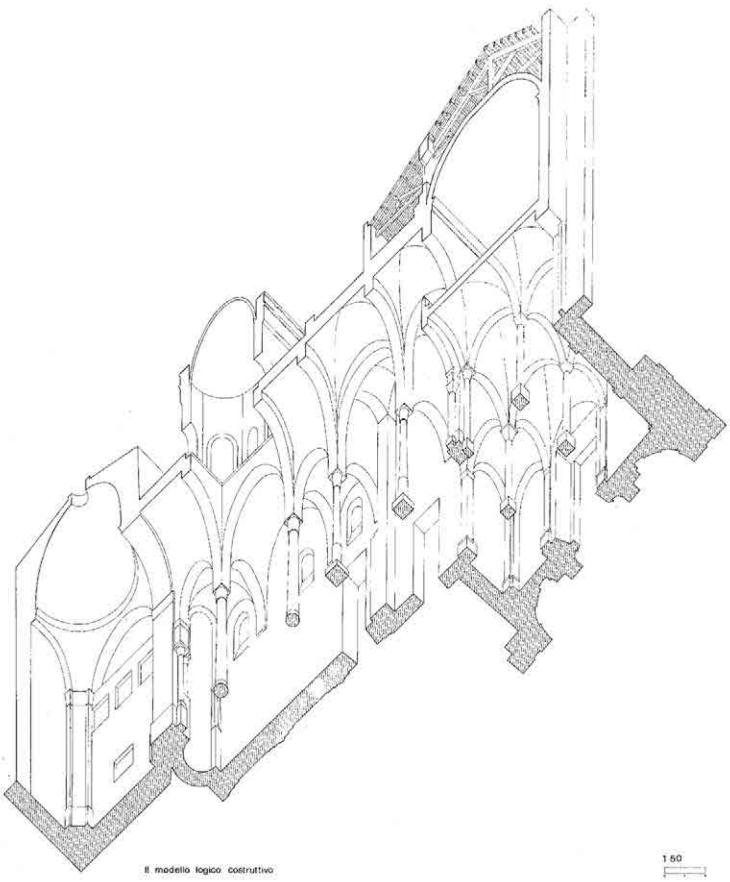


Fig. 23. Church of Martorana. Design by Calogero Bellanca. From C. Bellanca, *Methodical Approach to the restoration of Historic Architecture*, Alinea Editrice, Firenze 2011, p. 189.

STATE OF DAMAGE

Section of collapse with regular profile of a large portion of the bell tower. Almost vertical passing lesion, more open upwards than downwards, comes into contact with the shutter of the classroom roof; it has clearly detached flaps, placed on different levels.

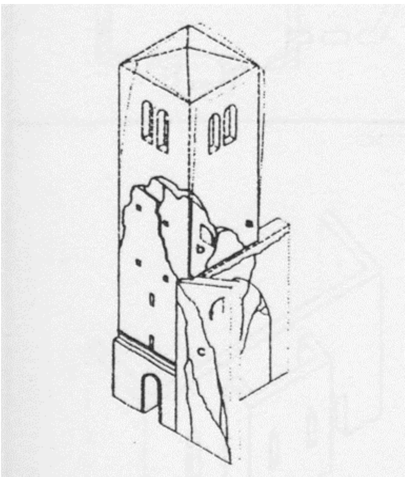
Lesion that continues the trend of discretization found on the bell tower, but has a less pronounced detachment between the edges, with breakage of the plaster facing.

Decohesion of the last parts of the walls, following the collapse of the curb. Oblique lesions differently oriented on the wall panel.

MECHANISM SCHEME

It is hypothesized that the upper part of the tower was affected by a torsion phenomenon, which caused the consequent "imbalance" towards the interior of the classroom, causing part of the roof and the underlying vault to collapse. Horizontal rotation of the wall portion at the intersection of the tower walls, with probable formation of a hinge point on the edge in contact with the classroom panels.

Irregular breaking of the masonry with block formation near the corner probably due to the excessive load of the tower on the foundation, which could have caused the breaking by traction of the corner wall portion (highlighted by the formation of "pillars" on the plaster facing.



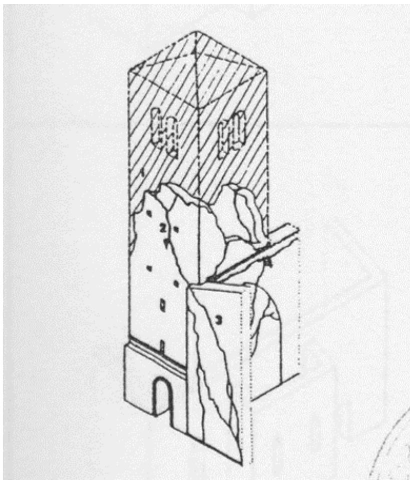


Fig. 28. Details for the state of damage. Church of Santo Stefano in Valeriano. From F. Doglioni e V. Petrini, *Le chiese e il terremoto*, Lint, Venezia 1994, p. 121.

Church of S. Stefano: The formation of a horizontal hinge at the height of the symmetrical holes is evident, with clear detachment at the intersection and off-plane displacement of the large discretized block, minor discretizations are visible near the hole.

Out-of-plane rotation with the formation of a cylindrical hinge with a horizontal axis at the height of the holes.

Out-of-plane displacement (or collapse) due to bending with hinge line at a lower level. The discontinuity constituted by the holes is the preferential line for the activation of the rotation hinge.

NOTES

A general view for the study and restoration of preexistence:

BONELLI R., DE ANGELIS d'OSSAT G., *Due lezioni di Restauro*, Roma 1987;

CARBONARA G., *Guida agli elaborati grafici*, Napoli 1990;

CARBONARA G., *Restauro da conservazione e ripristino, note sui più attuali orientamenti di metodo*, in "Palladio", 6, luglio-dicembre 1990, pp. 43-76;

ZANDER G., *Storia della scienza e della tecnica edilizia*, Roma 1991;

ZANDER G., *Scritti sul Restauro dei monumenti architettonici*, Roma 1993;

1) DOCCI M., MAESTRI D., *Il rilevamento architettonico*, *Storia metodi e disegno*, Roma-Bari 1984; see also DOCCI M., CHIAVONI E., *Saper leggere l'architettura*, Bari 2017; and dont forget to see "Disegnare, Idee / immagini", diversi numeri;

2) Particulary masonry in la Mattonata, quartier, survey R.Argalia 1992; GIOVANNETTI F., *Manuale del Recupero del Comune di Città di Castello*, Roma 1987;

3) From un *Manual de restauracion de la Arquitectura tradicional de la Comunidad Valenciana*, Conselleria de Medi Ambient, Aigua, Urbanisme i Habitatge. COACV Collegi d'Arquitectes de la Comunitat Valenciana;

4) Ibidem;

5) Project of restauration of the Monastry of Carracedo, Leon, Spain 1985-1991, Salvador Perez Arroyo and Susana Mora; BELLANCA C., *Architectural Conservation Studio*, with contributions by Susana Lopez Verdú and Alejandro Iniesta Muñoz, Roma 2019.

CARBONNELL M., *Apport de la metrologie photogrammetrique dans l'analyse geometrique et pathologique des structures anciennes*, in Stable – Unstable?, pp. 167-180.

CEN, Eurocore, *Actions sue les structures. Technical report*, AFNUR, 2005.

Methods of tests for Masonry Units, British Standards, Institution, London 1998.

MILETO C., VEGAS F., CRISTINI V., GARCIA L., *Architectural and archaeological heritage: management and new technologies*, online published e Göttingen 2020.

ROCA P., LOURENZO P.B., GAETANI A., *Construction materials and main structural elements*, in *Historic construction and conservation, materials, systems and damage*, Routledge, New York 2019, pp. 65-136.

CHAPTER 3. DAMAGE MAPS: DEGRADATION PROBLEMS AND TYPES, FISSURE AND CRACK PROBLEMS

DAMAGE MAPS: DEFINITION

The survey and the representation of the degradation of the materials are usually made using cartographic architectural survey, as a basis on which, using synthetic abstract symbologies, is portrayed the perimeter of the areas subject to some typical aspects of degradation, such as surface deposit, cracking, cracking, fracturing, scaling, alveolization, black crusts, pitting, corrosion, spotting, efflorescence, detachment, etc.

Methods of survey of degradation states mainly use the direct method and, in some cases, the photogrammetric method. After having identified on site the perimeter of the areas with different types of degradation, the technician should identify the areas in question with the appropriate symbols.
To delimit these areas it is necessary to use some horizontal and vertical references, using lead and level wires; bearing in mind that architectural surveying is normally carried out as a first operation, some elements already detected can be used as reference points, such as the joints of the walls, string courses, edges of doors and windows, etc. (1)

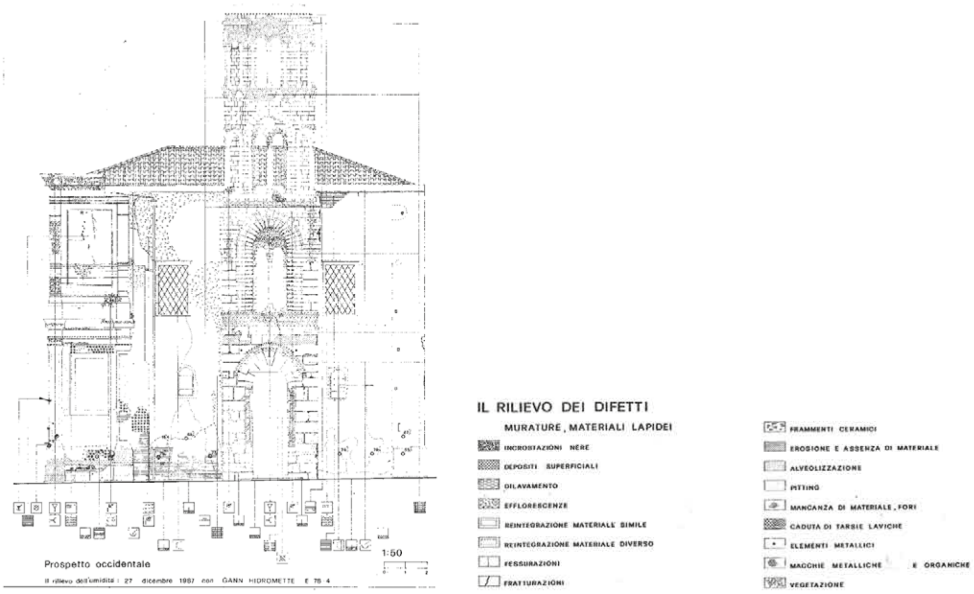


Fig. 1. Church of Martorana. From C. Bellanca, *Methodical Approach to the restoration of Historic Architecture*, Alinea Editrice, Firenze 2011, p. 201.
By C. Bellanca 1986 Study and Project

SYMBOLOGY

As regards the representation of degradation states, it is necessary to resort to symbologies, which, however, are not yet unified today. A first attempt, in this direction, was carried out by the Normal commission.

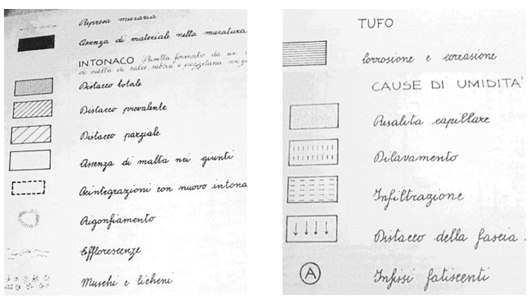


Fig. 2. Types of degradation and its conventional symbols, different degradation of materials. From G. Carbonara, *Restauro dei monumenti. Guida agli elaborati grafici*, Liguori Editore, Napoli 1990, LXIV.

MAP OF DAMAGES: DEGRADATION SURVEY

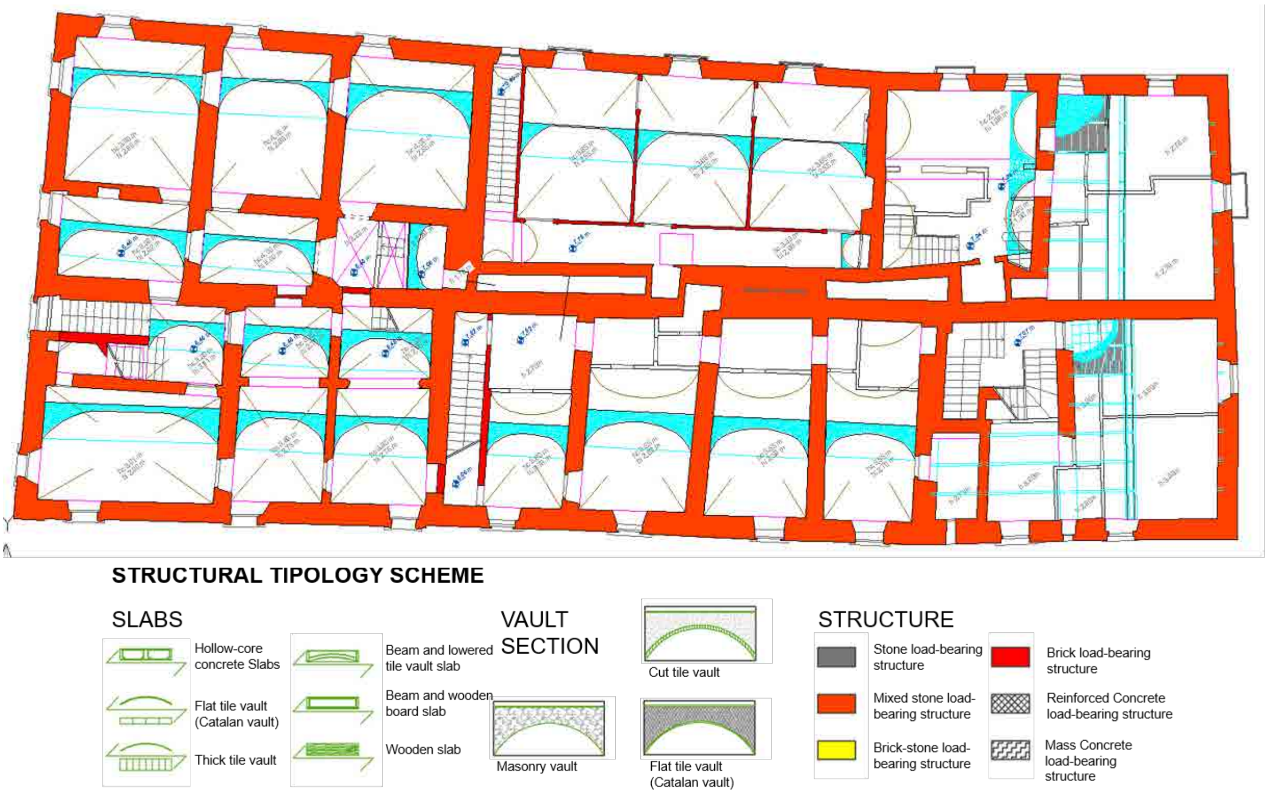


Fig. 3. Plan. Horizontal section and structure legend. Redesigned by Susana Mora. (2)

MAP OF DAMAGES: CRACK PATTERN SURVEY

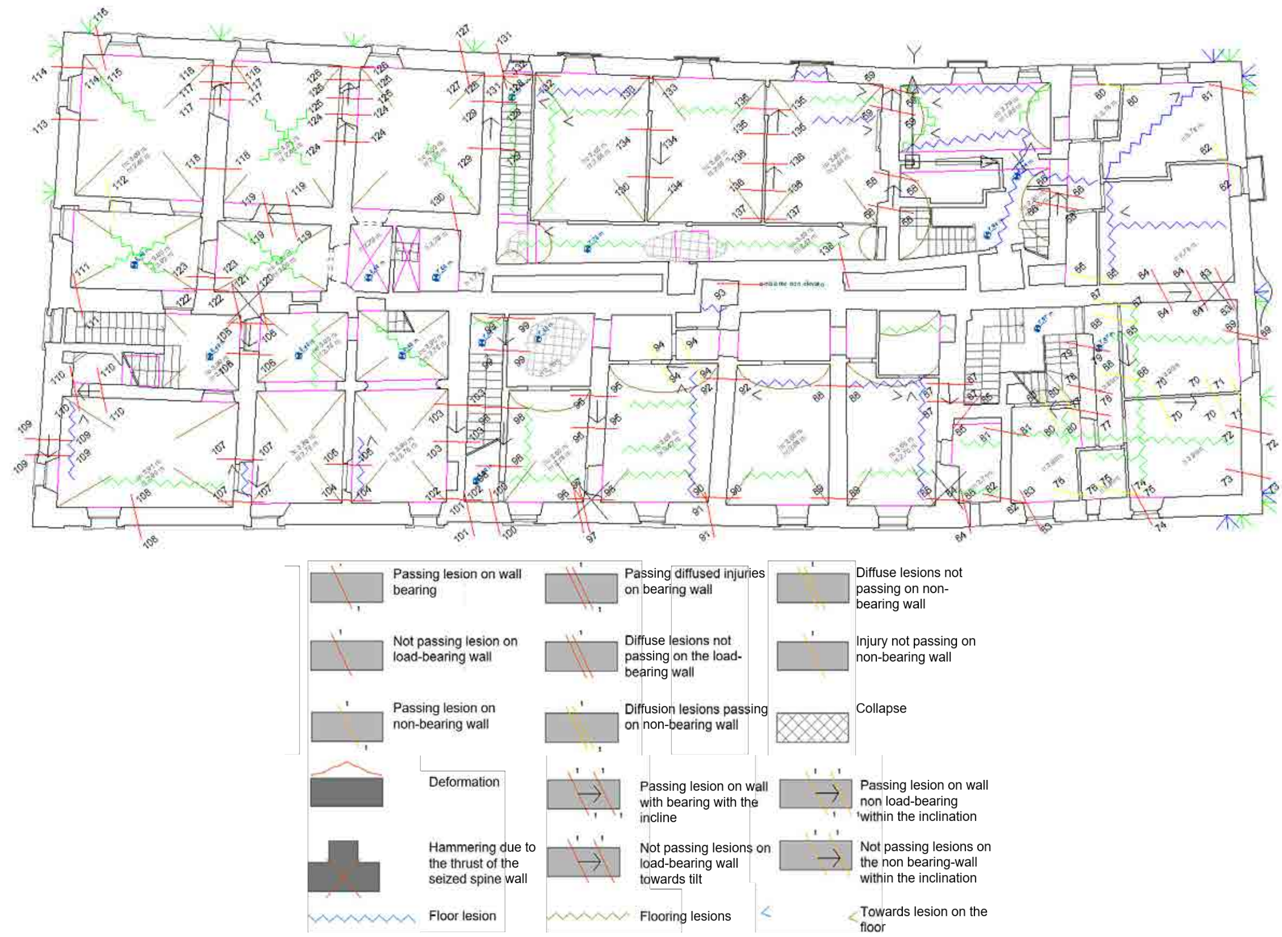


Fig. 4. Plan. Horizontal section and physcal damage legend. Redesigned by Susana Mora.

MAP OF DAMAGES: DEGRADATION SURVEY

Fig. 5. Chiesa di S. Maria Maddalena in Capranica Prenestina, Tesi di Laurea, Sapienza University of Rome.

ICOMOS GLOSSARIO FOR DEGRADATION

Crack & Deformation	Detachment	Material Loss	Discoloration & Deposit	Biological Colonization
• Crack • Deformation	• blistering • bursting • delamination • disintegration • fragmentation • peeling • scaling	• alveolization • erosion • mech.damage • missing part • perforation	• crust • deposit • discoloration • efflorescence • encrustation • film • glossy aspect • film • patina • soiling	• alga • lichen • moss • mould • plant

Fig. 6. Maps of damage. (3)

DEGRADATION TYPES: DEFINITION

As we have said, the survey and the representation of the degradation of the materials are usually made using cartographic architectural survey, as a basis on which, using synthetic abstract symbologies, is portrayed the perimeter of the areas subject some typical aspects of degradation, such as surface deposit, cracking, cracking, fracturing, scaling, alveolization, black crusts, pitting, corrosion, spotting, efflorescence, detachment, etc.

TYPES OF DEGRADATION


ALTERATION


DAMAGE


DECAY


DEGRADATION


DETERIORATION


WEATHERING

ALTERATION

Modification of the material that does not necessary imply a worsening of its characteristics from the point of view of conservation. For instance, a reversible coating applied to stone may be considered as an alteration.

DAMAGE

Human perception of the loss of value due to decay.

DECAY

Any chemical or physical modification of the intrinsic stone properties leading to a loss of value or to the impairment of use.

DEGRADATION

Decline in condition, quality, or functional capacity.

DETERIORATION

Process of making or becoming worse or lower in quality, value, character, etc.; depreciation.

WEATHERING

Any chemical or mechanical process by which stones exposed to the weather undergo changes in character and deteriorate.

Glossario ICOMOS

The glossary is arranged into 6 families composed of 2 to 11 terms:

CRACK & DEFORMATION

FRACTURING OR FISSURING / Fratturazione o fessurazione

Degradation that manifests itself with the formation of a lack of continuity in the material and which may involve the reciprocal displacement of the parts.



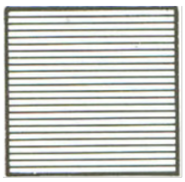
DEFORMATION / Deformazione

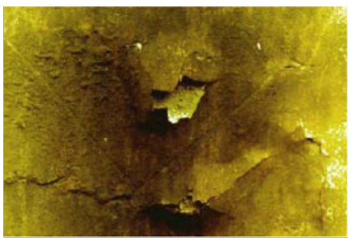
Variation of the shape that affects the entire thickness of the material and which manifests itself mainly in sheet-like elements.


DETACHMENT

BLISTERING / Rigonfiamento

Separated, air-filled, raised hemispherical elevations on the face of stone resulting from the detachment of an outer stone layer. This detachment is not related to the stone structure. Blistering, in some circumstances, is caused by the action of soluble salts.





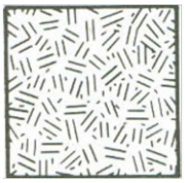
BURSTING:

Local loss of the stone surface from internal pressure usually manifesting in the form of an irregularly-sided crater. Bursting is sometimes preceded by star-shaped face-fracturing.



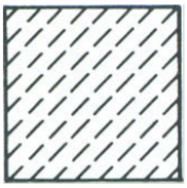
DELAMINATION / Esfoliazione

Detachment process affecting laminated stones (some sedimentary and metamorphic rocks). It corresponds to a physical separation into layers following the stone laminae. The thickness and the shape of the layers are variable. The layers may be oriented in any direction with regards to the stone surface.



SCALING / Scagliatura

Detachment of stone as a scale or a stack of scales, not following any stone structure and detaching like fish scales or parallel to the stone surface. The thickness of a scale is generally of millimetric to centimetric scale, and is negligeable compared to its surface dimension.

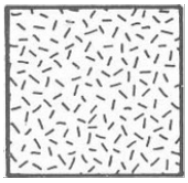
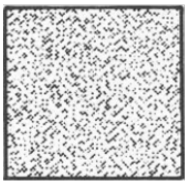


DISINTEGRATION / Disgregazione
POWDERING, CHALKING / Polverizzazione

It affects only the surface of the stone or can occur in depth. Damage generally starts from the surface of the material.

– Crumbling: Detachment of aggregates of grains from the substrate. These aggregates are generally limited in size (less than 2 cm). This size depends on the nature of the stone and its environment.
– Granular disintegration: Occurs in granular sedimentary (e.g. sandstone) and granular crystalline (e.g. granite) stones. Granular disintegration produces debris referred to as rock meal and can often be seen accumulating at the foot of the wall actively deteriorating. The following specific terms refer either to the size, or to the aspect of corresponding grains:

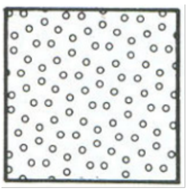
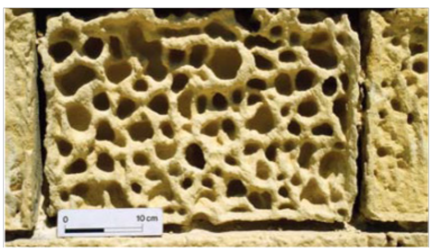
» Powdering, Chalking: terms sometimes employed to describe granular disintegration of finely grained stones.
» Sugaring: employed mainly for white crystalline marble,
» Sanding: used to describe granular disintegration of sandstones and granites.

MATERIAL LOSS

ALVEOLIZATION / Alveolizzazione

Degradation that manifests itself with the formation of cavities of variable shape and size. Alveoli are often interconnected and have non-uniform distribution. In the particular case in which the phenomenon develops essentially in depth with a diverticular course, the term carotene alveolization can be used.


EROSION / Erosione

Loss of original surface, leading to smoothed shapes. Erosion may have natural and/or anthropogenic causes. It can be due to chemical, physical or/ and biological processes.



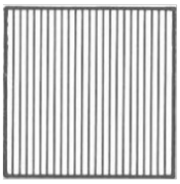

MECHANICAL DAMAGE

Loss of stone material clearly due to a mechanical action.
Impact damage: Mechanical damage due to the impact of a projectile
Cut: Loss of material due to the action of an edge tool.
Scratch: Line-like loss of material due to the action of some pointed object.
Abrasion: Erosion due to rubbing away by means of friction.
Keying: Impact damage resulting from hitting a surface with a pointed tool.




MISSING PART / Mancanza

Empty space, obviously located in the place of some formerly existing stone part. Protruding and particularly exposed parts of sculptures (nose, fingers…) are typical locations for material loss resulting in missing parts.




PERFORATION

A single or series of surface punctures, holes or gaps, made by a sharp tool or created by an animal. The size is generally of millimetric to centimetric scale. Perforations are deeper than they are wide, and penetrate into the body of the stone.



DISCOLORATION & DEPOSIT

PITTING / Pitting

Point-like millimetric or submillimetric shallow cavities. The pits generally have a cylindrical or conical shape and are not interconnected, although transitions patterns to interconnected pits can also be observed.

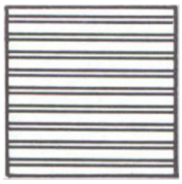


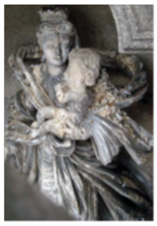
CRUST / Crosta

Generally coherent accumulation of materials on the surface. It may include exogenic deposits in combination with materials derived from the stone. A crust is frequently dark coloured (black crust). Crusts may have an homogeneous thickness, or have irregular thickness.


DEPOSIT / Deposito superficiale

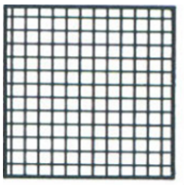
Accumulation of exogenic material of variable thickness. Some examples of deposits: splashes of paint or mortar, sea salt aerosols, atmospheric particles such as soot or dust, remains of conservation materials such as cellulose poultices, blast materials, etc.

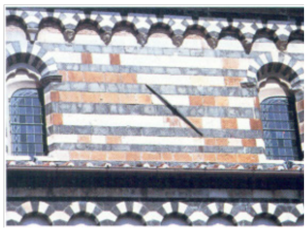





DISCOLORATION / Alterazione cromatica

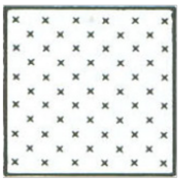
Alteration that manifests itself through the variation of one or more parameters that define the color: tint (hue), clarity (value), saturation. It can occur with different morphologies and can refer to large or localized areas.

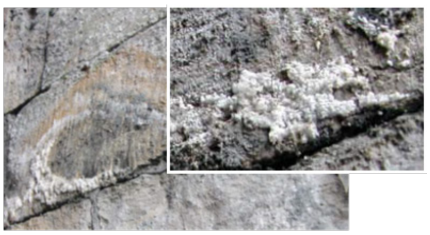




EFFLORESCENCE / Efflorescensa

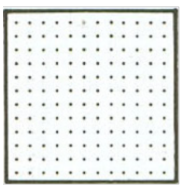
Generally whitish, powdery or whisker-like crystals on the surface. Efflorescences are generally poorly cohesive and commonly made of soluble salt crystals.





ENCROSTATION / Incrostazione

Compact, hard, mineral outer layer adhering to the stone. Surface morphology and colour are usually different from those of the stone.



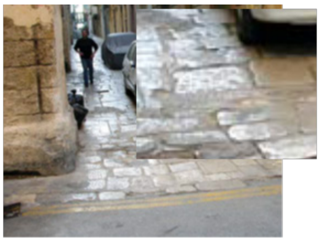

FILM / Pellicola

Thin covering or coating layer generally of organic nature, generally homogeneous, follows the stone surface. A film may be opaque or translucent.



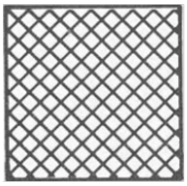
GLOSSY ASPECT

Aspect of a surface that totally or partially reflects the light, it has a mirror-like appearance. A glossy aspect may be due to previous polishing, (intentional or not), or to the presence of a transparent film which reflects light.

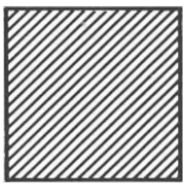

PATINA / Patina

Chromatic modification of the material, generally resulting from natural or artificial ageing and not involving in most cases visible surface deterioration.




SOILING / Macchia

Deposit of a very thin layer of exogenous particles (eg. soot) giving a dirty appearance to the stone surface. With soiling, the substrate stucture is not considered as affected. Soiling may have different degrees of adhesion to the substrate.



BIOLOGICAL COLONIZATION

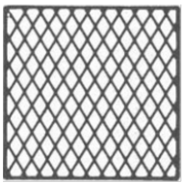
BIOLOGICAL COLONIZATION / Presenza di vegetazione

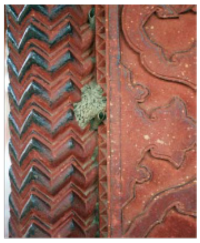
Colonization of the stone by plants and micro-organisms such as bacteria, cyanobacteria, algae, fungi and lichen. Biological colonization also includes influences by other organisms such as animals nesting on and in stone.




BIOLOGICAL PATINA / Alga

Algae are microscopic plant organisms without stem or leaves which can be seen outdoors and indoors, as powdery or viscous deposits. Algae form green, red, brown, or black veil like zones and can be found mainly in situations where the substrate remains moist for long periods of time.



LICHEN / Lichene

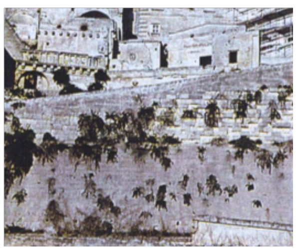
Plant organism forming rounded millimetric to centimetric crusty or bushy patches, often having a leathery appearance, growing generally on outside parts of a building. Lichen are most commonly grey, yellow, orange, green or black and show no differentiation into stem, root and leaf.



PLANT / Vegetazione

Vegetal living being, having, when complete, root, stem, and leaves, though consisting sometimes only of a single leafy expansion (e.g. Tree, fern, herb).

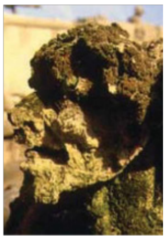




MOSS / Muschio

Plant organism forming small, soft and green cushions of centimetric size. Mosses generally look like dense micro-leaves tightly packed together. Mosses often grow on stone surface open cavities, cracks, and in any place permanently or frequently wet (masonry joints), and usually shady.

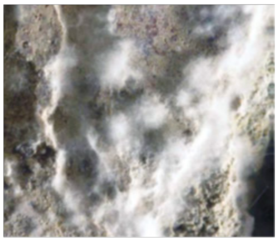




MOULD / Muffa

Microscopic fungus whose colonies, to the naked eye, look like a downy film or a network or star-like millimetric patches of filaments of diverse colours (white, grey, black).





FISSURE AND CRACK PROBLEMS

CRACK PATTERN SURVEY: DEFINITION

Survey of the fissure patterns through plans, sections, elevations and any axonometric representations, to provide a spatial vision of the lesions trend. The reliefs must highlight the slits, the micro-cracks, the wall deformations with possible inflection of the vestments, showing if they are in agreement or discord. For the cracks, you will have to highlight the position, the trend, the inflection and depression points, the trend edges, etc. The representation
(4) of the picture (levers use scales ranging between 1:50 and 1:10).

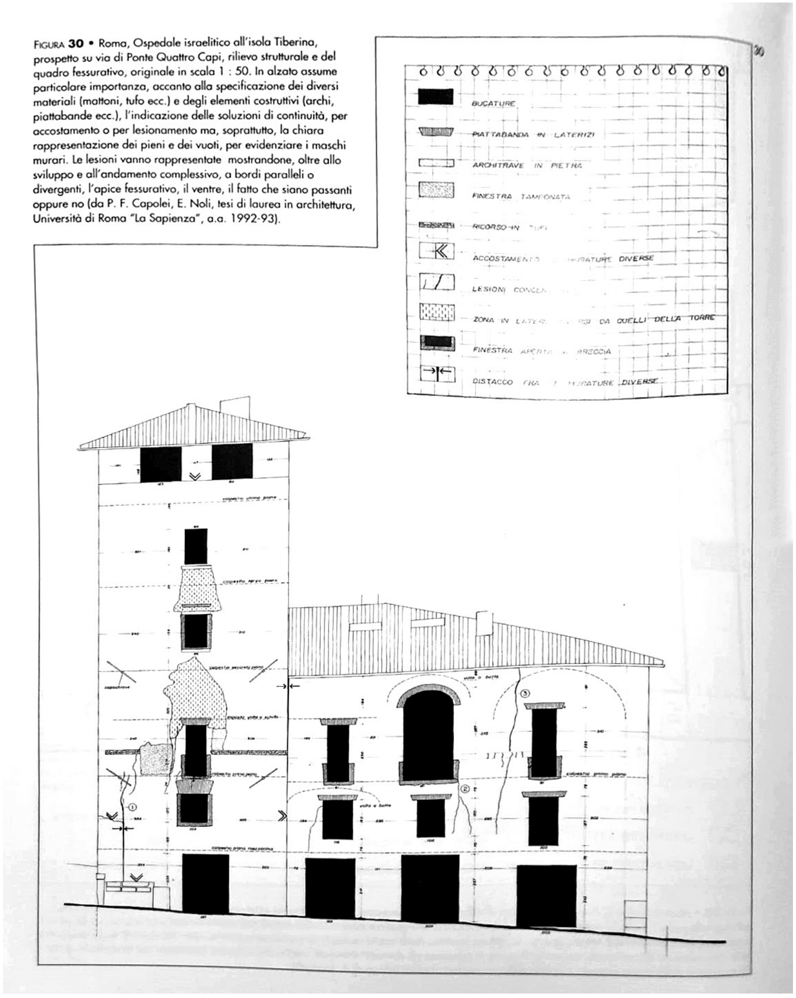


Fig. 7. Ospedale Isola Tiberina, Roma. From G. Carbonara, *Trattato di restauro architettonico,* vol. 2, Utet, Torino 1996, p. 460.

REPRESENTATION METHODS

Survey of the crack pattern must be performed with great care and accuracy, since it is possible to trace the causes that determined it from its analysis. In order to highlight the progress of the lesions, it is also advisable that the drawings contain little information to increase their legibility.
The methodologies to be used in detecting the crack pattern are generally direct and, in some particular cases, photogrammetric. In the application of the direct method, the general trend of the lesions should be emphasized, if they cross the wall thickness, or if they are superficial; it is also necessary to highlight whether they are slits or micro-cracks.

VAULTS AND DOMES. INJURIES.

In addition to the progression of the lesions, the wall deformations and any inflections of the vestments must also be noted and, in the case of vaulted structures, if a depression of the vaulted part has occurred. It has already been said that the progression of the lesions, their position or form can clearly indicate the causes that led to their emergence; therefore, the detector is called to account not only for the spatial trend of the lesions, but also for their size, and to document whether this is constant if it has a variable trend, as well as the beginning, the end and the point of maximum opening of the lesion itself; it is also necessary to highlight, with possible detailed drawings, the trend of the two margins, so that it can be ascertained whether there has been a simple detachment due to removal of the two parts of the masonry, or a rotation.

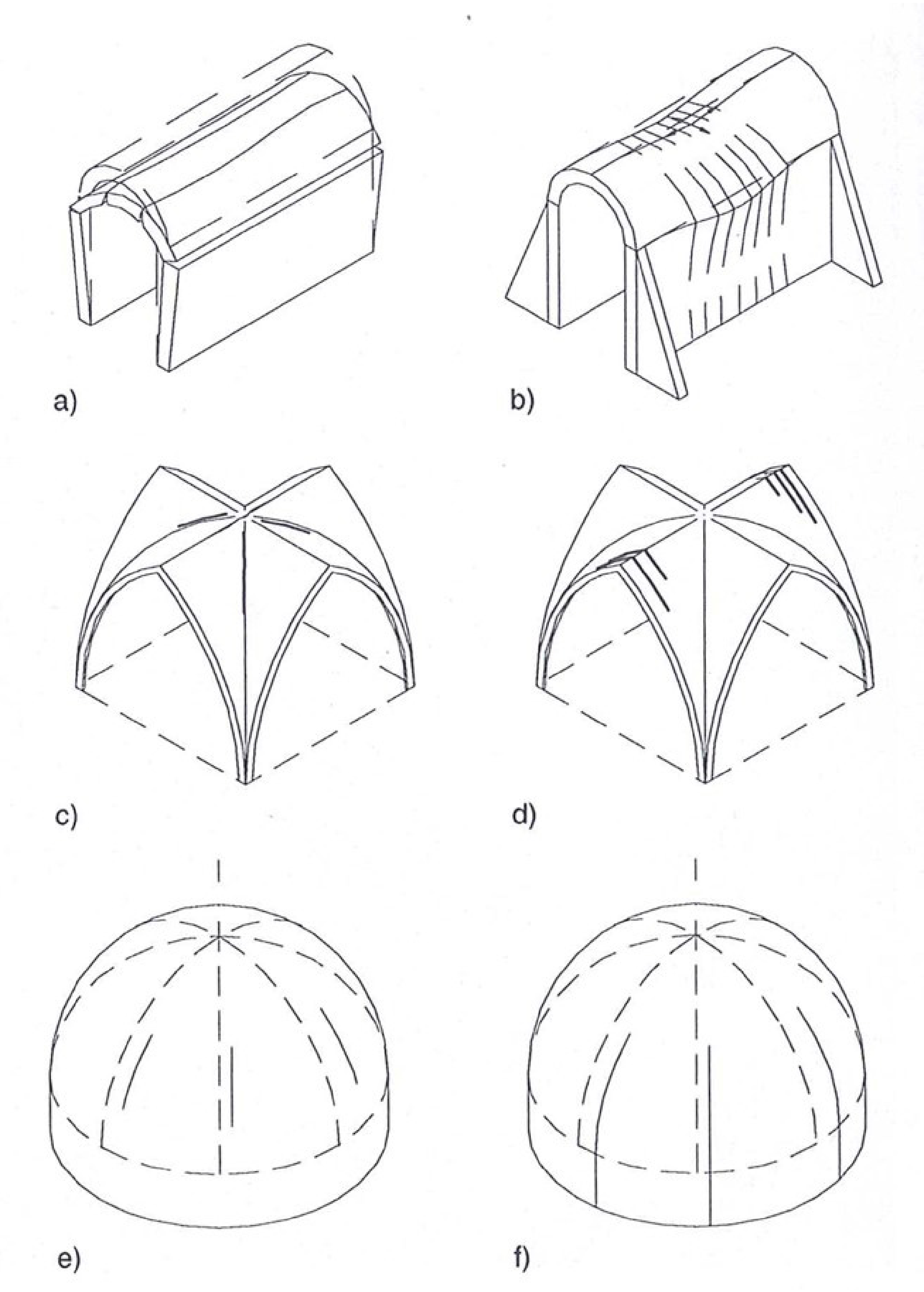


Fig. 8. Soil subsidence. Corner cracks.
From Giorgio Croci, *Conservazione e restauro strutturale dei Beni Architettonici*, Utet, Torino 2011, p. 130.

POSSIBLE CRACKS PATTERNS OF CRACKS IN MASONRY PILLASTER UNDER PRESSURE

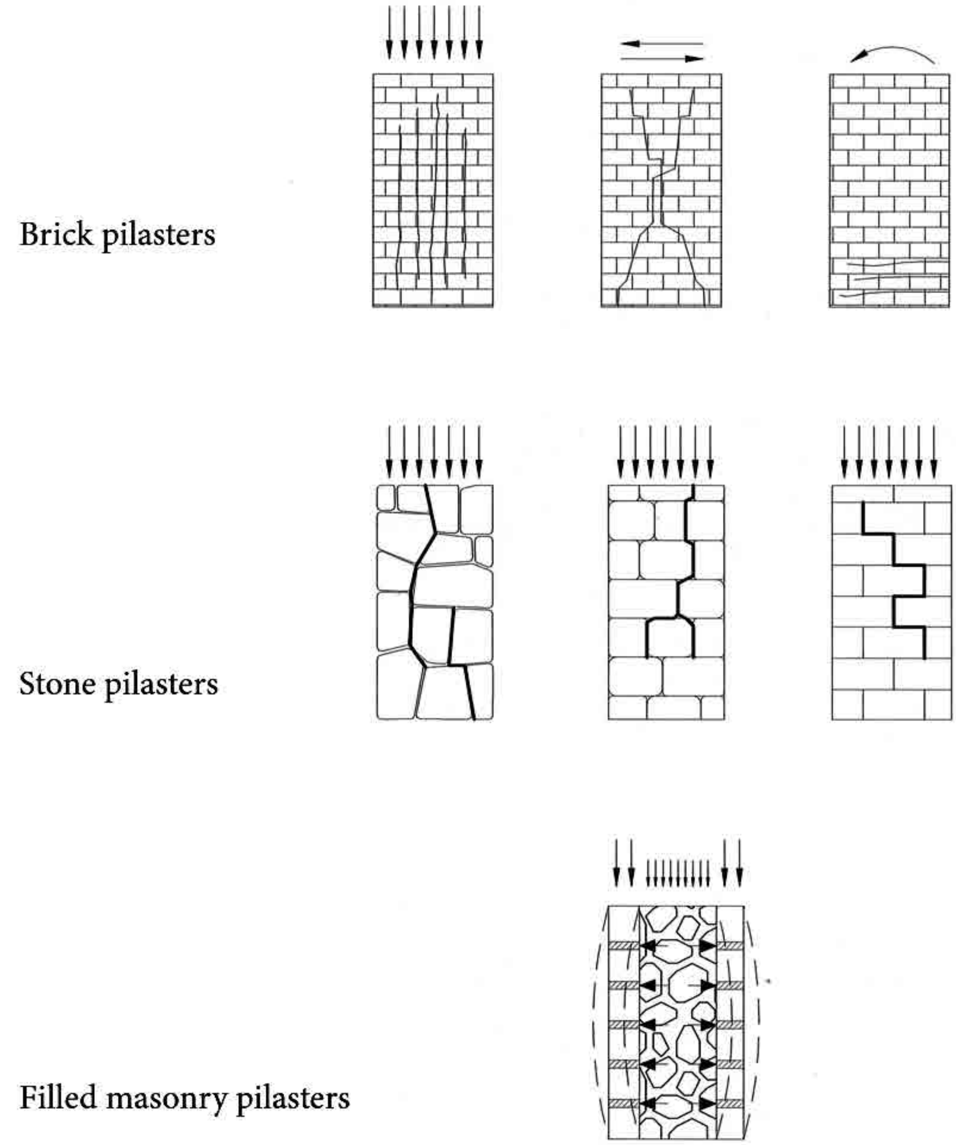


Fig. 9. Soil subsidence. Corner cracks. From Giorgio Croci, *Conservazione e restauro strutturale dei Beni Architettonici*, Utet, Torino 2011, p. 123.

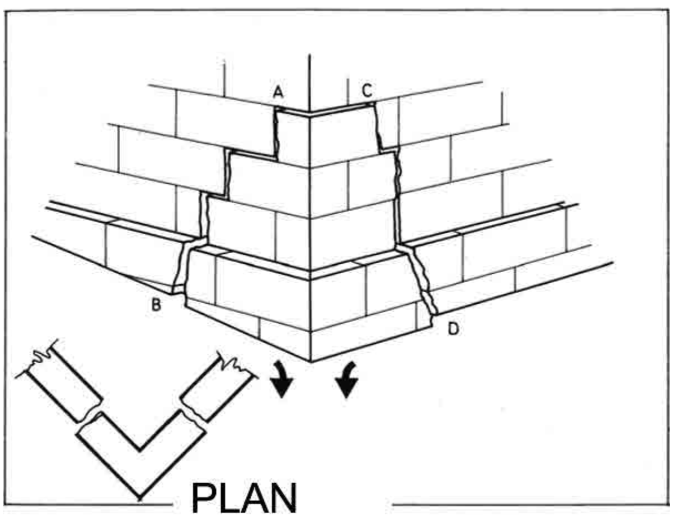


Fig. 10. Soil subsidence. Corner cracks. From Gabriel López Collado, *Las Ruinas en Construcciones Antiguas. Causas, consolidaciones y traslados*, MOPU, Madrid 1976, p. 63.

As can be deduced from these examples, it is essential that all the elements that characterize a lesion are taken into consideration in the survey operations. In particular, the angle of deviation of the lesion with respect to the vertical with the aid of plumb lines; for inclined injuries, it is advised to measure the angle with respect to the vertical or the horizontal.
In these cases it is essential that all the survey operations are accompanied by exhaustive photographic documentation and, regarding the detailed photographs, it is suggested to overlay a plumb line and a meter to the lesion to obtain reference elements on the photo that allow for a simple control of its progress.

Furthermore, photogrammetric filming carried out at a later time also allows deferred monitoring.

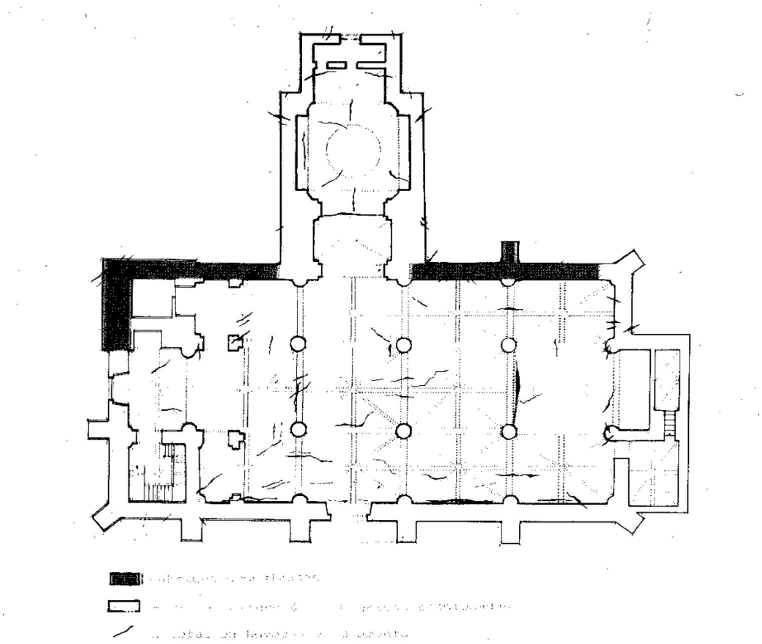


Fig. 11. Crack pattern of vaults. Santa María Church, Villalba del Rey (Cuenca). Plan by Susana Mora, 2000. (5)

For the representation of the cracking pattern, it is not only necessary to report the injuries in plan and elevation. In some cases it is necessary to have a spatial pattern of their progress, as well as normal representation, with axonometric views allowing for a synthetic spatial vision.

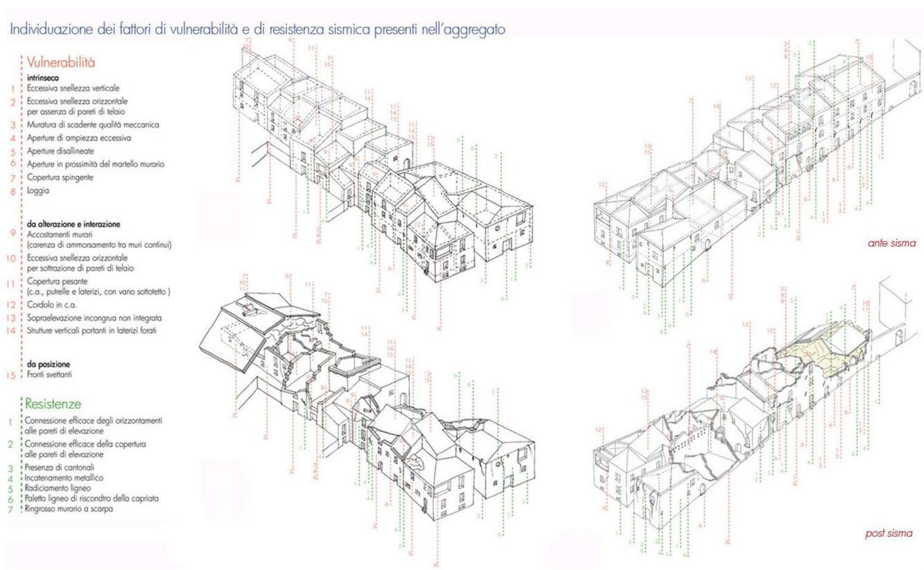
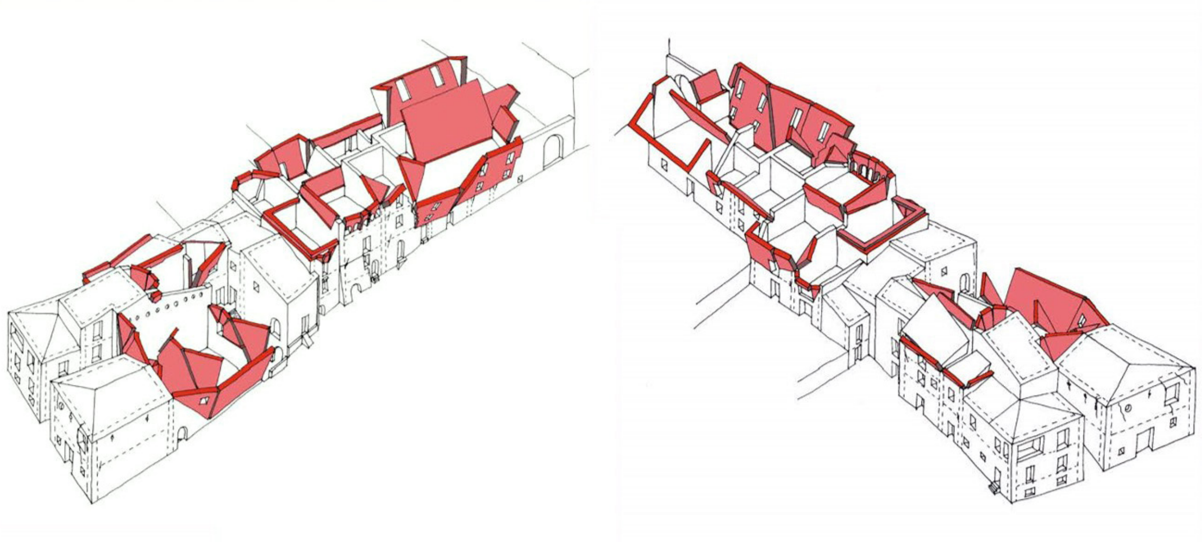
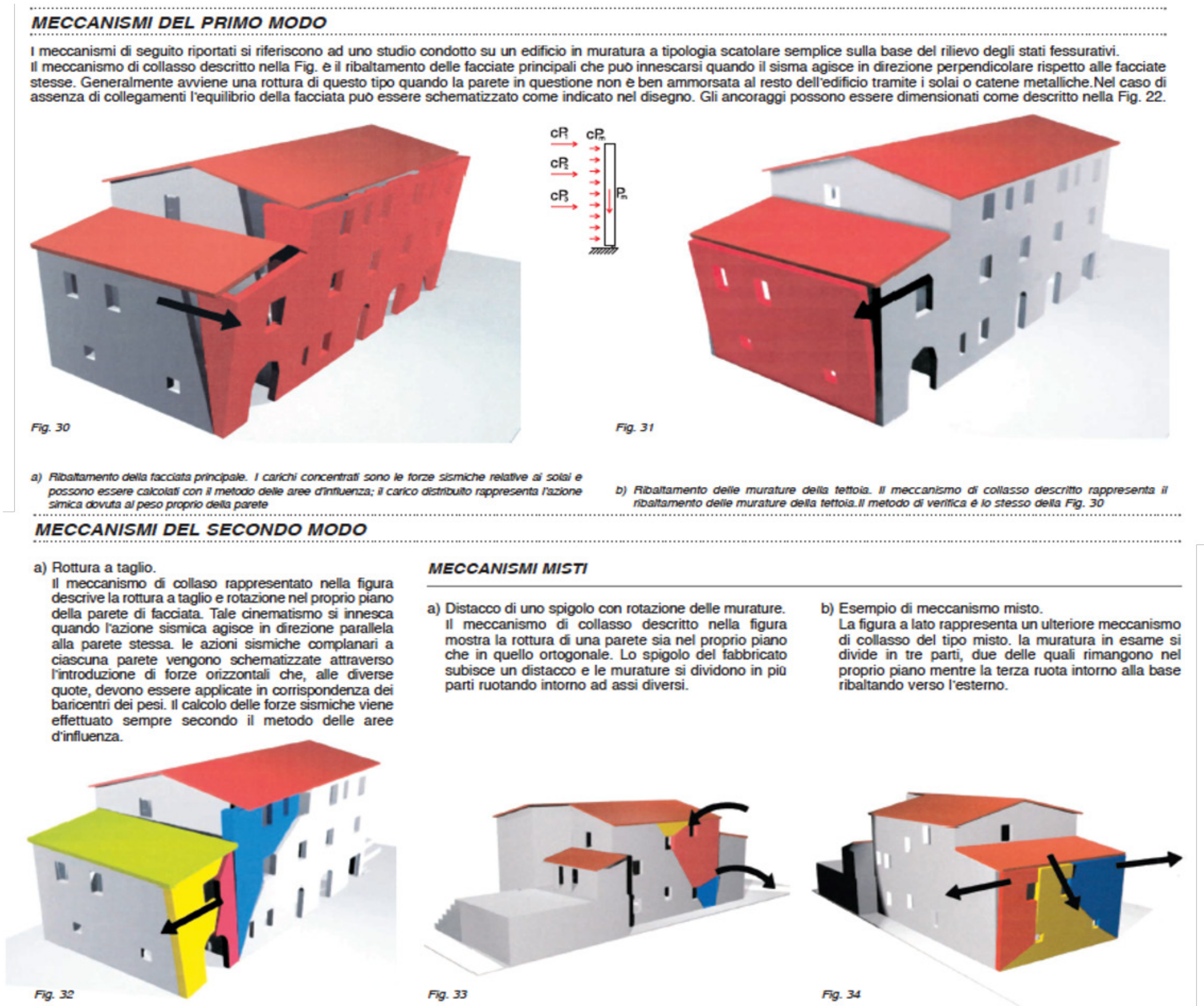


Fig. 12. Identification of the vulnerability and seismic resistance factors present in the aggregate. From F. Doglioni, *Codice di pratica (linee guida) per la progettazione degli interventi di riparazione, miglioramento sismico e restauro dei beni architettonici danneggiati dal terremoto umbro-marchigiano del 1997*, IUAV-D.S.A., Convenzione 1999.



Seismic damage scenario triggered by a macroseismic intensity of 9 degree MCS in the aggregate



MECCANISMI DEL PRIMO MODO

I meccanismi di seguito riportati si riferiscono ad uno studio condotto su un edificio in muratura a tipologia scatolare semplice sulla base del rilievo degli stati fessurativi.
Il meccanismo di collasso descritto nella Fig. è il ribaltamento delle facciate principali che può innescarsi quando il sisma agisce in direzione perpendicolare rispetto alle facciate stesse. Generalmente avviene una rottura di questo tipo quando la parete in questione non è ben ammorsata al resto dell'edificio tramite i solai o catene metalliche.Nel caso di assenza di collegamenti l'equilibrio della facciata può essere schematizzato come indicato nel disegno. Gli ancoraggi possono essere dimensionati come descritto nella Fig. 22.

Fig. 30

Fig. 31

a) Ribaltamento della facciata principale. I carichi concentrati sono le forze sismiche relative ai solai e possono essere calcolati con il metodo delle aree d'influenza; il carico distribuito rappresenta l'azione simica dovuta al peso proprio della parete

b) Ribaltamento delle murature della tettoia. Il meccanismo di collasso descritto rappresenta il ribaltamento delle murature della tettoia.Il metodo di verifica è lo stesso della Fig. 30

MECCANISMI DEL SECONDO MODO

a) Rottura a taglio.
Il meccanismo di collaso rappresentato nella figura descrive la rottura a taglio e rotazione nel proprio piano della parete di facciata. Tale cinematismo si innesca quando l'azione sismica agisce in direzione parallela alla parete stessa. le azioni sismiche complanari a ciascuna parete vengono schematizzate attraverso l'introduzione di forze orizzontali che, alle diverse quote, devono essere applicate in corrispondenza dei baricentri dei pesi. Il calcolo delle forze sismiche viene effettuato sempre secondo il metodo delle aree d'influenza.

MECCANISMI MISTI

a) Distacco di uno spigolo con rotazione delle murature.
Il meccanismo di collasso descritto nella figura mostra la rottura di una parete sia nel proprio piano che in quello ortogonale. Lo spigolo del fabbricato subisce un distacco e le murature si dividono in più parti ruotando intorno ad assi diversi.

b) Esempio di meccanismo misto.
La figura a lato rappresenta un ulteriore meccanismo di collasso del tipo misto. la muratura in esame si divide in tre parti, due delle quali rimangono nel proprio piano mentre la terza ruota intorno alla base ribaltando verso l'esterno.

Fig. 32

Fig. 33

Fig. 34

Fig. 13. Different parts and damages in one aggregate. From Franceso Doglioni, *Codice di pratica (linee guida) per la progettazione degli interventi di riparazione, miglioramento sismico e restauro dei beni architettonici danneggiati dal terremoto umbro-marchigiano del 1997*, “Il comportamento sismico dell’aggregato”, IUAV - D.S.A., Convenzione 1999.

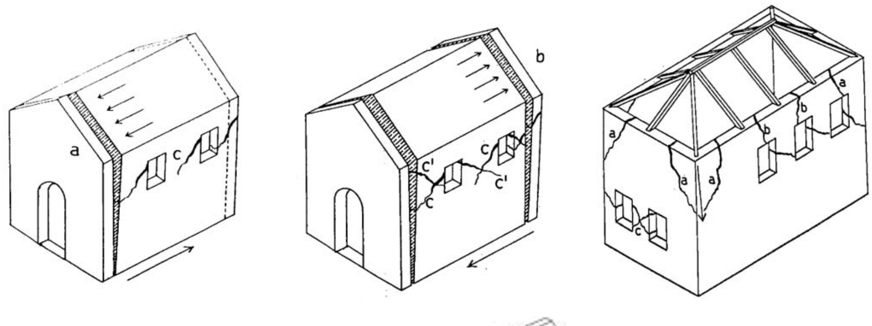


Fig. 14. From Giuseppe Cigni, *Il consolidamento murario. Tecniche d'intervento*, Edizioni Kappa, Roma 1978, pp. 307-309.

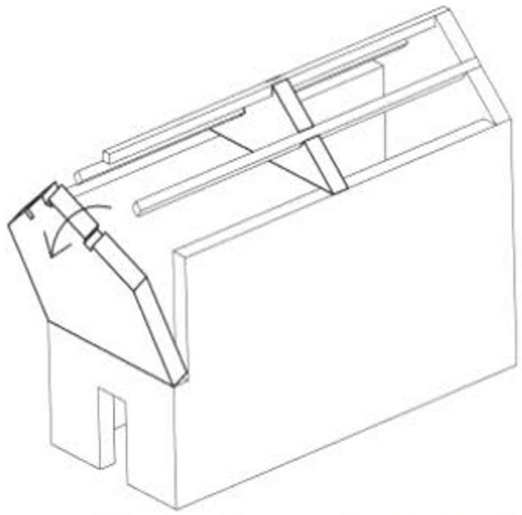
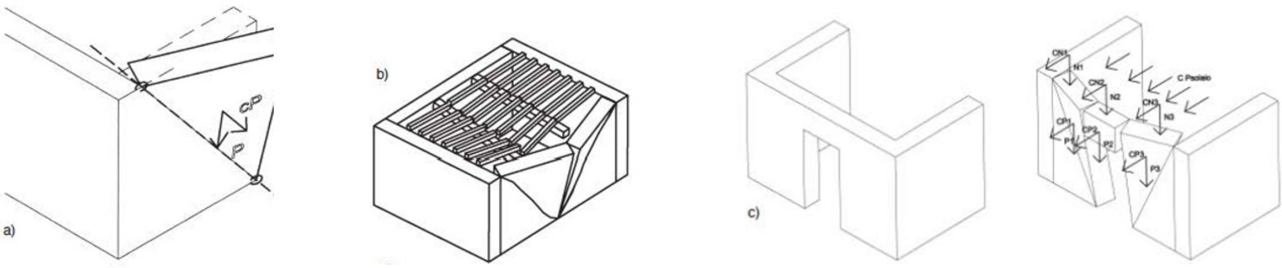
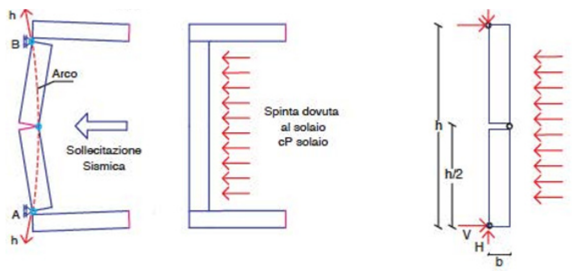


Fig. 15. Tilting of the wall triangles around inclined axes. Tipping of the spandrel in a gable roof. The mechanism occurs when the anchorage between the tympanum and the roof is insufficient or the roof beams are not braced. The beams, without straps or other connecting elements, do not retain the gable. If the masonry does not collapse, it will be damaged at the end of the beams.





a) Overturning of a wall triangle.

b) Breaking through of a wall.

c) Breaking through a wall with an opening.

Fig. 16. Tilting of the wall triangles around inclined axes. From Carlo Blasi, Giuseppe Tosti, *Manuale del restauro architettonico*, Mancosu, Roma 2001, Section D. Cedimento strutturale, metologie di rilievo, 38.

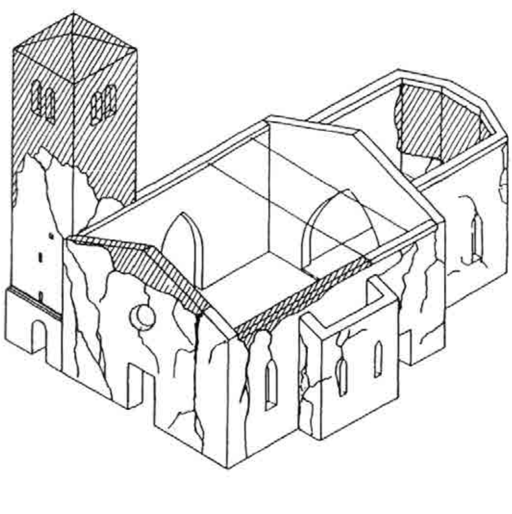


Fig. 17. Axonometry indicating the state of damage. Saint Stefano church in Valeriano, Pordenone (Italy). From F. Doglioni e V. Petrini, *Le chiese e il terremoto*, Lint, Venezia 1994.

NOTES

1) On the decay deterioration, there are numerous references: from the Normal lexicon see ICR (Istituto Centrale del Restauro) *Raccomandazioni Normal, alterazioni lapidei e trattamenti conservativi, proposte per unificazione dei metodi sperimentali di studio e di controllo*, Roma 1988. In Sapienza University of Rome we have applied in some degree and then the microbibliography: *Trattato di restauro architettonico*, ed. CARBONARA G., voll.1-4, Torino 1996; a seguire *Restauro architettonico e impianti*, Torino 2001, 3 voll., *Atlante del Restauro Architettonico*, Torino 2004, 2 tomi, e *Trattato del restauro architettonico, primo aggiornamento, grandi temi di restauro*, Torino 2007, *secondo aggiornamento, grandi temi di restauro*, Torino 2008, *Terzo aggiornamento, grandi temi di restauro*, Torino 2008, *Quarto aggiornamento, grandi temi del restauro, progetti e realizzazioni*, Torino 2011;

   BELLANCA C., *Ascoli Piceno e i suoi monumenti, Primi avvicinamenti e riflessioni attraverso lo studio e le proposte di restauro*, Roma-Ascoli Piceno 1999, BELLANCA C., *Ascoli Piceno, Palazzo Roverella, preliminary reflections through study and restoration of surfaces*, in *Methodical Approach to the restoration of Historic Architecture*, ed. by C. Bellanca, Firenze 2011, pp. 139-145; and from ICOMOS/International Scientific Committee for stone (ISCS), Illustrated *Glossary on Stone Deterioration Patterns, English version*, Monuments ans Sites XV, Champigny/Marne 2008;

2) In these two drawings saws a map of structural tipology with tips of vaults and slabs and the crack patterns, drawings reelaborated by Susana Mora;

3) From ICOMOS, Illustrated Glossary, Ibidem, For a particulary decay also see: NIMIS P.L. PINNA. D., SALVADORI O., *Licheni e Conservazione dei Monumenti*, Bologna 1992;

4) CROCI G., *Conservazione e restauro strutturale dei Beni Architettonici*, Torino 2001;

5) This crack patterns of vaults take parts of the restauration project the designed by Susana Mora for the church of Santa Maria in Villalba del Rey (Cuenca 2000-2009).

CARBONNELL M., *Apport de la metrologie photogrammetrique dans l'analyse geometrique et pathologique des structures anciennes*, in Stable – Unstable?, pp. 167-180.

CEN, Eurocore, *Actions sue les structures. Technical report*, AFNUR, 2005.

FISCHETTI D.C., *Structural investigation of Historic Buildings*, New Jersey 2009.

MILETO C., VEGAS F., CRISTINI V., GARCIA L., *Architectural and archaeological heritage: management and new technologies*, online published e Göttingen 2020.

ROCA P., LOURENZO P.B., GAETANI A., *Construction materials and main structural elements*, in *Historic construction and conservation, materials, systems and damage*, Routledge, New York 2019, pp. 65-136.

CHAPTER 4. DAMAGE MAPS: MOISTURE PROBLEMS

DEFINITION

The survey of humidity, including that deriving from phenomena of rising by capillarity, is generally carried out with the direct method, following the perimeter of the infiltration and leaching zones. Special equipment is available on the market which, supported by the walls, allows us to determine their degree of humidity.

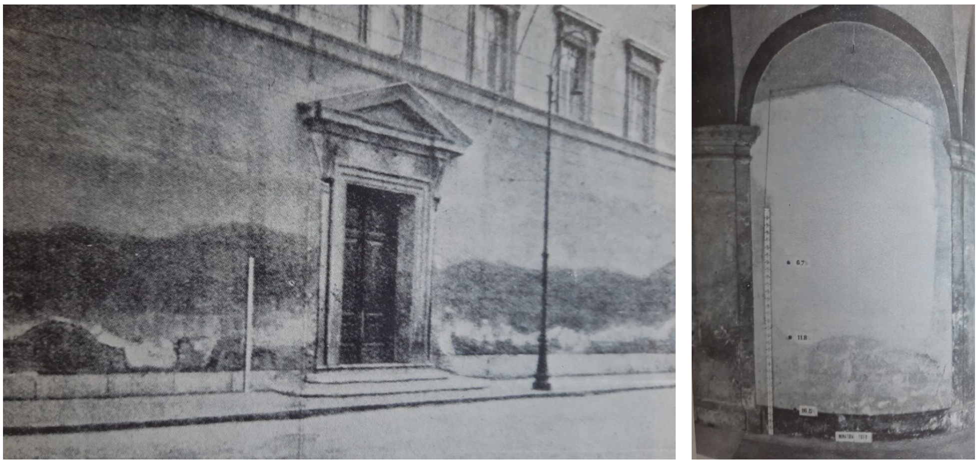


Fig. 1. From Giovanni e Ippolito Massari, *Risanamento igienico dei locali umidi*, Hoepli, Milano 1981, pp. 85-86.

It is essential that, before survey on site, we proceed to identify and perimeter the various areas where moisture is present and classify them depending on whether it is a capillary ascent, washout or infiltration.

The representation of humidity uses symbologies to highlight the different types, as can be seen in the chapter on the representation of the survey.

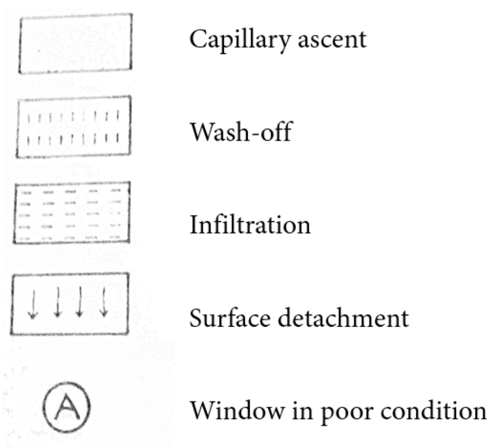
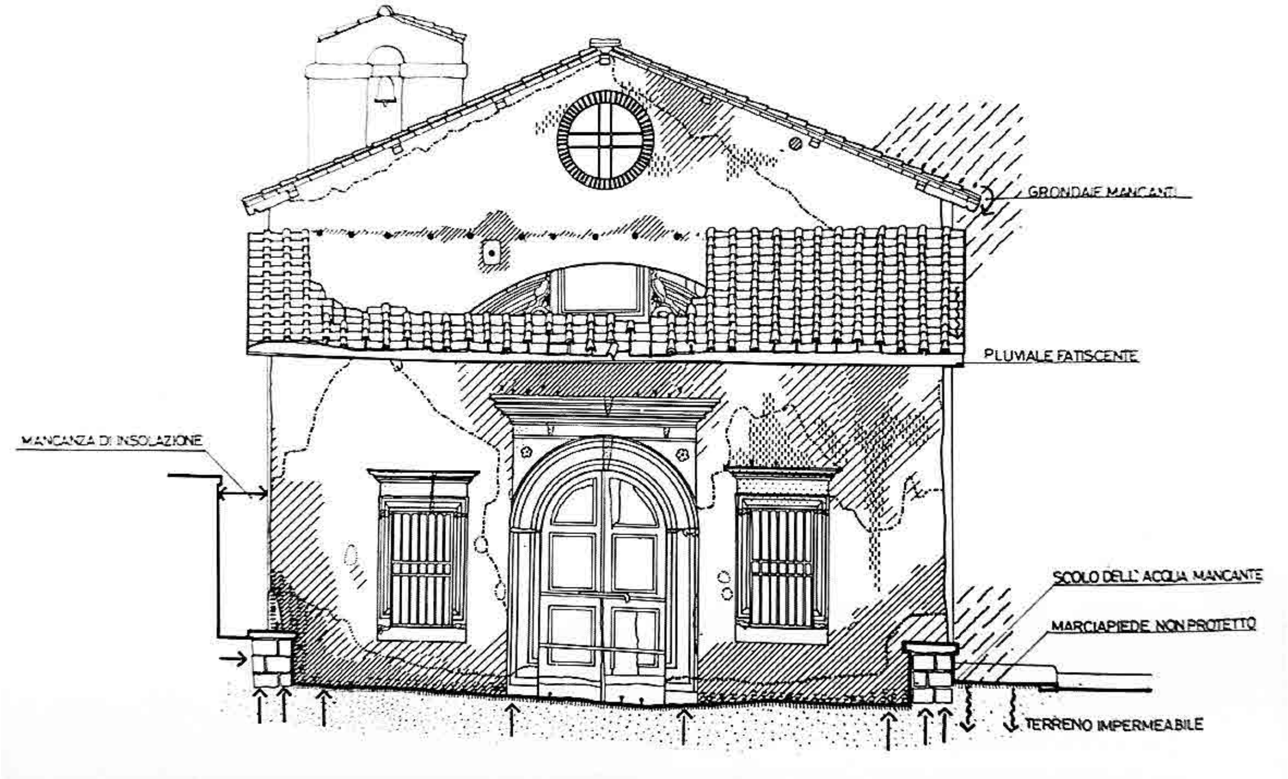


Fig. 2. Representation of Humidity Causes.



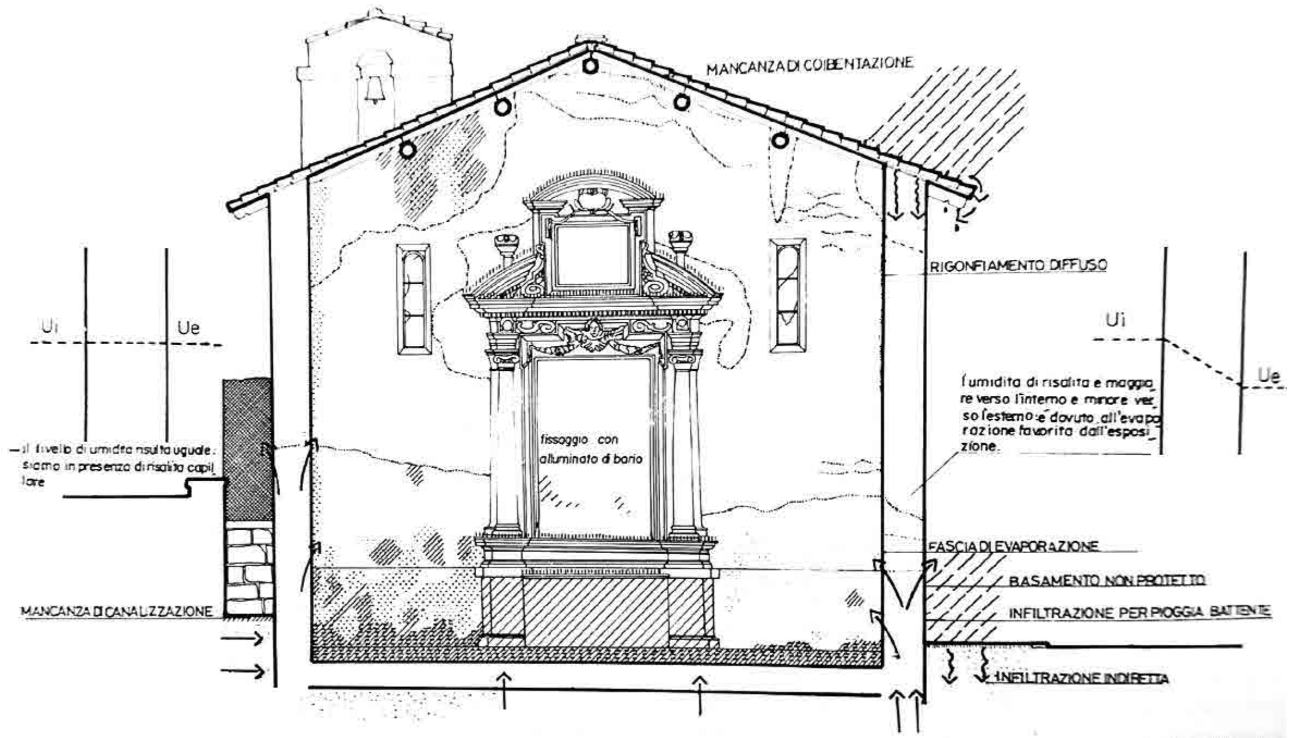


Fig. 3. Chiesa di San Salvatore a Tarquinia. From G. Carbonara, *Trattato di restauro architettonico,* vol. 2, Utet, Torino 1996, p. 571.

CAUSES OF DAMPNESS

1. Penetrating dampness (1)
2. Below ground moisture – capillarity
3. Air moisture condensation
4. Interstitial condensation
5. Superficial condensation
6. Internal plumbing leaks – accidental dampness

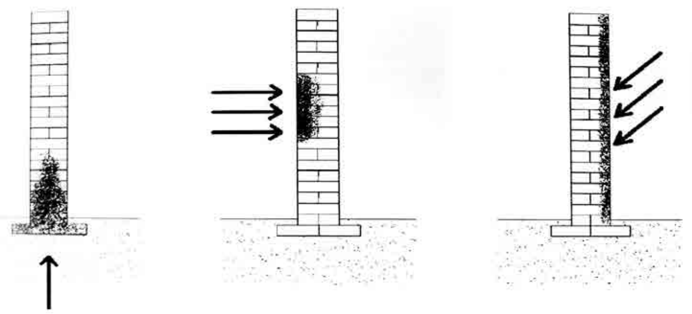


Fig. 4. From Rosa Agliata, Luigi Mollo, CNT-APPS Research Project, p. 53.

1. PENETRATING DAMPNESS

This is the result of the penetration of water from the outside into the enclosure due to rain. The water penetrates the interior or simply fills the surface pores without deepening the element, depending on the porous structure of the material, the water pressure and whether it is combined with wind. Therefore, these humidities can be both internal and external. In general, water can gain access through its porous structure, preferably by holes greater than 0.5 mm. By the presence of cracks or fissures (of capillary constitution), constructive joints, or if the gaps between bricks are not completely filled with mortar due to poor execution of the wall.

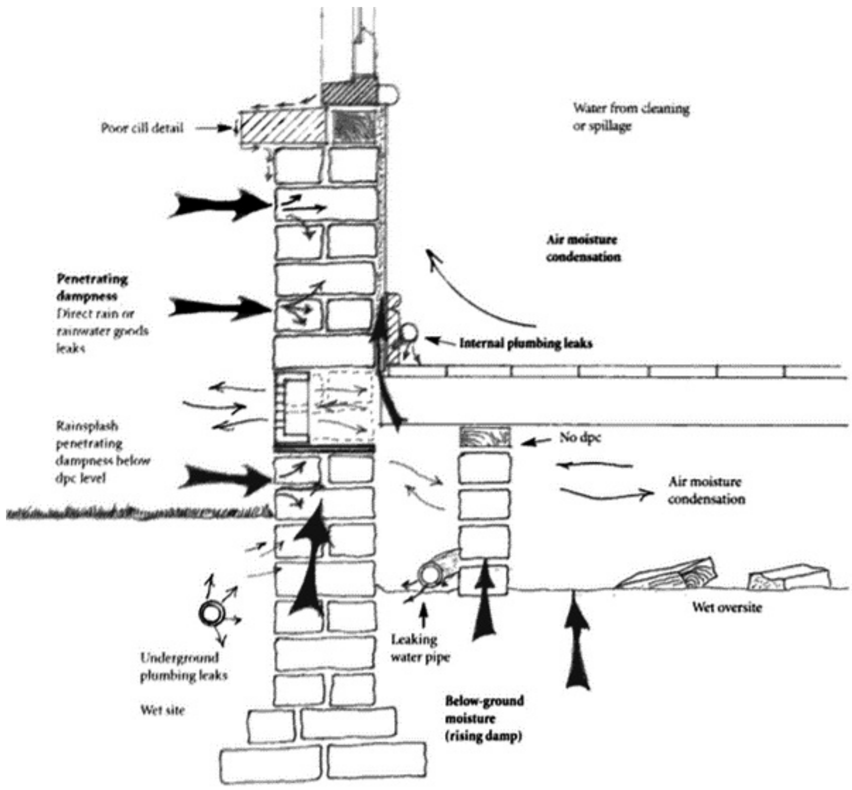


Fig. 5. From Luisella Gelsomino (a cura), *Recupero edilizio 6. Umidità, Tecniche e prodotti per il risanamento*, Alinea Editrice, Bologna 1988, p. 16.

2. BELOW GROUND MOISTURE – CAPILLARITY

When we introduce a tube into water we see how the latter rises. This is because the force of cohesion between their molecules is less than the adhesion of the liquid with the material through which it rises. The water will continue to rise until the surface tension with the tube balances with its weight.

In building, this phenomenon causes water to rise through the pores of the materials that are in contact with the ground.

These humidities can appear because the height of the water table has varied and now the foundation is in contact with the water, or because of the accumulation of water at this point because the slope of pavements or screeds is nonexistent, insufficient or has been deformed, among other causes.

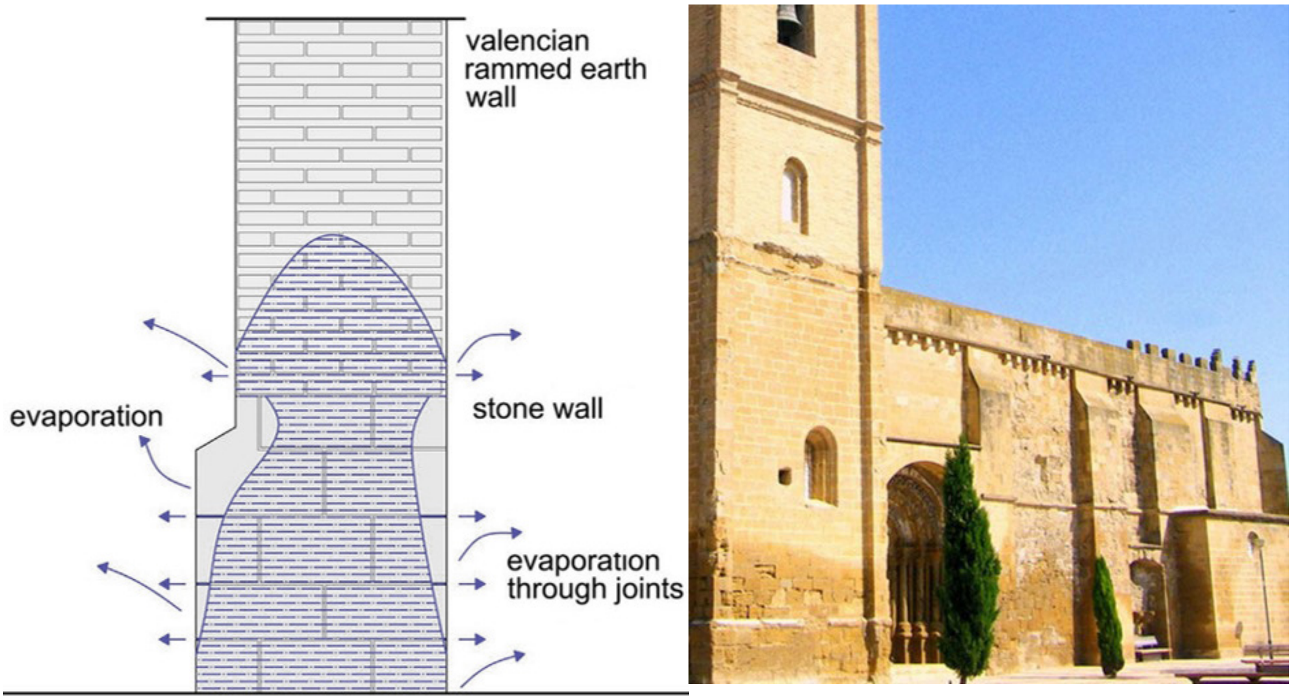


Fig. 6. From DCTA-UPM, *Tratado de rehabilitación*, Munilla-Lería, Madrid 1999, p. 98.

It can be identified because it is located at the base of the enclosure and follows a line more or less parallel to the ground. The height of this line will depend on the material and how the wall is coated.

- Why does it depend on the material? That the liquid rises to a greater or lesser extent is determined mainly by the diameter of the pore of the material of which it is composed. The smaller the radius, the higher the water rises on the element.

- Why does it depend on the coating? It will also depend on how easy it is to have access to the open air, which favors its evaporation. For example, in the case of exposed brick, the water that rises through the wall is able to evaporate earlier, due to its direct contact with the air, than if it were coated.

BELOW GROUND MOISTURE – EFFLORESCENCE

Sometimes the humidity is accompanied by white spots on the surface of the material. This is because the water drains salts from the lime of the foundation, mortar, brick, etc. and upon evaporation, the salts are deposited on the surface. The appropriate thing is to do an essay to know what type of salts are present to give an adequate treatment.
When the crystallization of the salts takes place inside the enclosure, the increase in volume that this phenomenon entails produces the breakage of the material. This phenomenon is called crypto-florescence. [1]

Fig. 7. From DCTA-UPM, *Tratado de rehabilitación*, Munilla-Lería, Madrid 1999, p. 101.

3. AIR MOISTURE CONDENSATION

The humidity of condensation occurs because at a certain moment the enclosure of an enclosure is saturated with water vapor until it reaches the point of condensation, or which the water vapor turns into liquid water. It is usually due to a drop in temperatures.
The vapor will go through the different materials that normally make up the facade and will lose pressure to the outside, but in turn the temperatures will decrease. It may happen that during this process the temperature reaches the dew temperature.
Depending on the point of the path where that temperature is reached, we can distinguish between two types of condensation: superficial and interstitial.

Fig. 8. From DCTA-UPM, *Tratado de rehabilitación*, Munilla-Lería, Madrid 1999, p. 102.

- Surface condensation: it will be characterized because inside the enclosure there will be a high humidity and may be associated with the appearance of fungi. This excess may be caused by the high production of steam in the premises and as a consequence of poor thermal insulation.

- Interstitial condensation: that which, as we have seen, is inside the wall. The manifestation of this type of humidity will be stains on the outside, possibly accompanied by efflorescence, fungus, detachments.

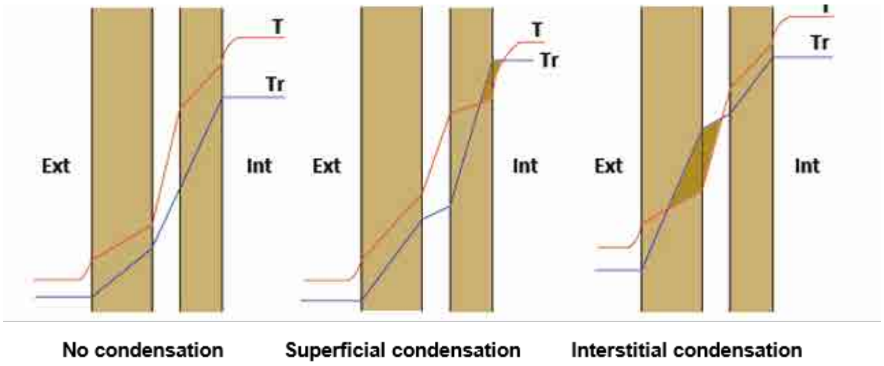


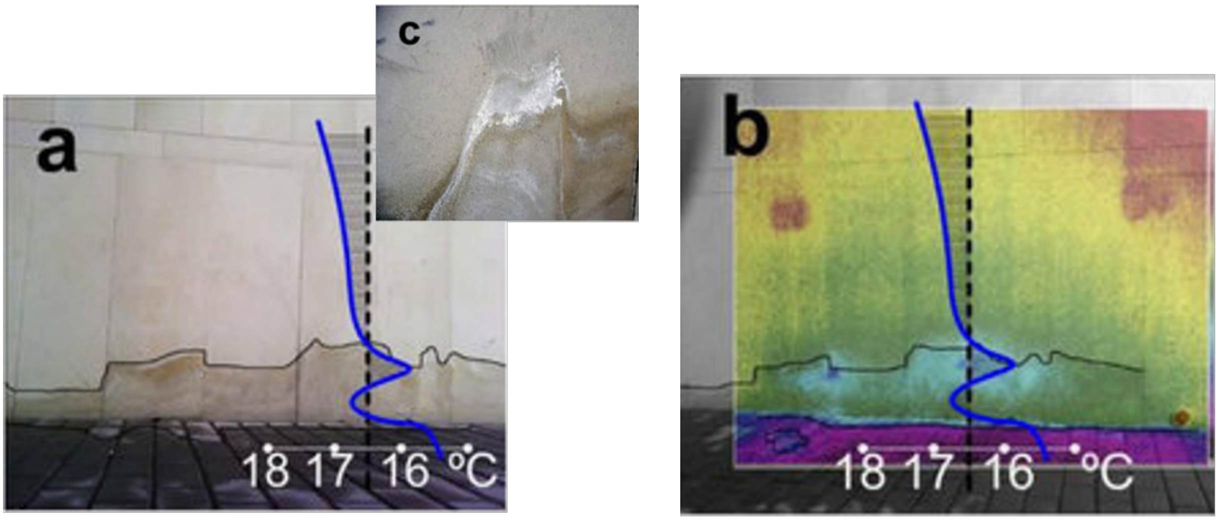
Fig. 9. From DCTA-UPM, *Tratado de rehabilitación*, Munilla-Lería, Madrid 1999, p. 103.

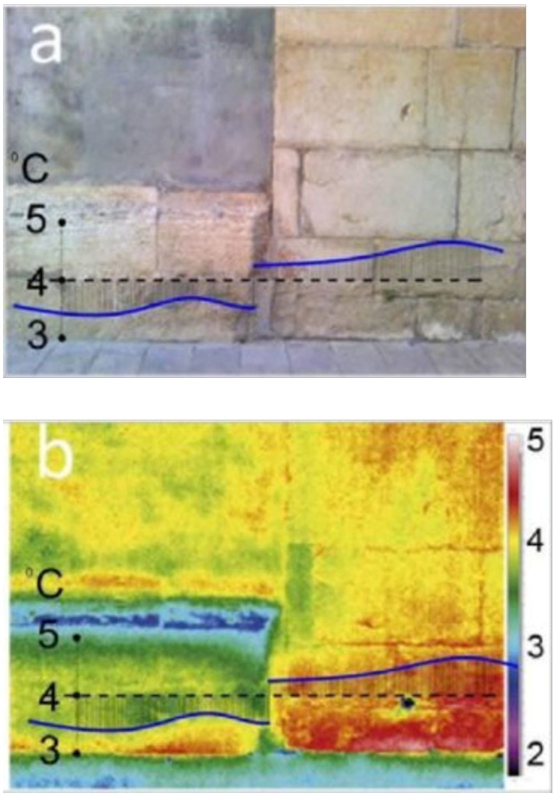
4. ACCIDENTAL

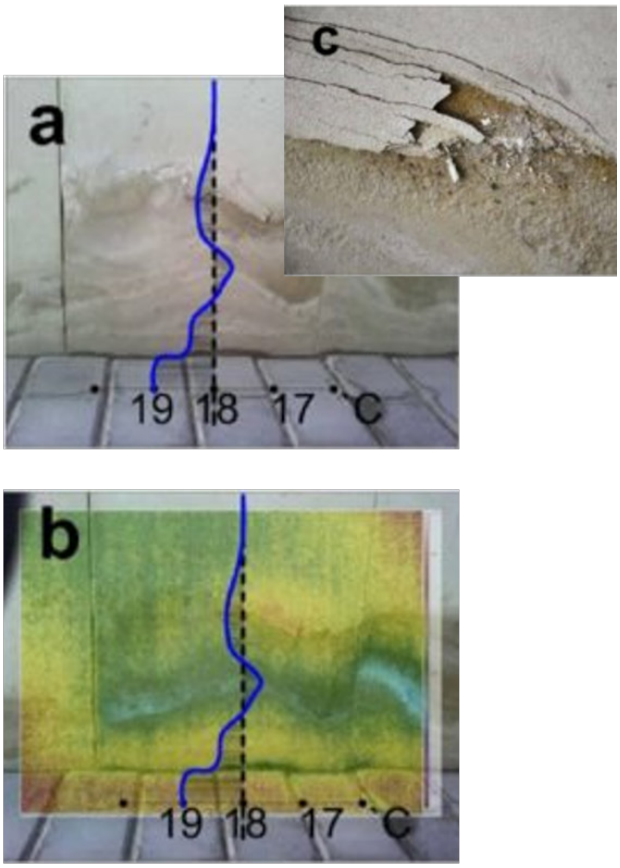
Fig. 10. From DCTA-UPM, *Tratado de rehabilitación*, Munilla-Lería, Madrid 1999, p. 105.

THERMOGRAPHY AND MOISTURE

The use of thermovision chambers makes it possible to carry out a very precise mapping of humidity, by detecting temperature differences in the masonry with this method; by detecting the different temperatures of the humid zones, it is also possible to ascertain the direction of the infiltration, especially in the case of capillary ascent. Moisture survey is usually performed by taking into account that the imaging shutters must be between 1:50 and 1:10. (2)







NOTES

For the thematics relative to the study of Moisture problems, the dampness, we have a long history in many different countries. It is important don't forget… we can see: KNAPEN M. A., *Le problème de la conservation des matériaux, des habitations et des monuments*, "Revue des Entrepreneurs de maconnerie Ciments et beton Armé", Paris, avril-decembre 1925;

MASSARI G., TALENTI M., *Soleggiamento ed umidità dei muri*, In "Annali d'Igiene", 2, gennaio-febbraio 1946; Commissione di studio per l'umidità delle murature, Consiglio Nazionale delle Ricerche, attività svolta nell'anno 1963-64 in La Ricerca Scientifica" vol. IV, 2, Roma maggio 1965, pp. 83-86; MAMILLIAN M., *Le Mouvement de L'eau dans les mur*, "Annales de L'Institut Technique du Batiments et des Travaux Publics", 217, janvier 1966, p. 132. PHILIPPOT P., MORA P., *Technique et conservation des peintures murales*, Reunion mixte de Washington et New York 1965, 17-25 september, PLENDERLEITH H. J. *La conservation des antiquités et des oeuvres d'art*, traduit de l'anglais par Philippot P., Paris 1966. See also ICOMOS, Palais de Chaillot, *Paris Actes du Congres International sur L'umidité des Monuments*, Roma 1967.

1) MASSARI G., *L'umidità nei Monumenti*, Roma 1969, english editions 1971, ID, *Batiments Humides et insalubres, pratique de lur assainissement*, Eyrolles Paris 1971, CIGNI G., *Murature degradate dall'umidità e dall'inquinamento ambientale, protezione e interventi di risanamento*, Roma 1977; MASSARI G.I., *Risanamento Igienico dei Locali umidi*, Milano 1981, and subsequent editions, See also ICR, *Fattori di deterioramento, corso sulla manutenzione dei dipinti murali, mosaici, stucchi*, DIMOS II, Roma 1979; see also MORA P., *Causes of Deteriorations of Mural Paintings*, Roma 1974;

2) To study the causes of dampness and its solutions: AA.VV., a cura di GELSOMINO L., *Recupero Edilizio 6, Umidità, tecniche e prodotti per il risanamento*, Firenze 1988, ROMANELLI F., *L'origine dell'Umidità nella Basilica di San Vitale a Roma*, Roma 2001.

* In Spain, and in other countries, many pubblication in this field uses the definition of Rehabilitation, instead of Restoration.

BSI, *Code of Practice for Protection of structures against water*, British Standard, London 1990.

BURKINSHAW R., PARRETT M.J., *Diagnosis Damp*, AICS Books, Coventry (UK) 2004.

ROCA P., LOURENZO P.B., GAETANI A., *Construction materials and main structural elements*, in *Historic Construction and Conservation. Materials, Systems and Damage*, Routledge, New York 2019, pp. 65-136.

ROCA P., LOURENZO P.B., GAETANI A., *Vaulted, Structures in history and modern structural solutions*, in *Historic Construction and Conservation. Materials, Systems and Damage*, Routledge, New York 2019, pp. 137-200.

CHAPTER 5. DAMAGE TESTS ON MASONRY CONSTRUCTIONS AND SURVEY, MAPS AND TESTS ON WOODEN CONSTRUCTION

INTRODUCTION: THE NECESSITY OF UNDERTAKING TESTS

Following an accurate structural survey and an in-depth and critical historical analysis, it is possible to identify possible extensions, tampering, raised areas, closures and openings in rooms, hidden cavities, shallow or deep lesions, further manifestations of static instability (detachment, rotations, subsidence, sinking, etc.), presence of humidity.

The above cannot always be detected through a simple direct visual examination of the monument by reconstructing the damage or deficiency inside the structures or hidden by the presence of plaster; on the other hand, this type of approach does not always allow to establish with certainty the cause generating the specific phenomenon or the static instability found. As far as the historical-archival analysis is concerned, the limitation may lie in the partial or total lack of documentation, as well as in the difficulties that lie in the temporal reconstruction of the successive construction phases and sometimes overlapping over the centuries.

(1)

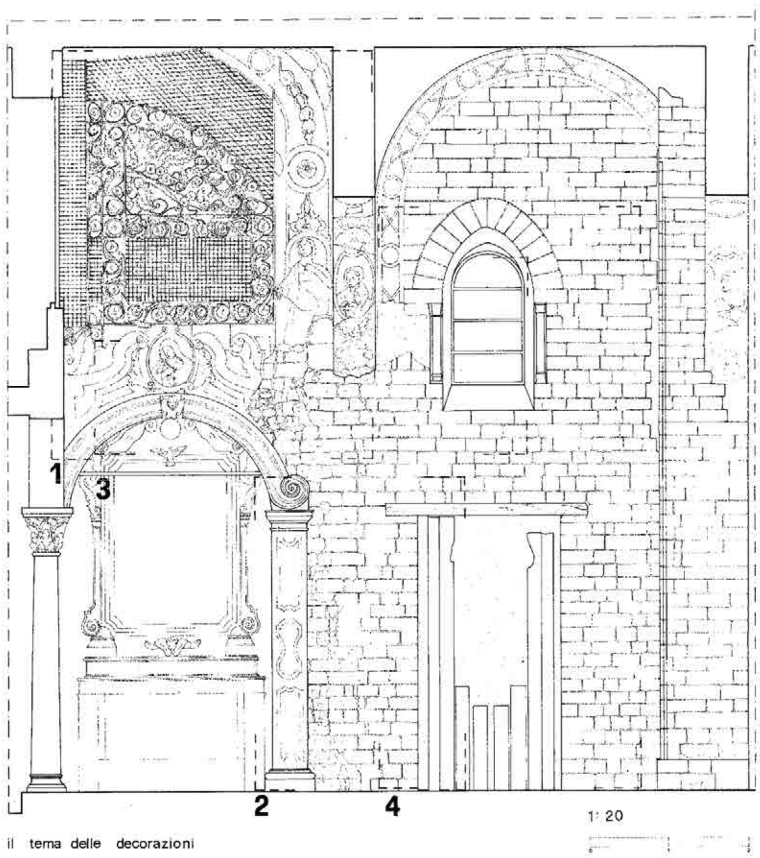
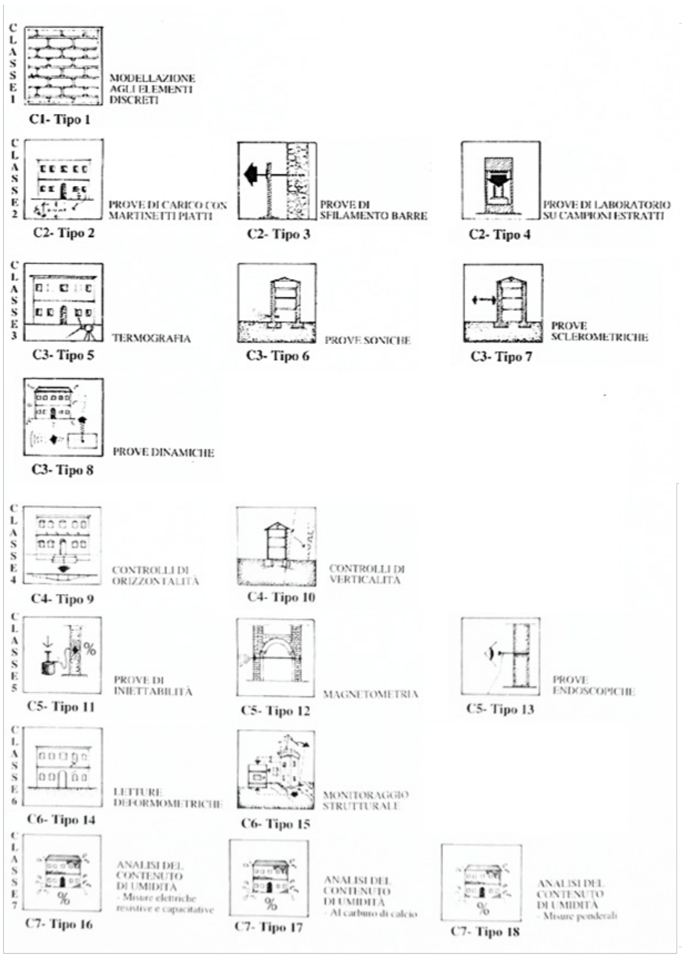


Fig. 1. Church of Santa Maria dell'Ammiraglio 1987. From C. Bellanca (a cura), *Una didattica per il restauro*, Atena Editrice, Roma 2008, p. 60.

STARTING POINT

The starting-point for the planning of the test are the material and mechanical survey and the maps of damage, including the different damage causes (deterioration, mechanical lesions and humidity problems).

MASONRY CONSTRUCTIONS: TEST CLASSIFICATION



Class I	**Theoretical analysis**
type 1	Discrete element modeling
Class II	**Mechanical analysis**
type 2	In situ flat-Jack load test
type 3	In situ bar extraction test
type 4	Sample extraction for laboratory test
Class III	**Quantitative analysis**
type 5	Thermography
type 6	Sonic test
type 7	Sclerometric test
type 8	Dinamic test
Class IV	**Instability verification**
type 9	Horizontality verification
type 10	Verticality verification
Class V	**Elementary tests**
type 11	Instability test
type 12	Magnetometry
type 13	Endoscopic test
Class VI	**Periodic analysis**
type 14	Deformation measure
type 15	Structural monitoring
Class VII	**Humidity content analysis**
type 16	Electric resistence and capacity measure
type 17	Calcium carbide analysis
type 18	Pondering measurement

Fig. 2. Masonry Construction: Test Classification. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 22.

CLASS I: THEORETICAL ANALYSIS

DESCRIPTION

The theoretical analysis with the method of the discrete elements allows to examine systems of structural elements, interacting with each other, without the postulate of the continuity and homogeneity of the constituent material, fundamental assumptions in the analysis of the finite elements, through which the structure is schematised as a continuum composed of a finite number of elements delimited by nodes.

Precisely for this reason, the discrete elements find the most suitable application in the field of masonry composed of blocks of stone or brick and sliding surfaces represented by appeals and mortar joints. Using data from the entire diagnostic campaign to support it, it is also possible to formulate a hypothesis on the behavior of the structure considering the system consisting of a series of bodies in itself whose movements are regulated by the interaction with the neighboring elements.

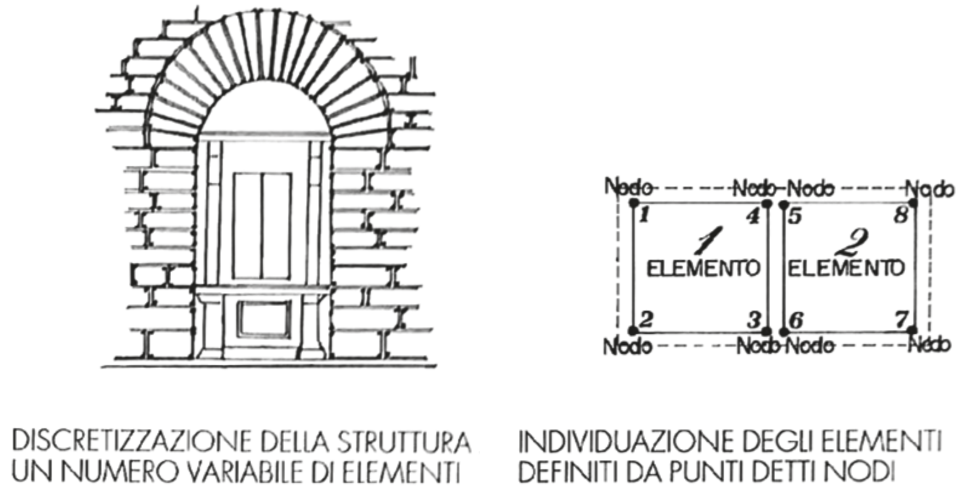


Fig. 3. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 45.

EXECUTION

a) Discretization of the structure into single elements delimited by nodes.

b) Following stress the initial contacts between the elements vary mutually; the elements adjacent to each other at the beginning of the analysis can, following displacements and rotations, lose the previous contacts and develop new ones.

c) Forecasting of loading conditions and analysis, by computer processing, of a static or dynamic type.

d) Graphicization of structures discretized by means of “Plotters” in plants, elevations, sections and axonometries.

e) Elaboration of representative diagrams of normal stresses, bending moments and deformed moments.

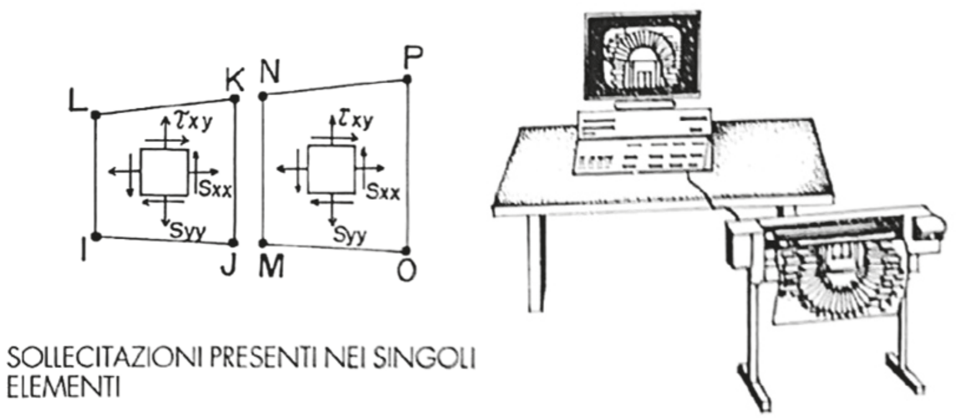


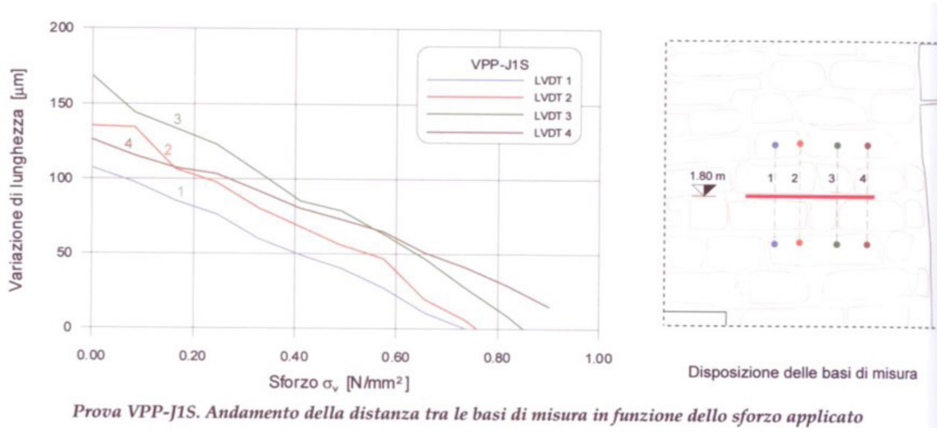
Fig. 4. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 45.

CLASS II: MECHANICAL ANALYSIS
TYPE 2: IN SITU FLAT-JACK LOAD TEST

DESCRIPTION

The load test with flat jacks has the purpose of determining the tensile state of the walls and their elastic modulus. It is of the non-destructive type – with the exception of irregular walls – since the cut is performed in mortar applications and the jack can be easily removed. The test instrumentation is simple and of relatively quick execution. If consolidation operations are carried out, it is also possible to use the jacks, previously installed, as pressure cells, leaving them connected to a pressure gauge, to detect any changes in voltage consequent to the work carried out, always taking into account the influence of temperature variations. By positioning a second jack orthogonal to the first one can determine the shear strength of the masonry, a parameter of considerable importance in seismic areas.

Fig. 5. Reading of the vertical movements with the flat jack inserted in the masonry wall. Hydraulic system connected to the flat jack inserted in the masonry wall. 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

Sforzo corrispondente all'annullamento della variazione di lunghezza tra le singole basi (valori interpolati)

Fig. 6. Single flat jack test results (PP.MM. Laboratory, Politecnico di Milano, prof. L. Binda). From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 208.

EXECUTION

a) Identification of the most representative areas, favouring the lower parts, more loaded, and avoiding wads of doors or windows.

b) Positioning of three pairs of measurement bases and initial reading δO.

c) Execution of a horizontal cut in the normal direction to the surface and of two lateral cuts to allow free transversal expansion; reading δ1 < δO.

d) Insertion of the jack, connection to a hydraulic circuit, gradual increase in pressure; readings at each load level until it returns to the value δO, this load corresponds to the existing original stress.

e) Increase of the load up to the formation of the first lesions, indicative of the breakage of the masonry, and construction of the load movements chart.

f) Determination of the deformability characteristics by means of further deformometric bases in the masonry portion not disturbed by the cut.

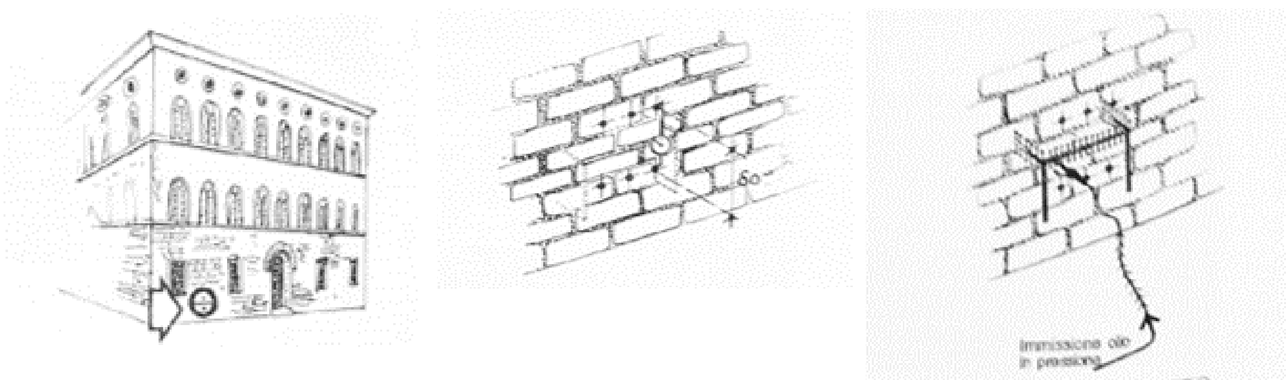


Fig. 7. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 48.

a) Compressive strength test of masonry wall with flat jacks and size of jack.

b) Compartments in the masonry for the two jacks and deformation meter.

c) Extension of the contact surface between jack and masonry wall.

d) Loading-Deformation diagram.

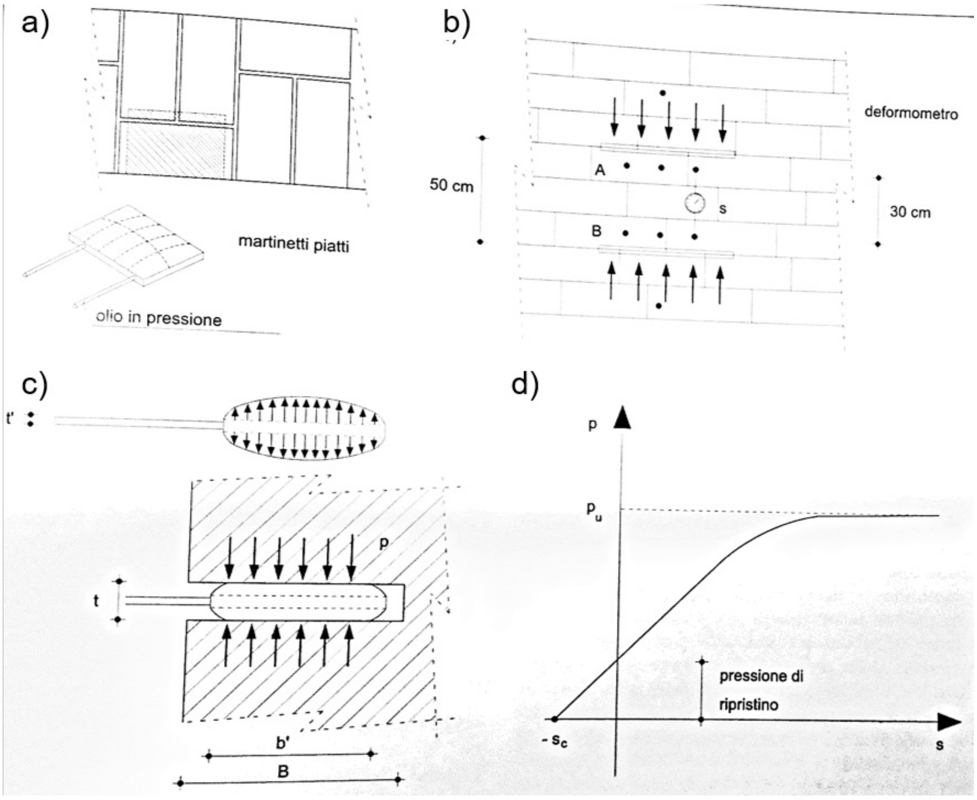


Fig. 8. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 83.

CLASS II: MECHANICAL ANALYSIS
TYPE 3: IN SITU BAR EXTRACTION TEST

DESCRIPTION

The in situ slip test allows for the detection of the limit tangential stresses present in the masonry to be examined. It consists in the tensile stress of a steel bar, previously inserted and anchored in the wall, by means of a jack, with the consequent extraction of a portion of masonry. By measuring the magnitude of the load until it breaks and detecting the surface of the extracted solid, the shear strength of the examined structure is evaluated.

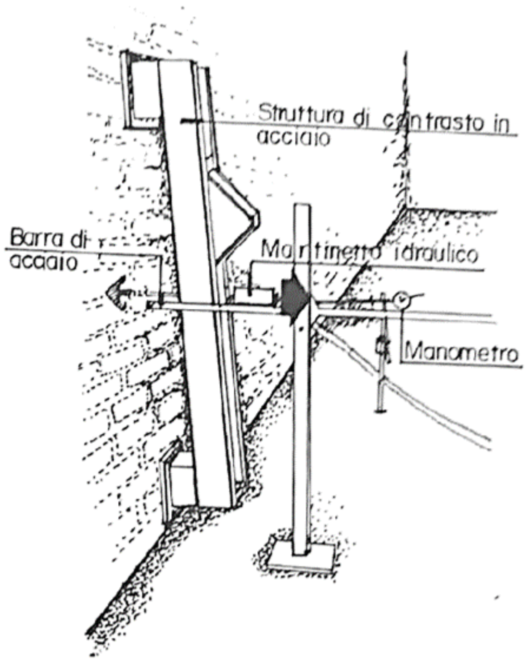


Fig. 9. Load application with hidraulic jack. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 51.

CHARACTERISTICS

This type of methodology allows us to define, together with the compression tests – in situ with flat jacks, in the laboratory on extracted samples – the "breaking domain" of the masonry. the proof allows for the direct verification of the values and is sometimes able to reconstruct very realistic conditions such as anchorages, chains.

EXECUTION

Insertion and anchoring of a steel bar in the wall to be examined.
Applying a steel contrast structure and applying a pulling force by means of a hydraulic jack, driven by a pump, to the steel bar previously inserted.
Measurement of the applied load gradually, until it breaks, by means of a precision manometer inserted in the hydraulic circuit.
Relief of the extracted solid, of conical shape, and determination of the limit tangential tensions.

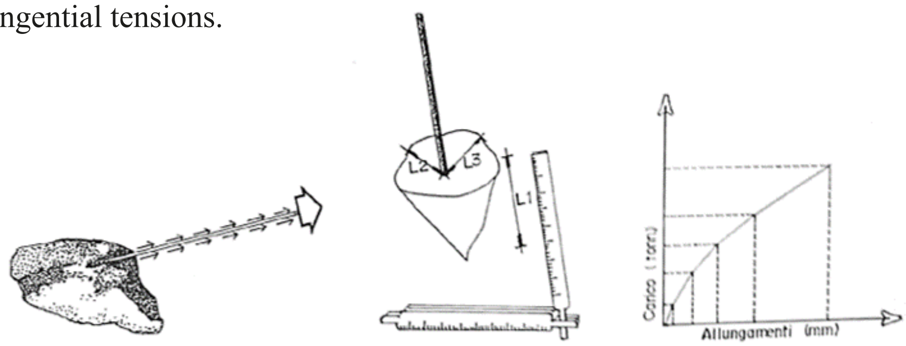


Fig. 10. Load application with hidraulic jack. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 51.

CLASS II: MECHANICAL ANALYSIS
TYPE 4: SAMPLE EXTRACTION FOR LABORATORY TEXT

DESCRIPTION

The execution of direct tests on samples taken on site is of great help in the quantitative evaluation of the mechanical, deformability and resistance characteristics, and of the chemical and physical characteristics of the examined models. It is important to pay attention in extracting the samples and for these to have sufficient dimensions to be sufficiently representative of the behavior of the masonry. The extraction of the specimen must be carried out using suitable instruments so as not to disturb the static equilibrium of the masonry and of the sample itself until its arrival in the laboratory. Once the core removal operation has been completed, the missing portion of masonry will have to be rebuilt, restoring the continuity of the wall with stone elements or bricks similar to those existing with mortar.

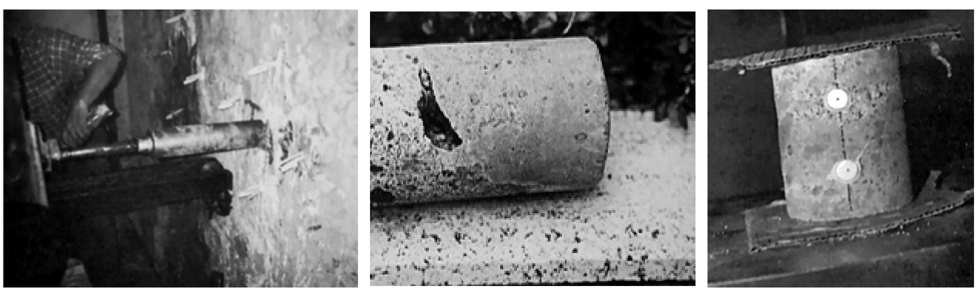


Fig. 11. 1. Sample extraction with rotating tube; 2. Extracted sample; 3. Mono-axial stress test. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 51.

EXECUTION

a) Identification of the most representative areas and extraction of the sample.

b) Conduction of the extracted specimen in the laboratory in order to submit it to:

b1) monoaxial compression test; longitudinal stress; determination of the breaking load and the deformation diagram;

b2) direct cutting test; loading the specimen and its stress in the normal direction increasing the load up to determine the sliding of the upper part with respect to the lower part to define the horizontal displacements according to the constant vertical load;

b3) direct traction test; application of a monoaxial tensile stress to obtain the breaking load;

b4) indirect tensile test; stress, compression in a horizontal direction along two opposed generators and, indirectly, tensile.

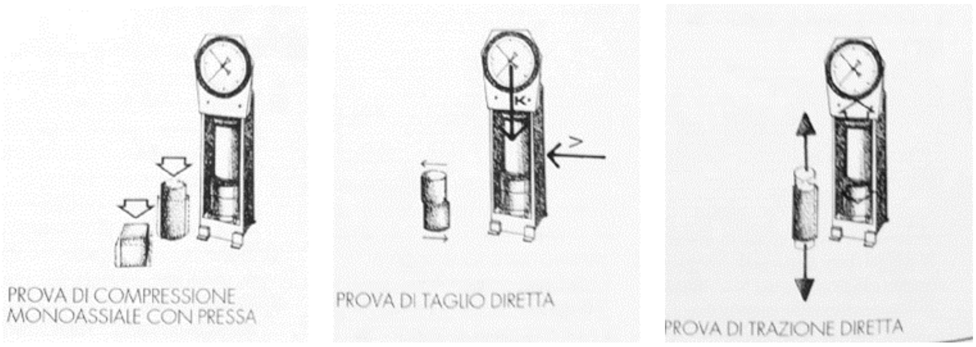


Fig. 12. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 46.

CLASS III: QUANTITATIVE ANALYSIS
TYPE 5: THERMOGRAPHY

DESCRIPTION

The thermographic analysis allows for quick and non-invasive detection of a series of data on structural and construction elements hidden by the presence of plaster. In particular, it makes it possible to identify the presence of: load-bearing structures, reinforced concrete elements, hidden stone elements, flues, voids, infills, tears, detachments, fractures, humidity, etc. The plaster is affected by the differences in temperature between the different materials underlying it and returns them, though attenuating them, to the external surface.

Thermography is essentially based on the ability of a material to retain or transmit heat. Through the detection of the thermal radiation emitted by the hot irradiated bodies it is possible to obtain, through thermographic images, video or photographic, a representative mapping of the materials present.

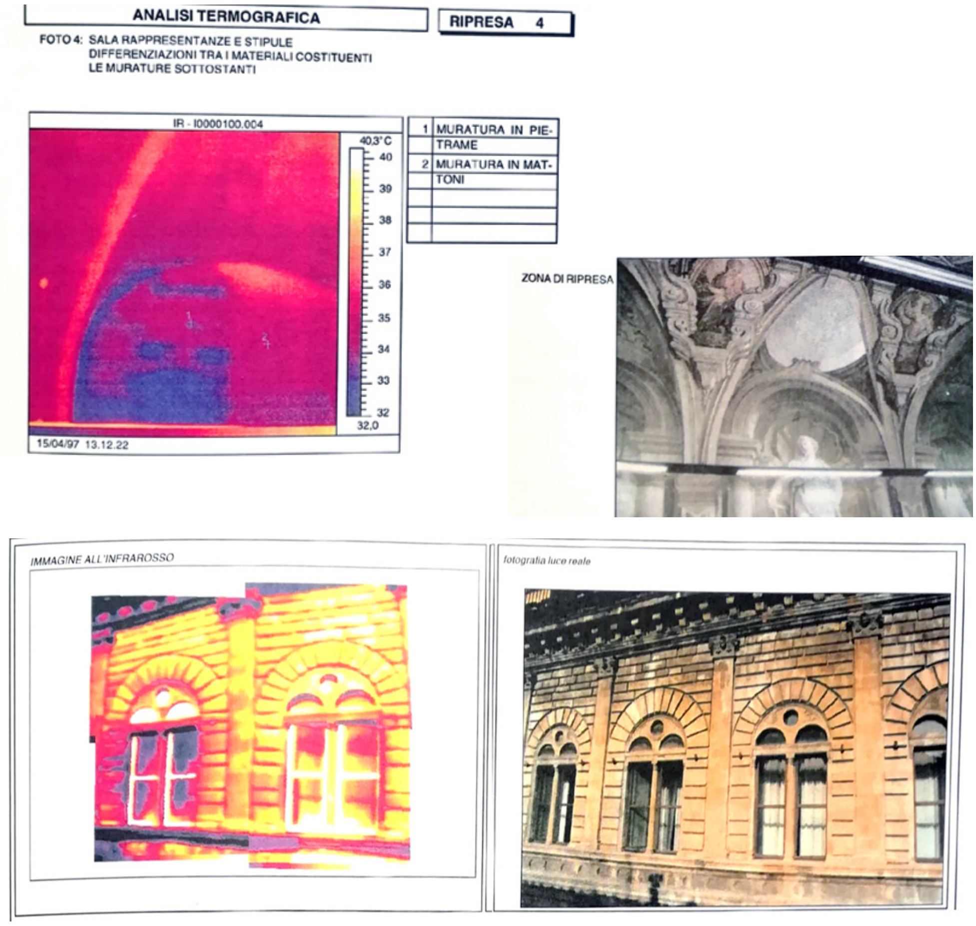


Fig. 13. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 55.

EXECUTION

a) Analysis of the camera-framed surface and transmission of the signal detected to a control unit. It varies according to the infrared radiation emitted by each individual point.
b) The field framed by the objective is divided into lines and focused points with very close intervals by means of a scanning system with rotating optical prisms; each element of the image is associated with an integer that varies from 0 (black) to 255 (white) according to the shade of grey.
c) Formation of an image in different shades of grey where the lighter areas correspond to the points of greatest radiance and therefore of greater temperature.
d) Recording of the digitized images on magnetic tape or photographic printing of the same directly from the monitor.

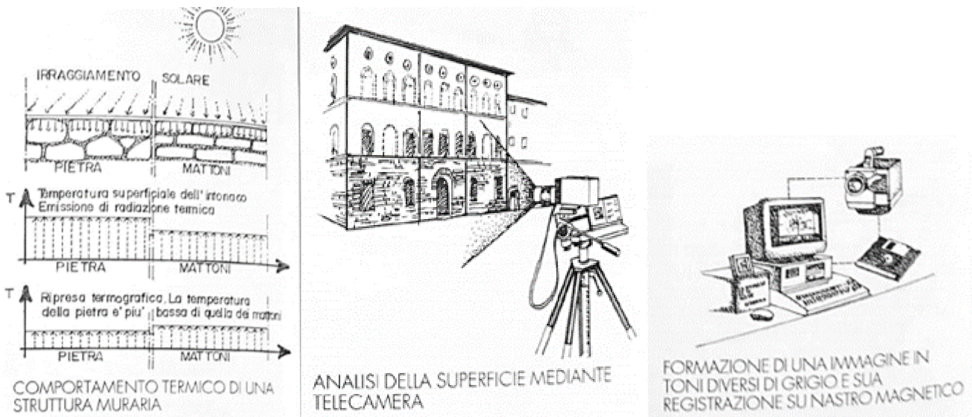


Fig. 14. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 52.

Fig. 15. Thermographic diagnostic. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 54.

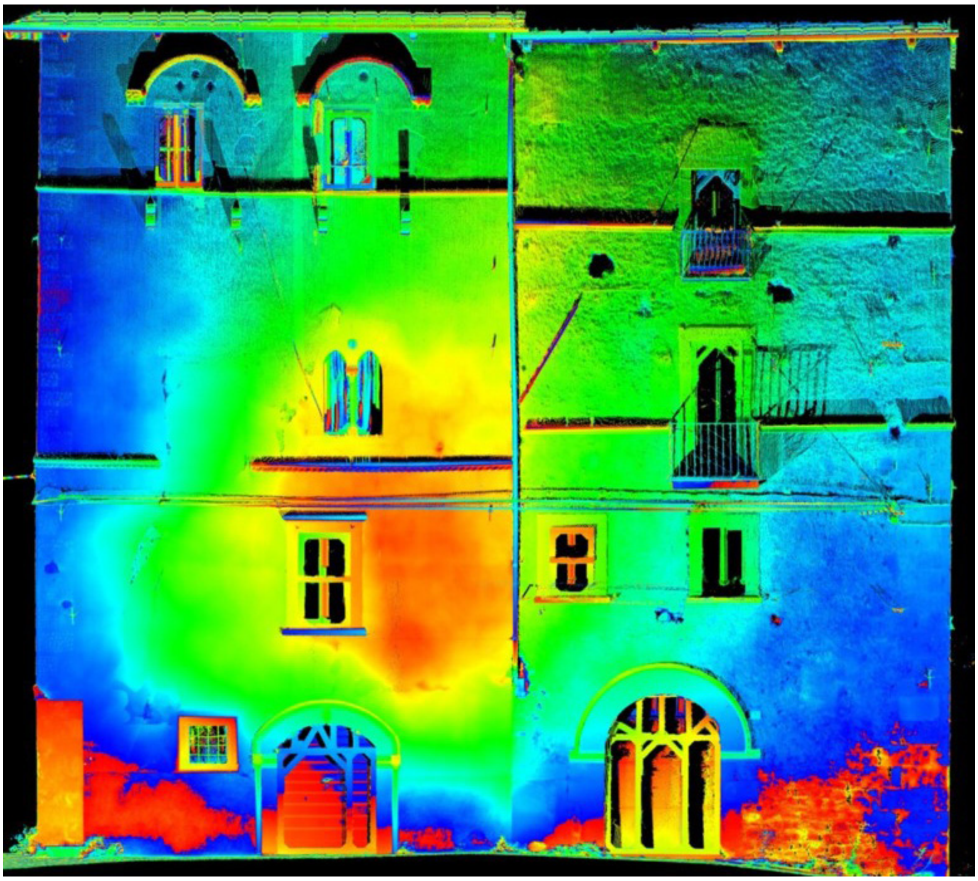


Fig. 16. Thermographic camera images. From F. Doglioni, G. Mirabella, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011.

CLASS III: QUANTITATIVE ANALYSIS
TYPE 6: SONIC TEST

DESCRIPTION

The dynamic auscultation method of a material allows us to determine, in an absolutely non-destructive way and with a good level of precision, the quality as well as the heterogeneity of the medium, be it stone, brick, lumber or concrete. The sonic tests consist in direct measurement of the propagation speed of the sound waves through an element and on the examination of the received signal. The more the material is compact and homogeneous, the greater the propagation speed of the sound impulses, since it does not find any attenuation or interference along its path, deriving from the presence of voids or discontinuities. Sonic investigations basically allow us to verify the distribution of the state of degradation – usually unevenly variable in historical walls – as a completion to the remaining static surveys.

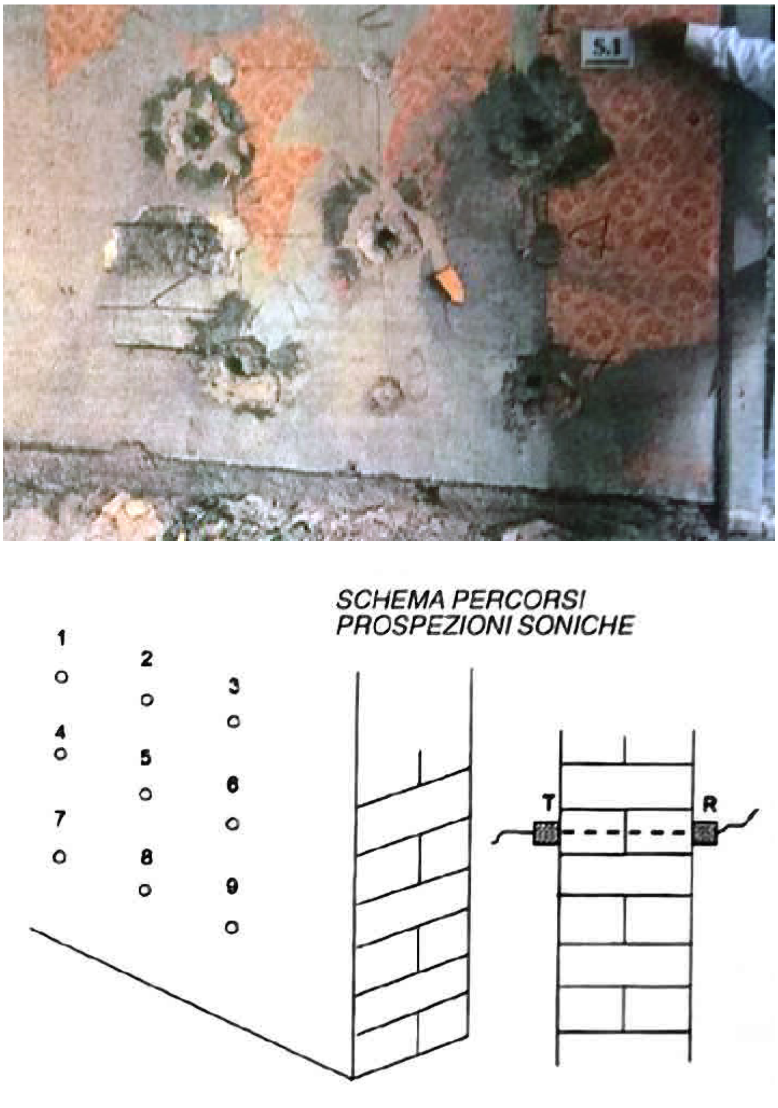


Fig. 17. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 57.

EXECUTION

a) Start of the measurement of time by sending a synchronized acoustic signal emitted by a transmitter placed in contact with the masonry portion to be examined and recording the arrival of the sound wave through a receiver, this in turn sends the signal to the receiver. measuring device that represents it on an oscilloscope.

b) Measurement of the time “t” between the emission and reception and analysis of the following parameters: frequency, amplitude, damping, reflection.

c) Note the distance “d”, path of the acoustic signal, the velocity “V” (V = d/t) is directly proportional to the mechanical qualities of the material.

d) It is possible to carry out three different types of measurements according to the location of the two transducers: on the surface on the same face; radiated on two adjacent faces; for transparency on two opposite sides.

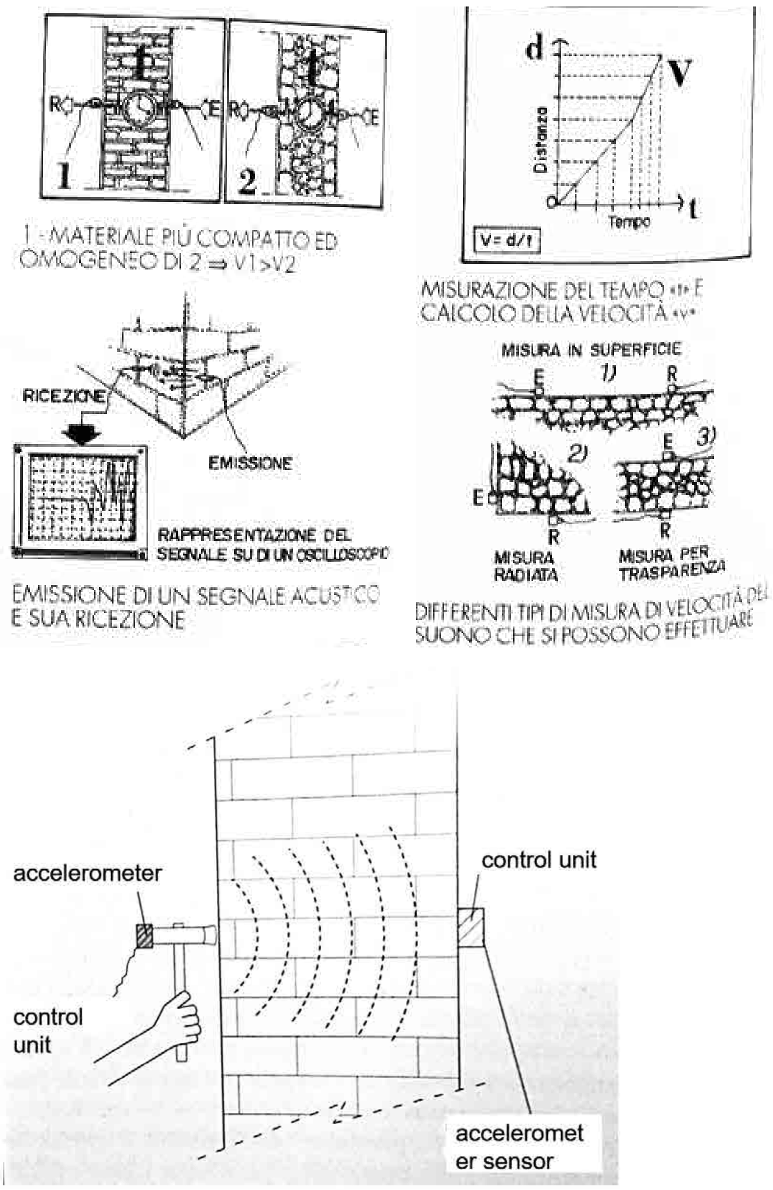


Fig. 18. Text execution. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 56.

CLASS III: QUANTITATIVE ANALYSIS
TYPE 7: SCLEROMETRIC TEST

DESCRIPTION

The sclerometric tests fall into the category of non-destructive tests to be carried out on site for the historical walls, not requiring the extraction of any sample. They consist in the detection of an indirect quantity by means of a special instrument, the sclerometer, defined by the rebound of a hurled flying mass, through a suitable mechanism, on the wall under examination. The parameter thus obtained, the surface hardness of the material, allows for the determination of the maximum breaking strength by compression of the investigated structure.

Fig. 19. Sclerometric test. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999.

EXECUTION

a) Removal of the plaster for a wall portion such as to perform from 5 to 10 beats at increasing pressure on the sclerometer continuously with spring loading; the rod retransmits the reaction to the mass by means of a rebound, the greater the more hard and compact the examined surface is.

b) Reading of the value of the same rebound on the graduated scale from which, through a suitable diagram, according to the chosen stop angle, the corresponding value of the compressive strength is obtained.

c) Average between measures taken by discarding those having a dispersion higher than the average square deviation replacing them with new ones.

d) The instrument can be used both on vertical surfaces and on floors, ceilings, and inclined surfaces. Representing the rebound of gravity uses different curves depending on the different positions or angles.

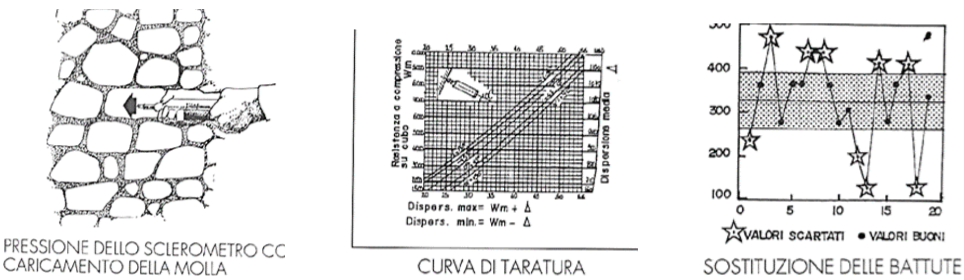


Fig. 20. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 59.

CLASS III: QUANTITATIVE ANALYSIS
TYPE 8: DYNAMIC TEST

DESCRIPTION

Non-destructive investigations conducted by means of dynamic tests are a valid tool for judging and controlling the conservation of the product. These aim to verify directly the stability of the building and to provide an overall evaluation of its dynamic characteristics according to different modalities: survey and analysis of the vibrational disturbances already present on the structure to be examined, of a continuative nature, such as road or rail traffic, or occasional, such as neighboring site activities, bell motions, wind, and low intensity forced vibration tests. Once the behavior of the building has been defined, it will be possible to calculate its structural response against dynamic actions having known characteristics, for example it will be possible to evaluate their real exposure to seismic risk.

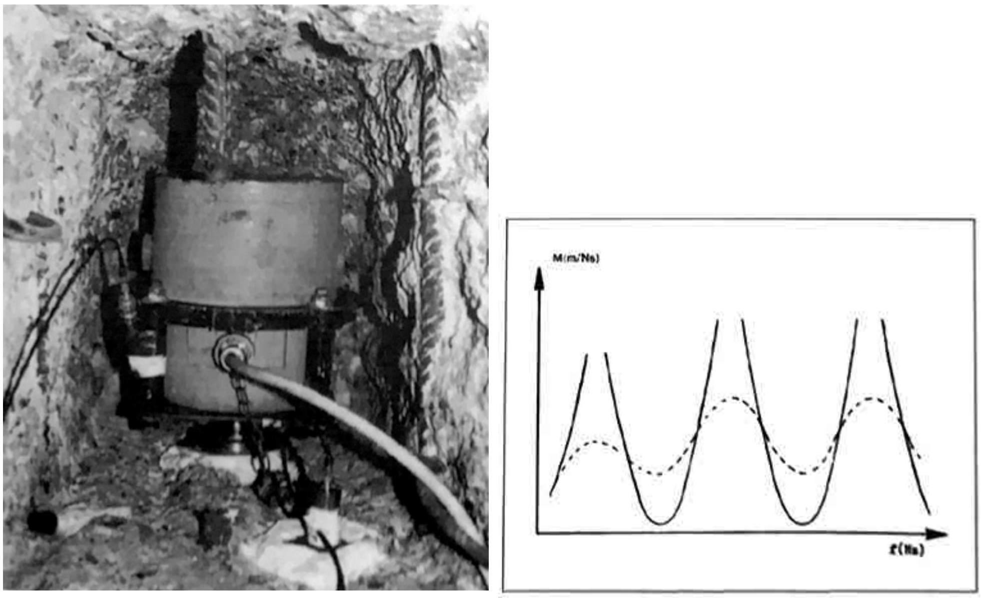


Fig. 21. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 61.

EXECUTION

a) Placement of seismometers at various altitudes located in the selected areas.

b) Possible recourse to an electrodynamic exciter:

b1) subjecting of the elements under analysis to forced dynamic excitation at low intensity, in order not to compromise the integrity of the structure;

b2) repetition of the excitation at regular intervals in two directions, parallel and normal, orthogonal to the plane of arrangement of the investigated structure.

c) Determination of modal parameters, frequencies, modal forms and damping, by means of the measured values and calculation of the dynamic response, in terms of displacements, velocities and accelerations, to the reference spectrum.

d) Interpretation of the response and evaluation of the structural integrity of the complex; possible realization of a finite element model, with proper distribution of masses and constraints.

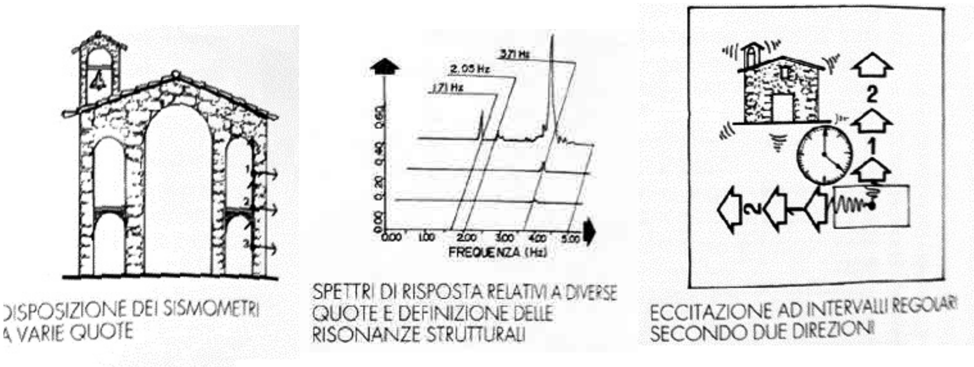


Fig. 22. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 60.

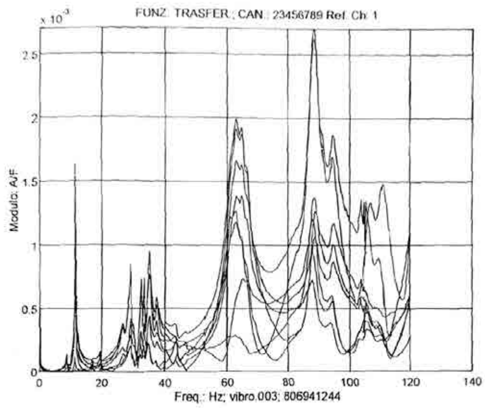


Fig. 23. Curves related to the resonance of a seismometer. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 61.

CLASS IV: INSTABILITY VERIFICATION
TYPE 9: HORIZONTALITY VERIFICATION

DESCRIPTION

A structure is subject in time to changes in its structure induced by static or dynamic phenomena. The former can also be controlled with intervals spaced over time, the latter require continuous measurements. In order to identify altimetric displacements, lowerings or elevations, we perform horizontality checks through the use of optical instruments, levels, and in some special cases, where it is not possible to perform horizontal readings, using tacheometers or theodolites.

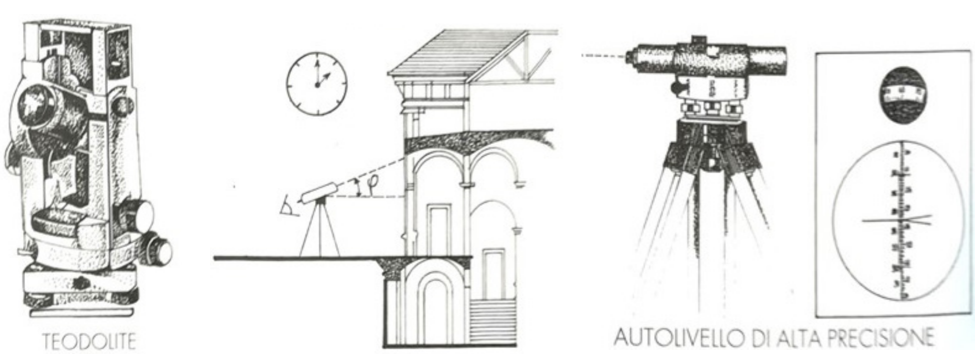


Fig. 24. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 62.

EXECUTION

The horizontality checks can be carried out by:
a) Optical precision measurements carried out with level:

a1) affixing a series of measurement bases, and detecting, at predetermined time intervals, the quotas relative to each base through mobile invariant stages; or by fixed stages if the checks are carried out in a monitored environment;

a2) ascertainment of vertical movements determined by the difference of two readings.

b) Optical measurements with a tilted view with instruments equipped with a vertical circle and distance graticule.

b1) Indirect assessment of vertical movements determined by trigonometrically known angle and inclined distance.

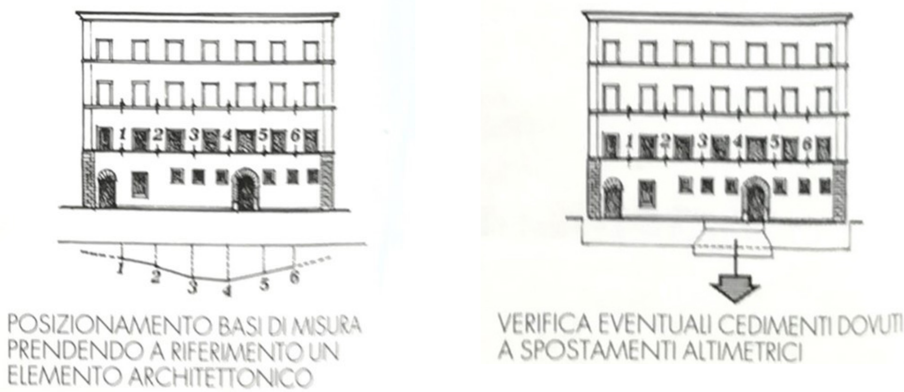


Fig. 25. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 62.

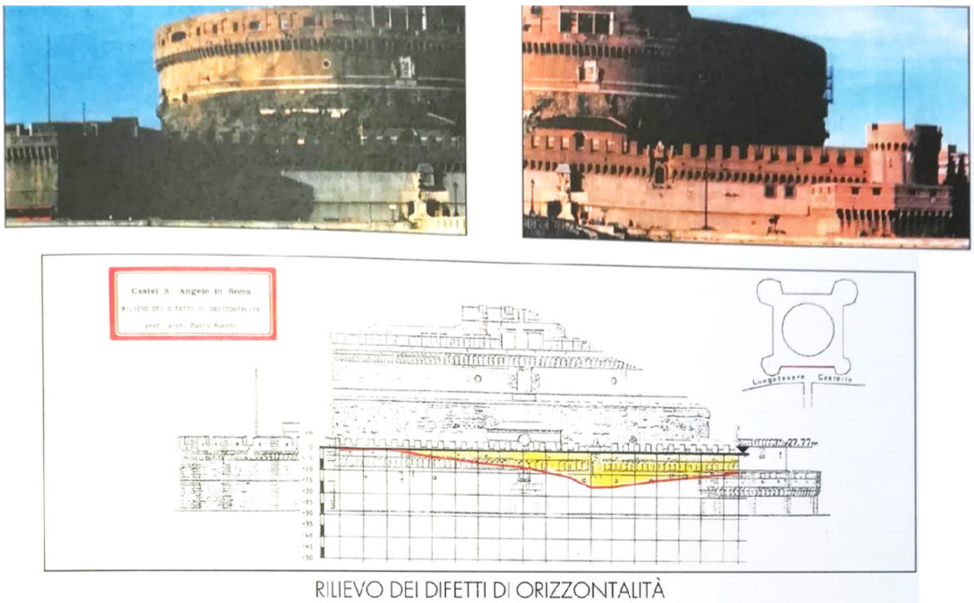


Fig. 26. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, pp. 62-63.

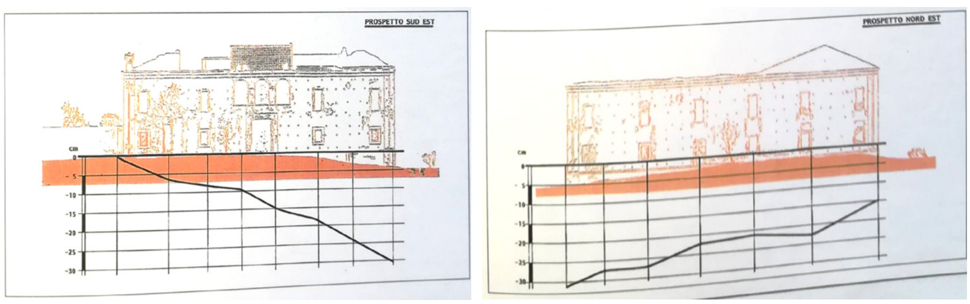


Fig. 27. Instability verification. Horizontality verification. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 63.

CLASS IV: INSTABILITY VERIFICATION
TYPE 10: VERTICALITY VERIFICATION

DESCRIPTION

The vertical controls make it possible to identify the displacements relative to the vertical of some points of the structure to be examined. Through the use of ordinary and rather simple methods such as: plumb line, electric slitter, inclinometer, tachometer, some movements of the structure can be detected: rotations, terminal failures, inflections outside of one's plane. With measures interspersed over time, for periods of typically not less than one year, seasonal variations can also be taken into account, and the evolutionary law of the movements detected can be determined.

Fig. 28. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 65.

EXECUTION

For the detection of vertical defects the following tools can be used: a) Plumb line: positioning of a wire, in a high area of the building, carrying a lead weight at its end. Measurement of the distance between the projection on the ground of the wire and the base of the product itself. b) Electric slitter: Inserting the plumb line in a container containing oil, which stops the oscillations, the lead is connected by means of a horizontal electric transducer to a switchboard which detects its displacements. c) Inclinometer: laying of a series of fixed instruments, positioned at different heights, which indicate their axis offset from the vertical to an automatic data acquisition system. d) Tacheometer: ascertaining horizontal movements determined trigonometrically by known angle and inclined distance.

Fig. 29. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 64.

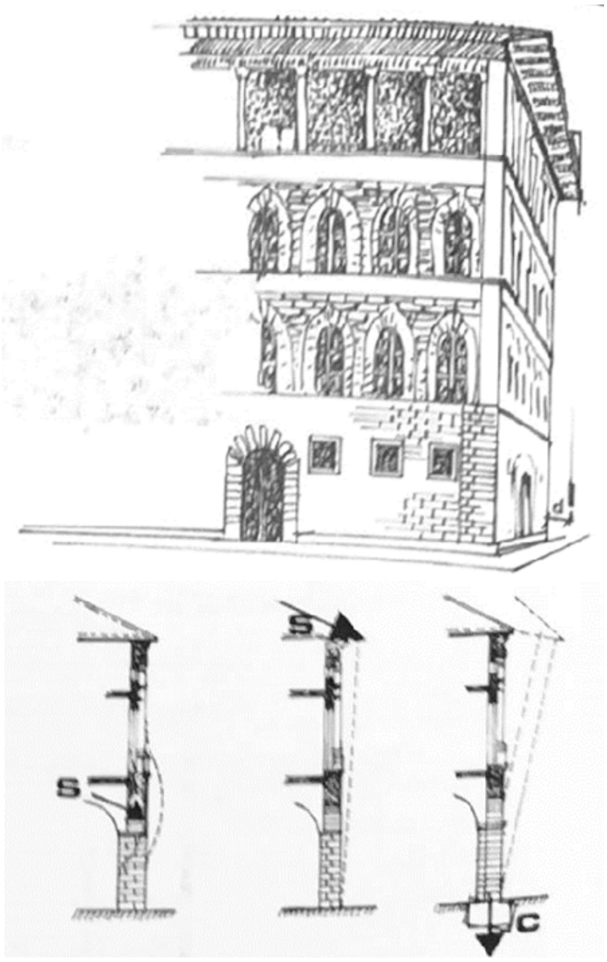


Fig. 30. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 64.

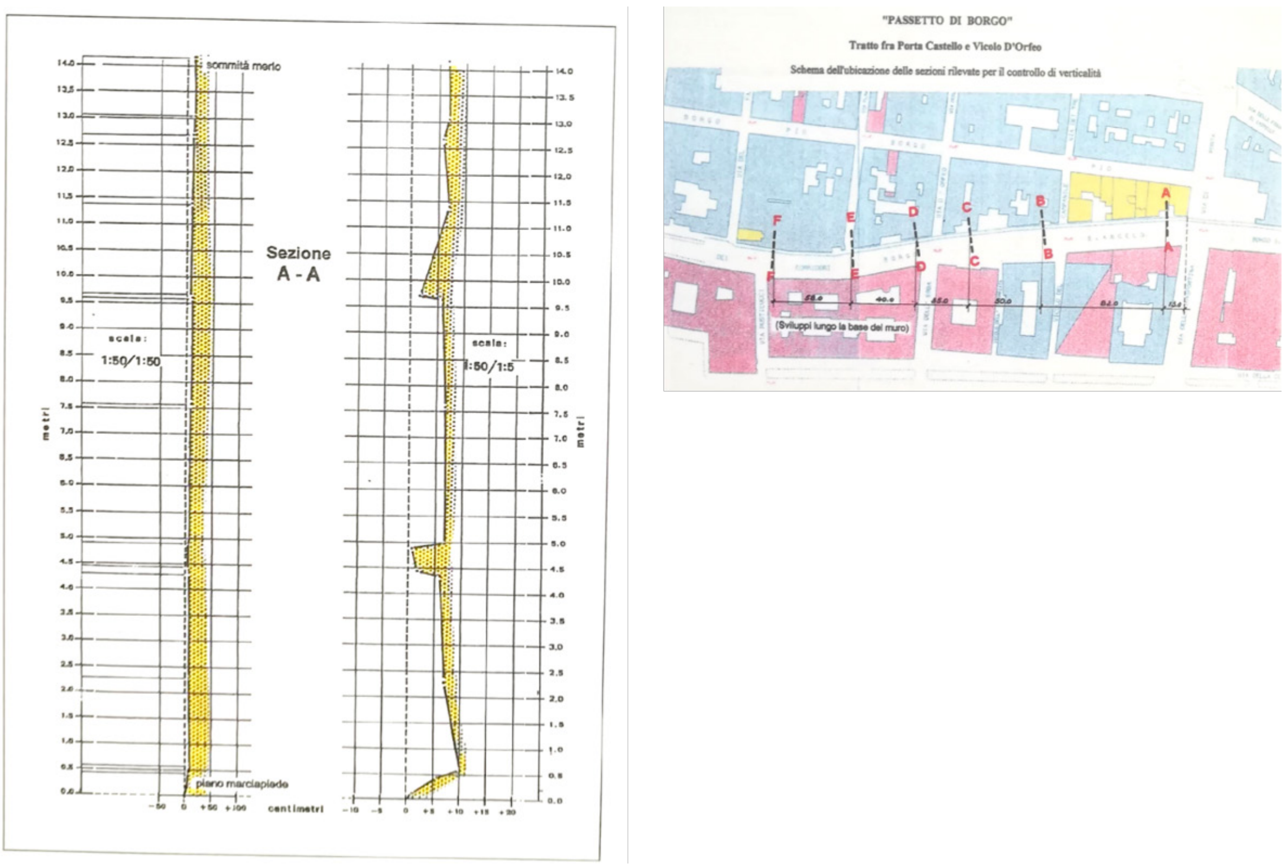


Fig. 31. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 66.

CLASS V: ELEMENTARY TESTS
TYPE 11: INJECTABILITY TEST

DESCRIPTION

The injectability tests allow a priori assessment of the preparation of the masonry towards the regeneration technique, that is the level of absorption of the mixture and the consequent effectiveness that is achieved. They also allow for the calibration of the input parameters by determining: pumping pressure and time, hole spacing, optimal proportion of the individual water components, binders, possible additives. The methods of execution are consequently variable according to the type of wall and its state of conservation. The described diagnostic method allows us to verify, through a comparison of the results obtained before and after the execution of the reclamation intervention, the effectiveness of the mixture injections performed.

EXECUTION

a) Execution of a series of small diameter perforations, having a depth equal to about 2/3 of the wall thickness, at predetermined distances by successive approximations.

b) Insertion in the prepared holes of tubes for the introduction of the mixture and their sealing. Subsequent wetting several times until saturation.

c) Pumping of the mixture into the masonry through the appropriate tubes.

d) Detection of the quantities absorbed according to the different pressures, interaxes, and the composition of the mixtures. Possible removal of masonry specimens, so as to be able to control the mechanical resistance in the laboratory.

e) Determination of the optimal dosages of the components of the mixture and of the injection methods for the execution of the wall regeneration intervention, in relation to the values obtained.

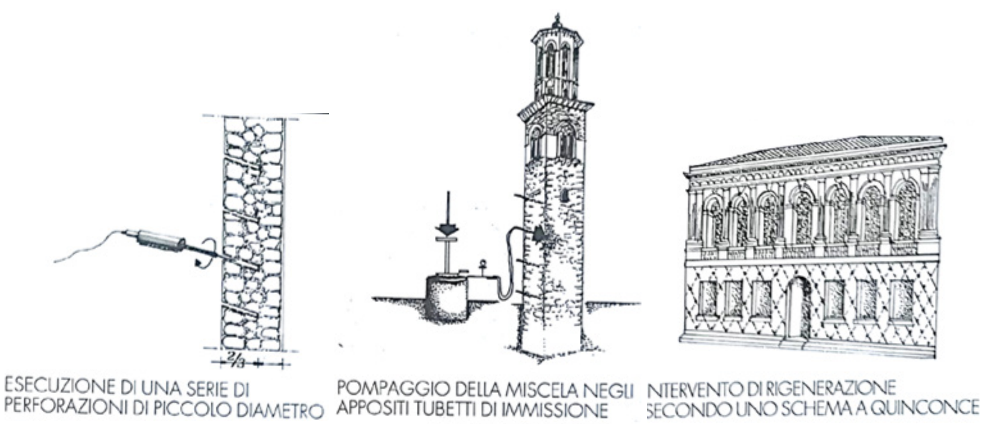


Fig. 32. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 67.

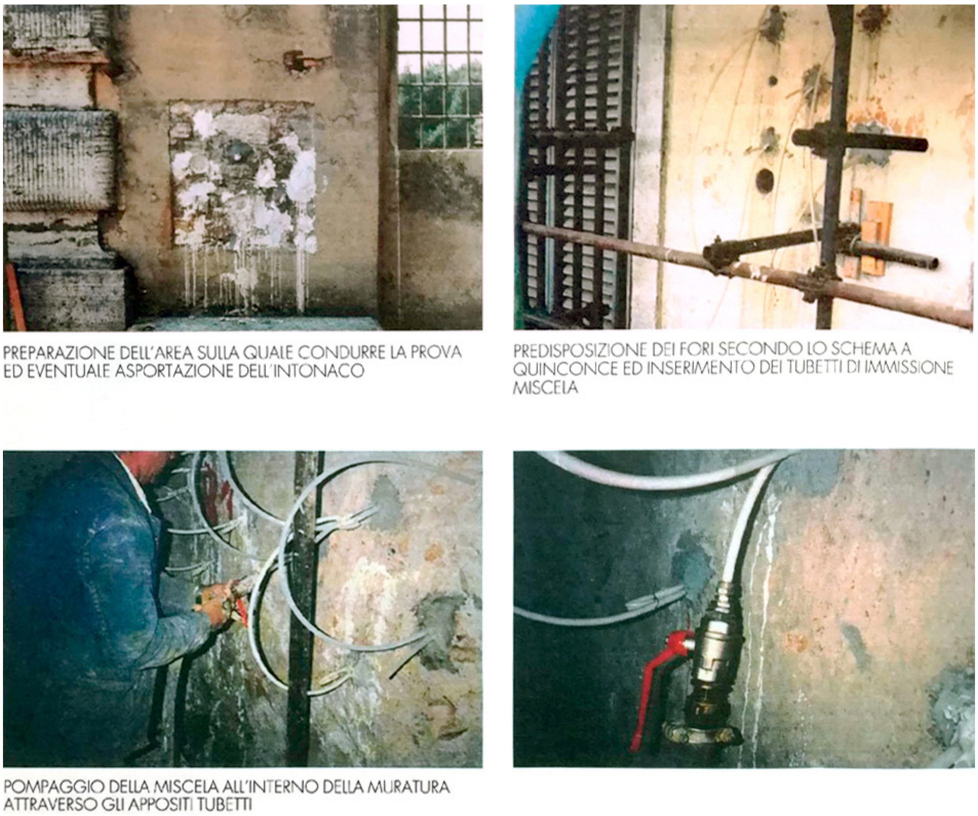


Fig. 33. Elementary tests. Injectability tests. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 68.

CLASS V: ELEMENTARY TESTS
TYPE 12: MAGNETOMETRY

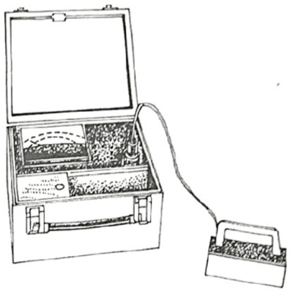
DESCRIPTION

The magnetometry technique has the purpose of determining the presence of metallic elements hidden inside the walls, by means of a special detection instrument, without causing any damage to the integrity of the walls itself. The pachymeter, a transistorized portable device powered by a low-voltage battery, is used to conduct the test. Generally the described investigation is used to locate and identify the reinforcement in the context of non-destructive tests on concrete. The precision instrument is able to localize the depth of the reinforcement on site, or to determine its diameter. However, the investigation can be applied with good results to masonry buildings if you want to locate capes of metal rods hidden by the external covering, wall covering or plaster, or pipes, pipes, slabs, etc.

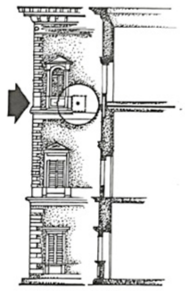
EXECUTION

a) Definition of the areas to be investigated, in which metallic elements are presumed to be hidden.

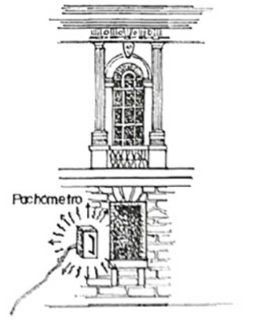
b) Positioning of the instrument against the structure to be examined and detection of the depth indicated by the index of the instrument calibrated in centimetres. The instrument locates and identifies reinforcements up to 200 mm deep.



PACHOMETRO - APPARECCHIO PORTATILE TRANSISTORIZZATO ALIMENTATO A BATTERIA



DETERMINAZIONE DELLE ZONE DA INDAGARE OVE SI PENSA POSSANO CELARSI ELEMENTI METALLICI

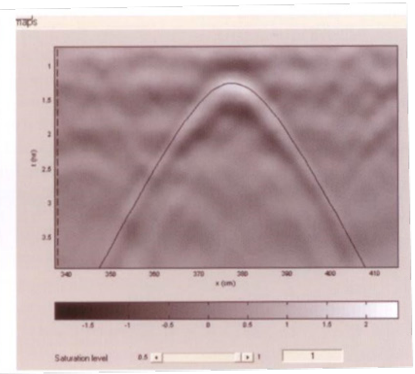


POSIZIONAMENTO DELLO STRUMENTO CONTRO LA PARETE DA ESAMINARE

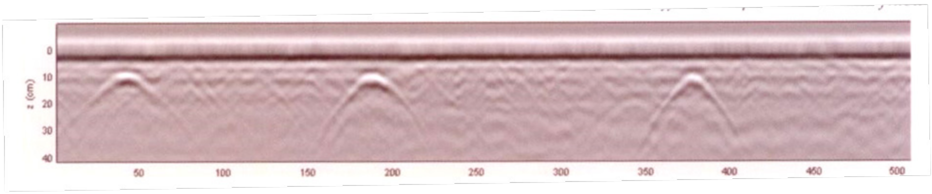
Fig. 34. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 69.

- Indagine geoRadar

Execution of surveys on the 2nd floor of Palazzo Pisani through GPR with 2 Ghz antenna with double polarity.



Elaboration of a radar trace: speed analysis conducted on the diffraction produced by a fiuba.



Example of processed data in which 3 diffractions are observed. The vertex position identifies the distance and depth of the metal element that produced it.

Fig. 35. Elementary tests. Magnetometry. GeoRadar surveys at Palazzo Pisani in Venice (Italy) (PP.MM. Laboratory, Politecnico di Milano) From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011.

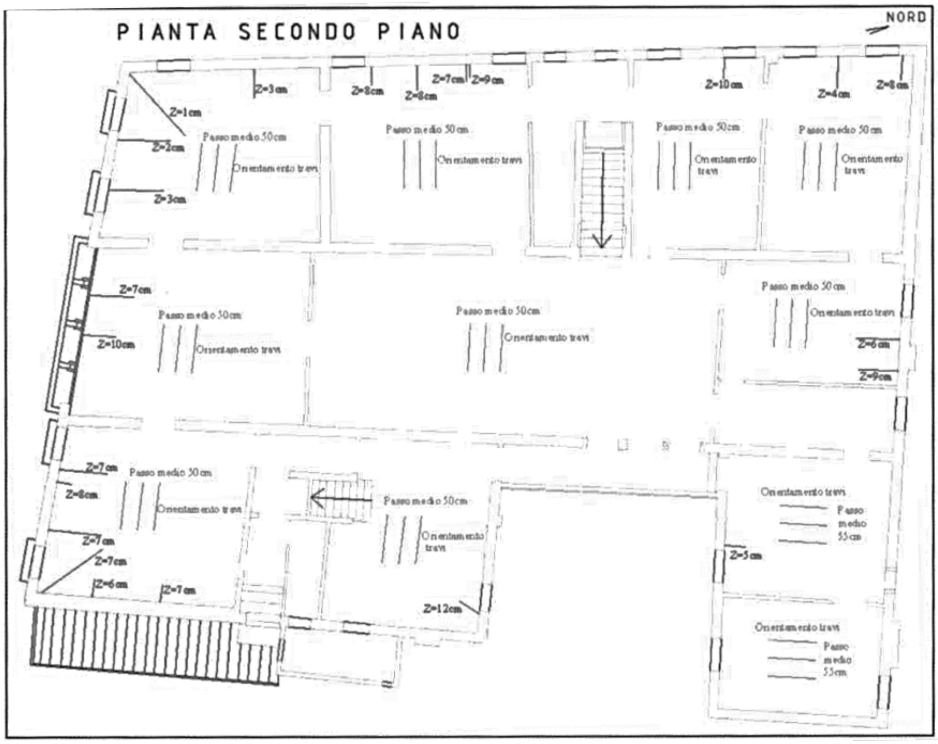


Fig. 36. GeoRadar surveys at Palazzo Pisani in Venice (Italy) (PP.MM. Laboratory, Politecnico di Milano) From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011, p. 211.

Location of the "fiube", not visible from the outside, and orientation of the beams of the second floor at Palazzo Pisani. The orientation consistent with that expected, which varies only in the north-east wing, can be observed.

CLASS V: ELEMENTARY TESTS
TYPE 13: ENDOSCOPIC TEST

DESCRIPTION

The tests consist of the direct visual examination within the building body in order to identify: construction types, morphological variations, discontinuities between the masonry walls, presence of internal cavities, detachments and lesions, efficiency of mortar joints and state of conservation of the same. The endoscopic examination allows us to evaluate the internal conformation of areas not reachable otherwise, carrying out an in-depth visual examination with the help of particular optical instruments employing two or more lenses. Generally, they use rigid endoscopes with a front view, consisting of a rigid metal casing provided at one end with a objective lens and at the other with an eyepiece, connected to a camera. The endoscopic investigation in the field of elementary tests is totally reliable, based essentially on the direct vision of the structure.

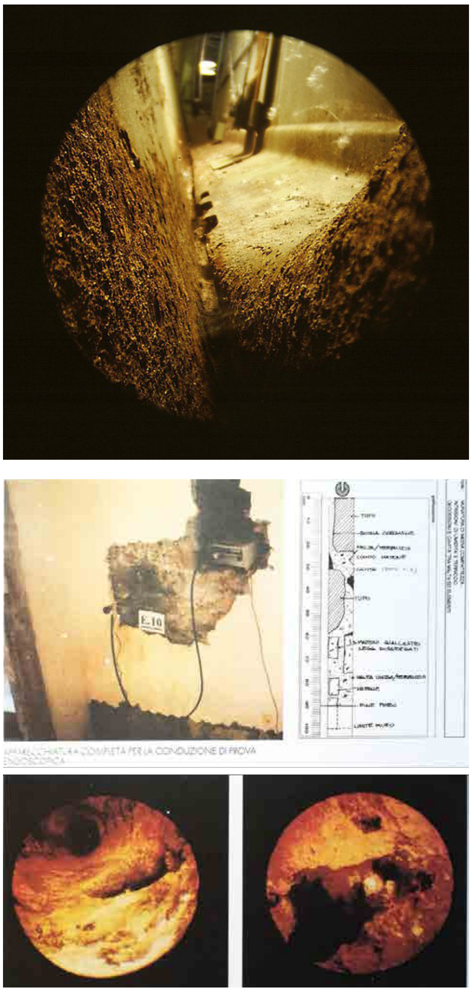


Fig. 37. Observation of non accesible areas by means of a camera. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 71.

EXECUTION

a) Execution of a passing inspection hole, having a diameter equal to 30-40 mm, by coring performed with rotary core with a diamond crown.

b) Insertion of a continuous metric reference inside the hole, whose beginning corresponds to one of the ends.

c) Inspection of the prepared hole, following the insertion of a rigid or flexible endoscopic probe connected to a light source with variable brightness, taking care to insert the probe coaxially and parallel to the hole itself.

d) Slow progress of the instrument in the thickness of the wall, noting what was detected during the test, and taking some shots in concomitance with the most significant situations.

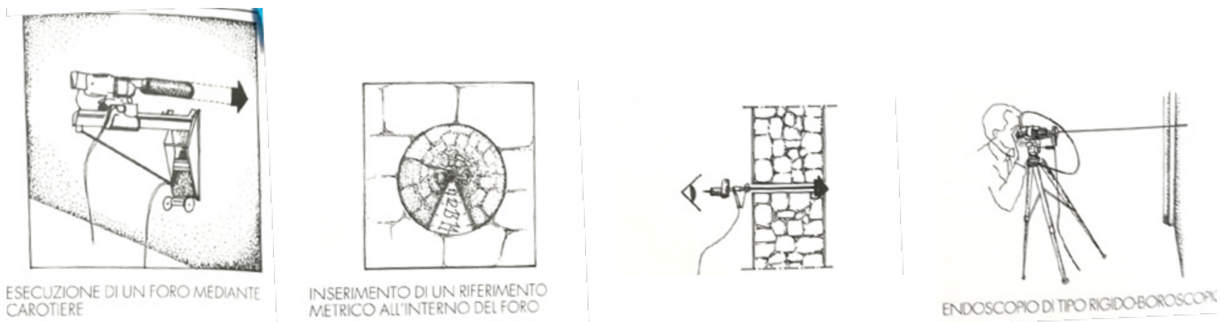


Fig. 38. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 70.

CLASS VI: PERIODIC ANALYSIS
TYPE 14: DEFORMATION MEASURE

DESCRIPTION

The methodology in question allows us to check the movements over time, cyclically measuring deformations or displacements relative to two close points. Since the lesions are the visible manifestation of the inadequacy of the structure to withstand the load conditions to which it is subjected, it is important to distinguish active fissures from inert ones. This will allow us to identify the critical areas in which to intervene after determining the characteristics of the relative movements. Measurements are made, after preparation of reading positions, by means of a deformometer, consisting of a casing in which two metal bars slide connected to a clockwork movement with a graduated quadrant. The bars have at their ends a point to be centered in the already installed bases, in the point-like markings prepared in them. The instrument has a high sensitivity, in the order of 1/100; 1/1000 mm.

Fig. 39. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 73.

EXECUTION

a) Removal of the plaster.

b) Placement on the lesion of appropriate reading bases made of stainless steel, steel or brass, at a distance equal to the length of the reading instrument, by means of a spacer bar. A standard deformometer is about 10 inches (= 25 cm).

c) The measurements and the initial calibration on an invar basis are carried out by recording the measured values, and the thermal conditions of the product, at each inspection, usually by scanning them at regular time intervals.

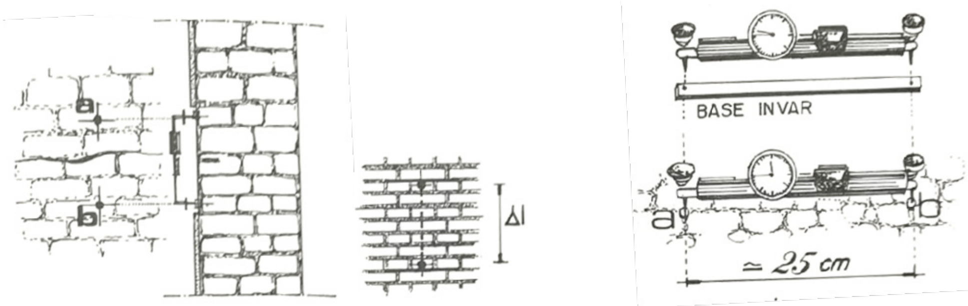


Fig. 40. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 72.

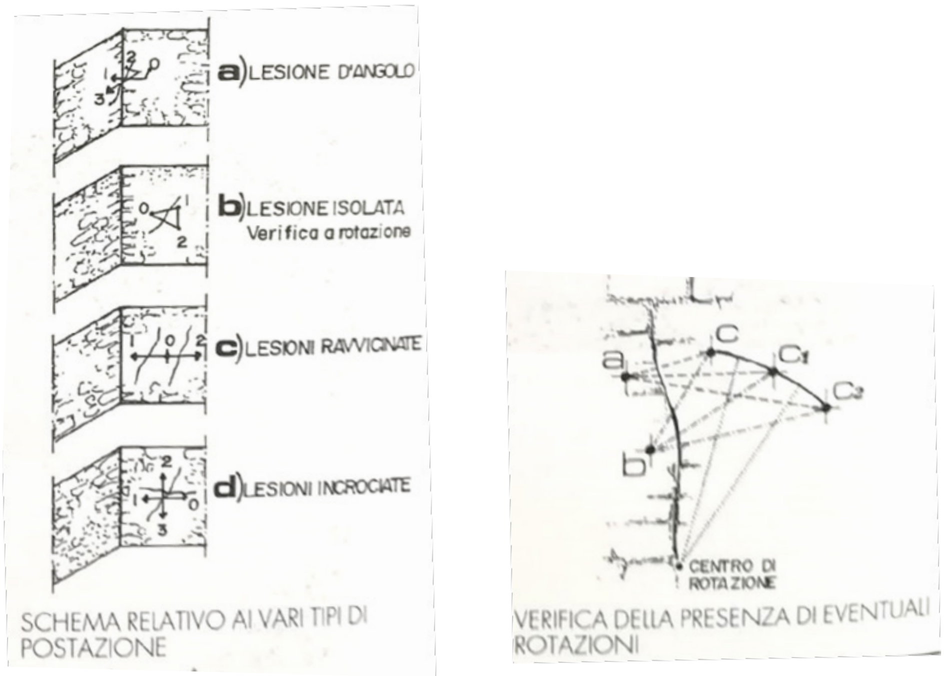


Fig. 41. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 72.

Fig. 42. San Bartolomé Parish Church. Susana Mora. Tarazona de la Mancha, Albacete 2000. (2)

Fig. 43. San Bartolomé Parish Church. Structural consolidation. Foundation reinforcement through micropiles. Sewed of factories. Follow-up through instrumentation. Susana Mora. Tarazona de la Mancha, Albacete 2000.

CLASS VI: PERIODIC ANALYSIS
TYPE 15: STRUCTURAL MONITORING

DESCRIPTION

The structural monitoring allows to control the evolution of the deformation process, or of the displacements, continuously in time, through the survey of the assembly movements of the structure and of the local alteration phenomena. The installed instrumentation network provides real-time information and is connected to a data acquisition unit and to alarm systems able to promptly report any anomalous situations; the purpose of the test is to get to know the structural behavior of the examined building as well as to check the evolutionary laws of previous failures, or still in progress, arriving at a timely assessment of risk levels. This will allow the consolidation work to be optimized from the point of view of minimal and targeted intervention while respecting the artistic and historical value of the work.

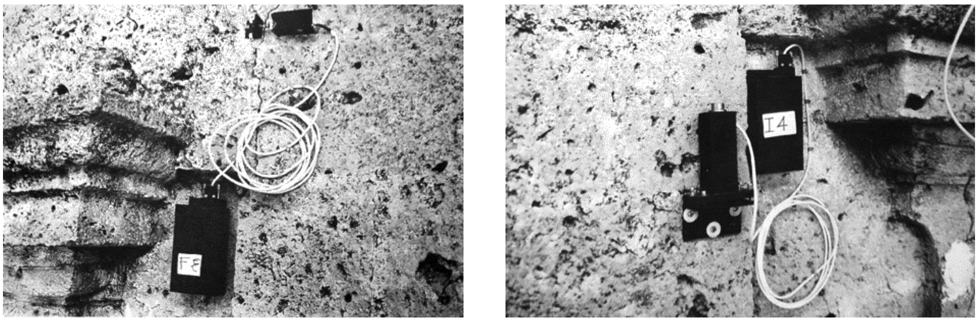


Fig. 44. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 75.

EXECUTION

a) Structural survey of the building to be examined and preliminary identification of critical points to be monitored.

b) Positioning of sensors, inductance transducers, at the identified points.

c) Connection of peripheral units, transducers, to the central data acquisition unit, referring to detection of: horizontal, vertical displacements, rotations and lesion variation, based on an intelligent system able to acquire analog signals and transform them into digital signals.

d) Transmission of data collected by the device by telephone, by modem, to the control station, and processing of data transmitted by electronic calculator.

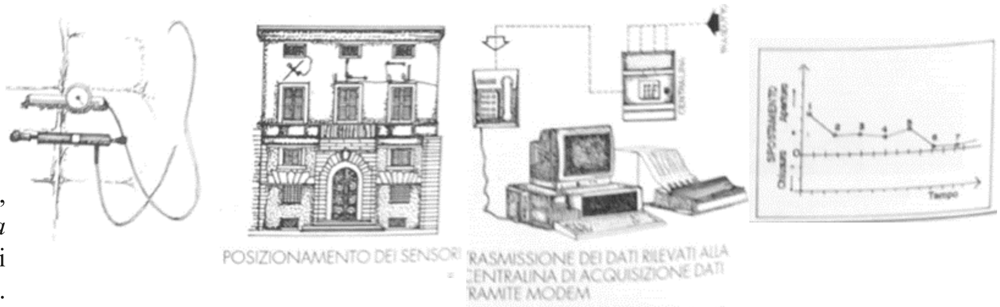


Fig. 45. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 74.

CLASS VII: HUMIDITY CONTENT ANALYSIS
TYPE 16: ELECTRIC RESISTENCE AND CAPACITY MEASURE

DESCRIPTION

Both methods measure the moisture content of a porous material. The method of resistive electrical measurements is based on the consideration that masonry can be assimilated to a resistance by applying two close probes the material connected to a reading instrument. The measuring devices provide the values, expressed as a percentage, of the water content. The electric current will be inversely proportional to the measurable resistance between the two fixed needles, and directly proportional to the amount of water present. The capacitive measurements consist in detecting the dielectric constant of a portion of plaster on which two plate electrodes are placed on the surface. The latter can both be located on the same wall, or on two sides of the structure; in the first case the measured constant is that of the contact material, in the second one of the entire section interposed between the two detection plates.

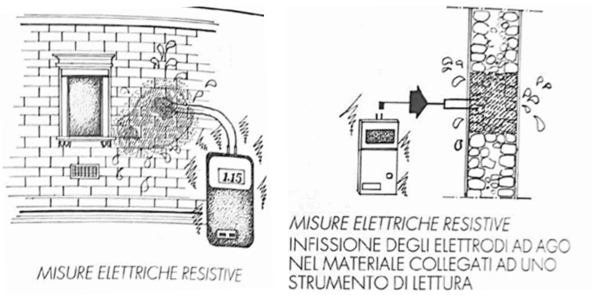


Fig. 46. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 76.

EXECUTION

a) Resistive electrical measurements: after preliminary calibration, inserting needle electrodes into the material. Sealing of holes and activation of current passage. Instrumental measurement through ohmmeters and comparison of the values measured with the initial calibration.

b) Capacitive electrical measurements: positioning of two plate electrodes on the portion to be investigated, determining the dielectric constant of the contact material, or of the entire section, in a dry area. Definition of the dielectric constant of the material, or of the entire section, humid. Even small amounts of water are detected through a substantial change in the dielectric constant; purification of results by comparison between the two measurements, in a dry and humid zone, and determination of the presence of moisture by subtraction.

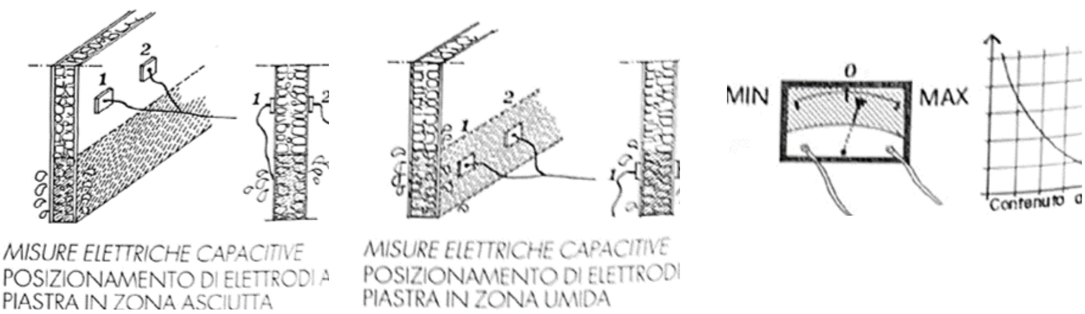


Fig. 47. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 76.

CLASS VII: HUMIDITY CONTENT ANALYSIS
TYPE 17: CALCIUM CARBIDE ANALYSIS

DESCRIPTION

This methodology has a greater reliability than that of electrical, resistive and capacitive measurements, if the composition of the examined material is known precisely, otherwise it is completely similar to them. The principle on which it is based is that of reading the pressure generated by a gas that is released as a result of a particular chemical reaction, in the presence of water. More precisely, by mixing a sample of damp masonry with calcium carbide (Ca C2), a gas, acetylene (C2 H2) develops, directly proportional to the amount of water contained in the specimen. When the chemical reaction occurs in a closed environment, the gas released exerts a pressure, the greater the quantity of gas, and therefore the water content; the stress measured by a manometer indicates the values relative to the humidity present in the material.

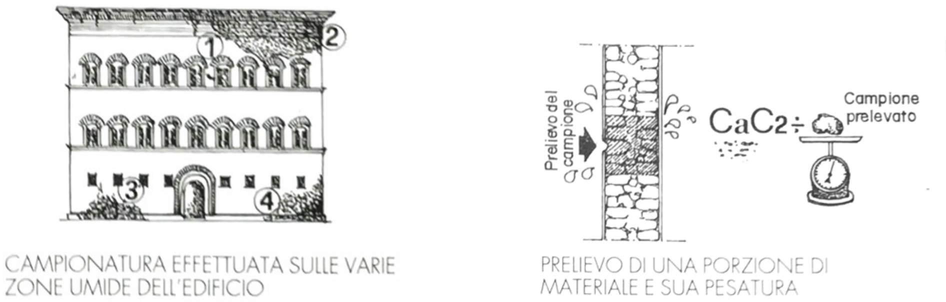


Fig. 48. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 77.

EXECUTION

a) Collection of a standard amount of material and its reduction to powder; predisposition of a predetermined dose of calcium carbide in proportion to the material taken.

b) Placing the two materials separately, in successive stages, inside a special non-deformable and hermetic metal container.

c) Closure of the container and its shaking.

d) Acetylene, which develops as a result of the chemical reaction between the calcium carbide and the water contained in the material, confined by the rigid wall of the container, exerts pressure on the manometer that closes the container.

e) The value of the detected pressure is a function of the water present in the masonry sample, and therefore indicates the values of the humidity present in the material referred to the dry weight.

Fig. 49. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 77.

CLASS VII: HUMIDITY CONTENT ANALYSIS
TYPE 18: PONDERING MEASURES

DESCRIPTION

The type of analysis described here, of rapid execution, based on a very simple principle, if carried out correctly, provides results of considerable precision, much better than those achievable with the methods described in the other entries of the same class 7. The test consists of taking a sample of masonry using a core drill, and weighing it when drawing and after having dried it; the difference between the two weights indicates the water content present in the sample. Usually, several samples are taken at the depths to be investigated. The execution of the assessment does not require the use of specific equipment, in fact it is sufficient to have a stove to dry the sample and a precision scale.

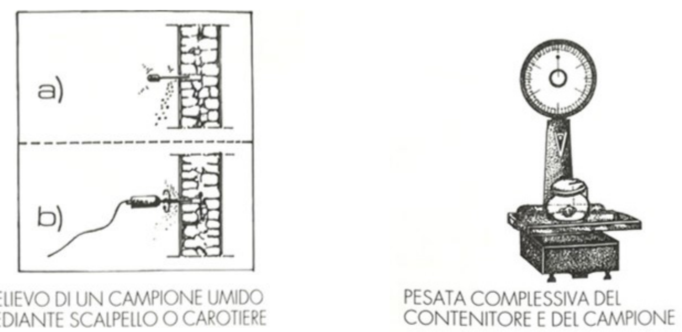


Fig. 50. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 78.

EXECUTION

a) Collection of a wet material sample by means of a chisel or core drill, at very low rotation speed (100/200 rpm), in order to avoid heat development with consequent evaporation of the water.

b) Insertion of the sample taken in a special glass container, or in polyethylene, previously weighed, with a sealed cap, and transported to the laboratory. Care should be taken not to expose the container containing the sample to temperature changes in order to ensure good preservation.

c) Execution of a total weigh, container and sample.

d) Additional weighing, this time only of the sample extracted.

e) Drying in an oven at a temperature of about 105 °C, up to constant weighing; determination of the weight of the dried sample and the percentage of relative humidity referred to wet weight, dry weight, and volume.

Fig. 51. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999, p. 78.

WOODEN CONSTRUCTIONS

(3) A. Geometrical, material and mechanical survey

B. Damage maps

C. Damage tests

A. GEOMETRICAL, MATERIAL AND MECHANICAL SURVEY

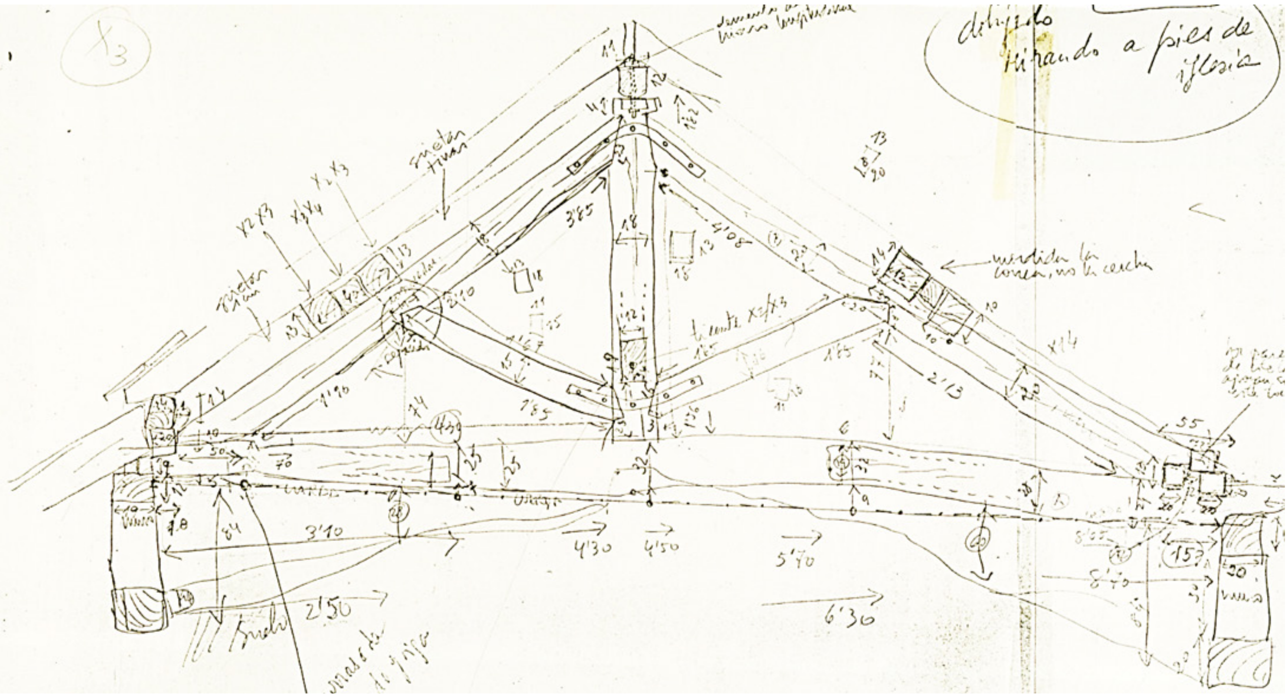


Fig. 52. Sketch of a wooden truss with measurements and constructive indications. Santa María de los Reyes, Grijalba, Burgos. Susana Mora. (4)

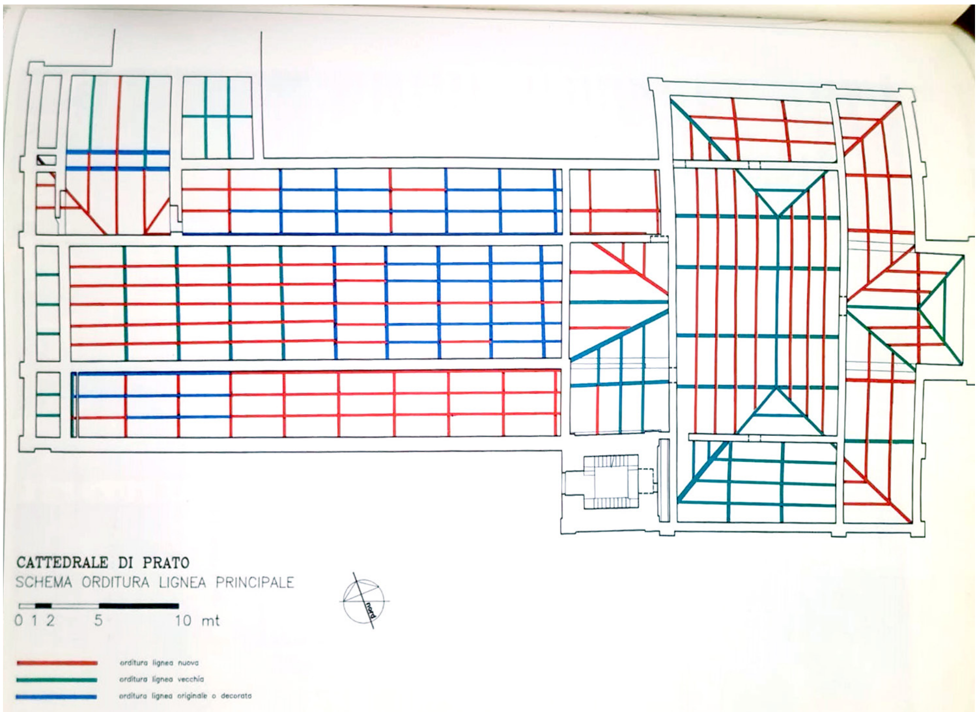


Fig. 53. Roof survey. From G. Carbonara, *Trattato di restauro architettonico,* vol. 4, Utet, Torino 1996, p. 303.

Constructive detail and material characterization

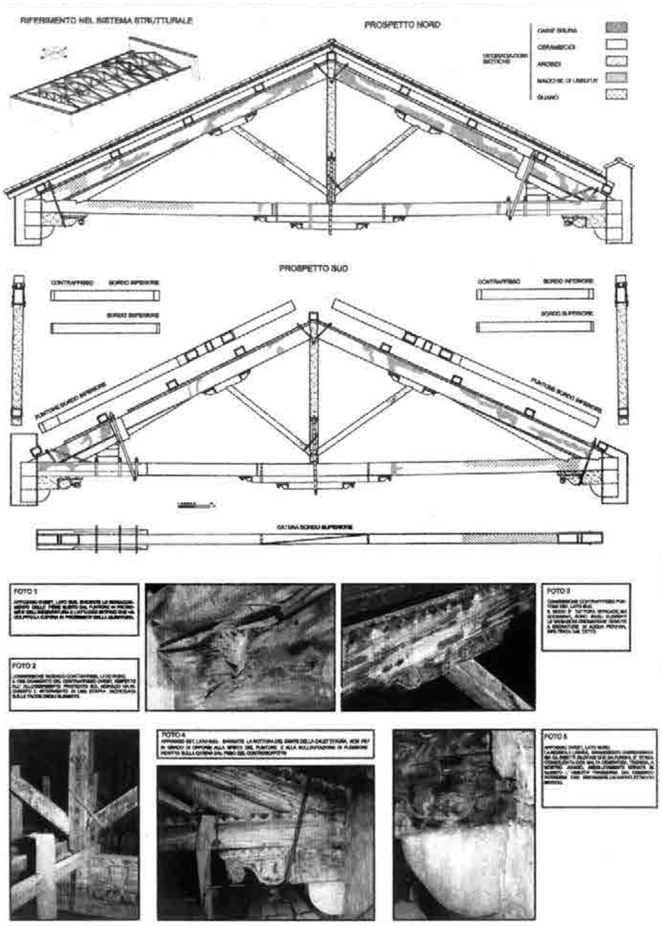


Fig. 55. From G. Tampone, *Conservation of Historic Wooden Structures*, Florence 22-27 february 2005, vol 1. Alter Ego Ing Arch, Firenze 2005, p. 156.

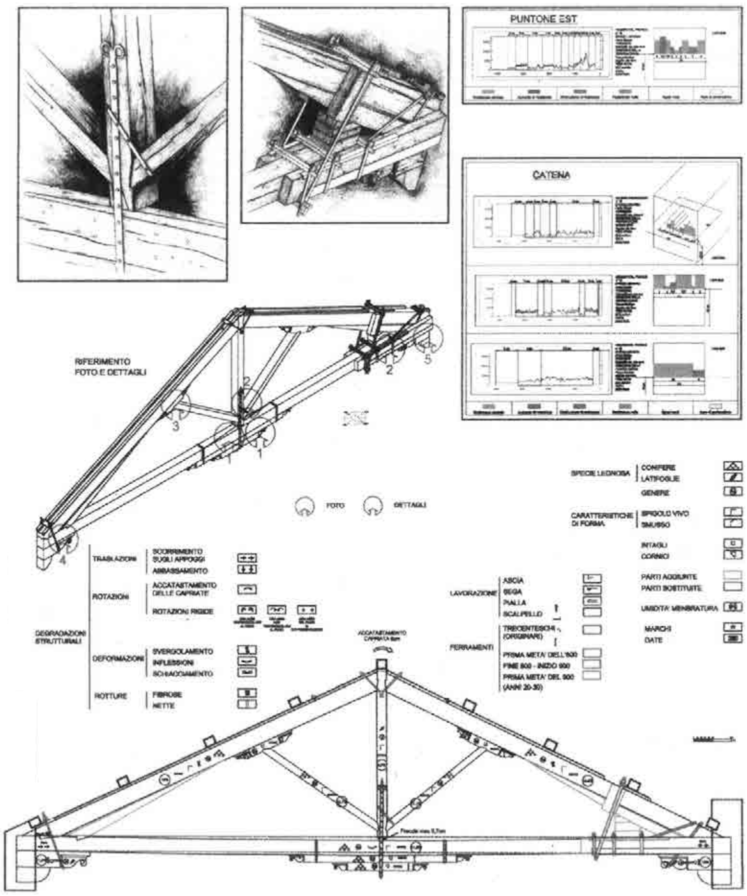


Fig. 55. From G. Tampone, *Conservation of Historic Wooden Structures*, Florence 22-27 february 2005, vol 1. Alter Ego Ing Arch, Firenze 2005, p. 156.

B. MAPS OF DAMAGE

Fig. 56. Analitical diagnosis data card including: list of damages, location and codification of test performed on the truss and typological recognition of wood species. Redesgined by Susana Mora.

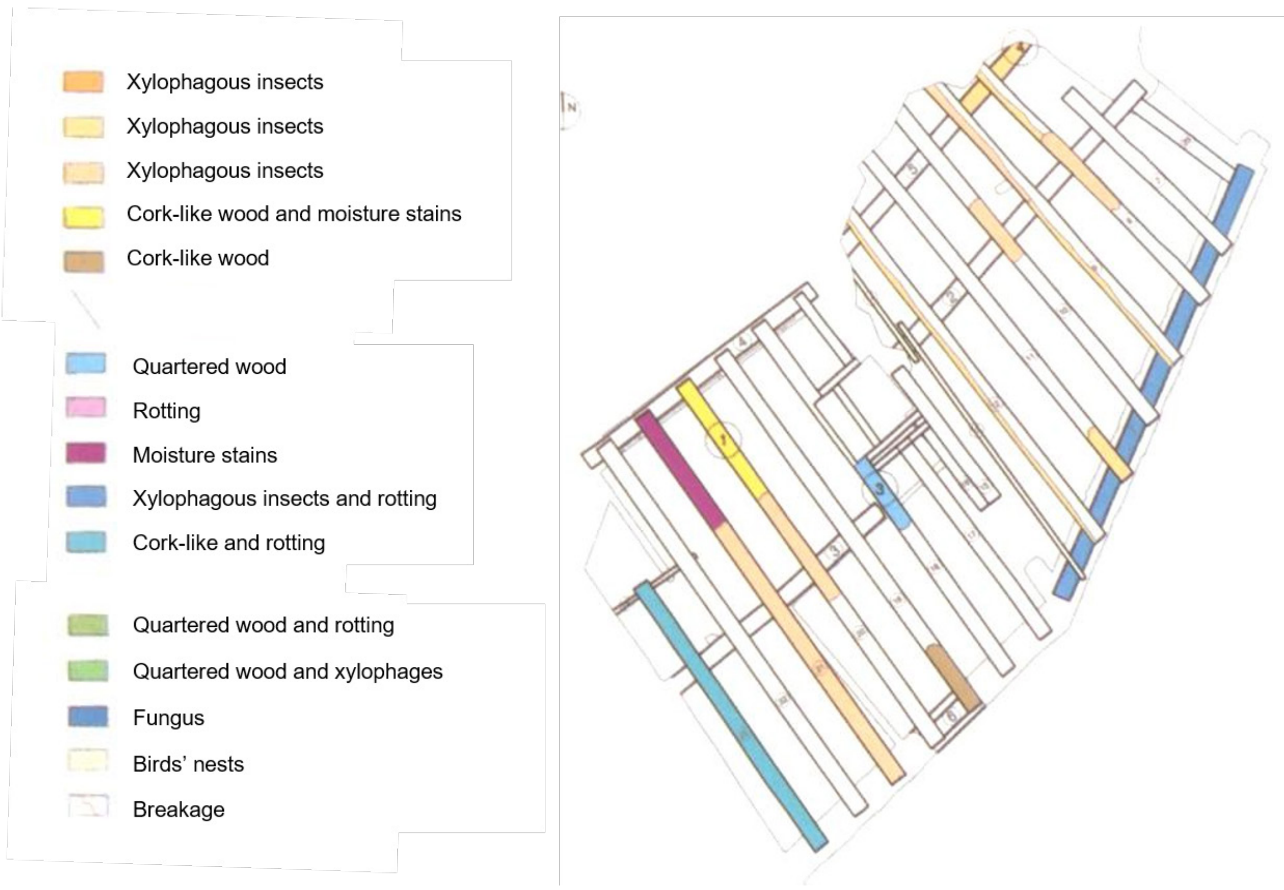


Fig. 57. Damages types identification. Redesigned by Susana Mora.

C. DAMAGE TESTS

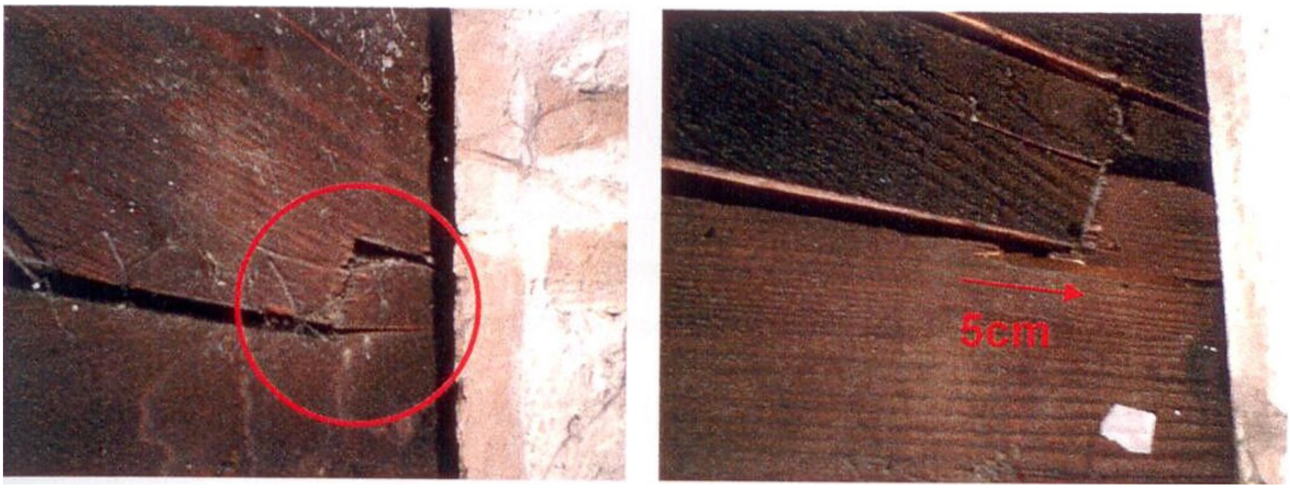


Fig. 58. Analysis of specific damages. Suffering of the cutting tooth (left). Breakage with relative sliding of the elements (right). From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999. (5)

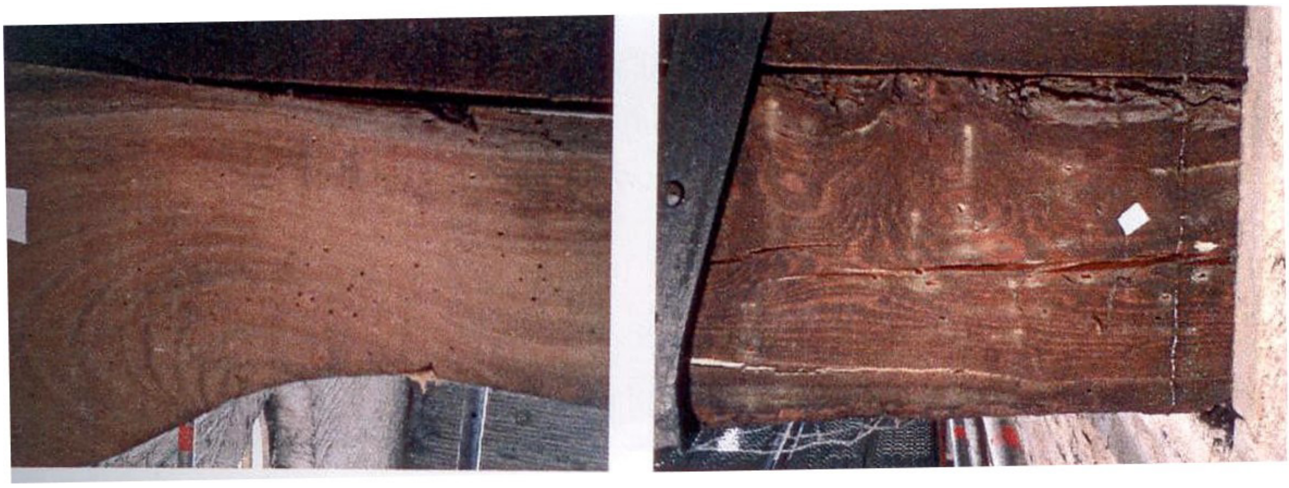


Fig. 59. Analysis of specific damages. Attack of anabids xylophagous (left). Attack of cerambicides xylophagous (right). From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999.

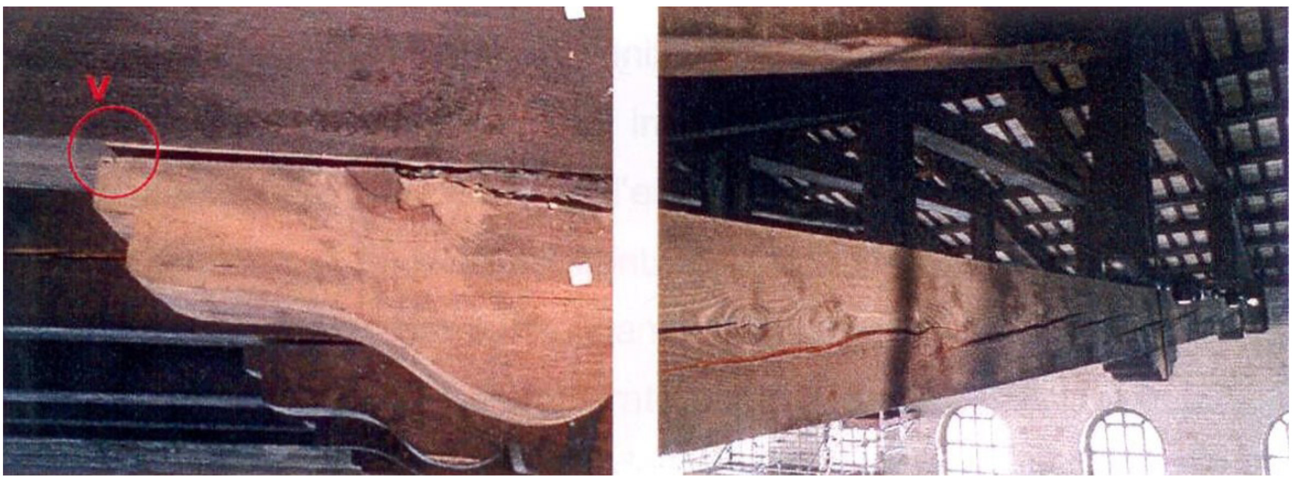


Fig. 60. Vertical deviation between bracket and tie-beam (left) and longitudinal fissures due to tie-beam shrinkage (right). From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999.

Fig. 61. Visual, photographical and geometrical survey. From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999.

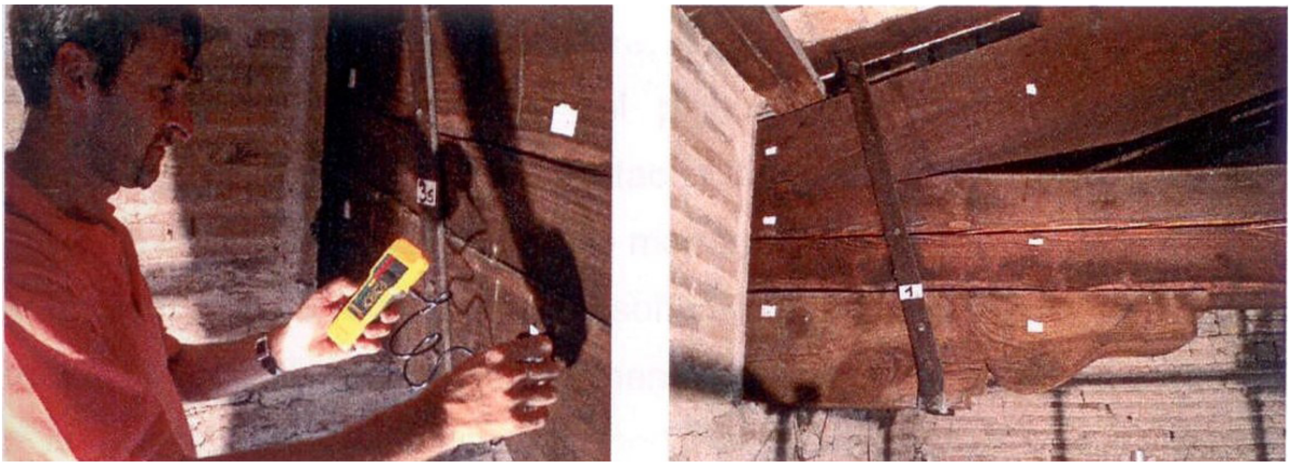


Fig. 62a. Moisture survey (left) and example of the coding assigned to the truss head with indication of the execution points (right). From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999.

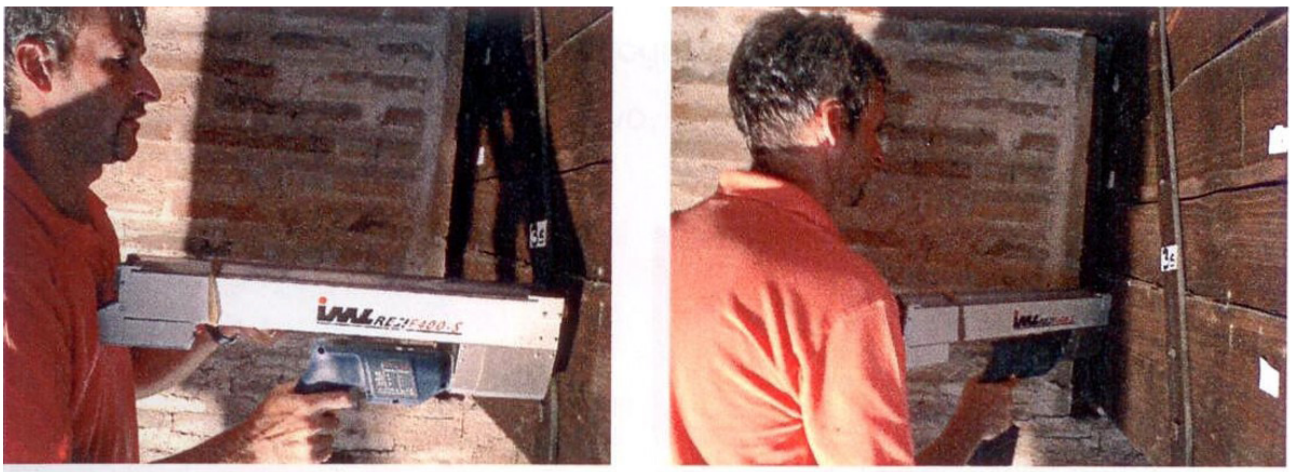


Fig. 62b. Perforations with resistograph in span (left) and in correspondence of the support (right). From P. Rocchi, C. Piccirilli, *Manuale della Diagnostica*, Edizioni Kappa, Roma 1999.

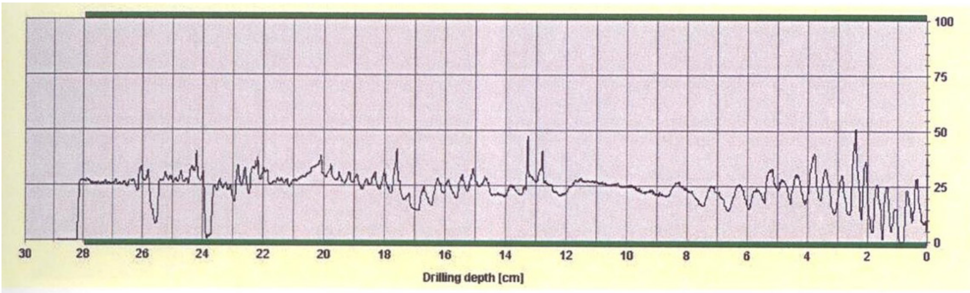


Fig. 63. Drilling depth-Resistance diagram for a «healthy» shelf.

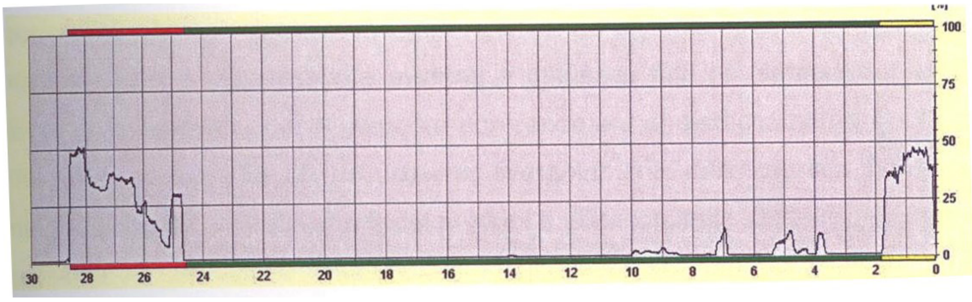
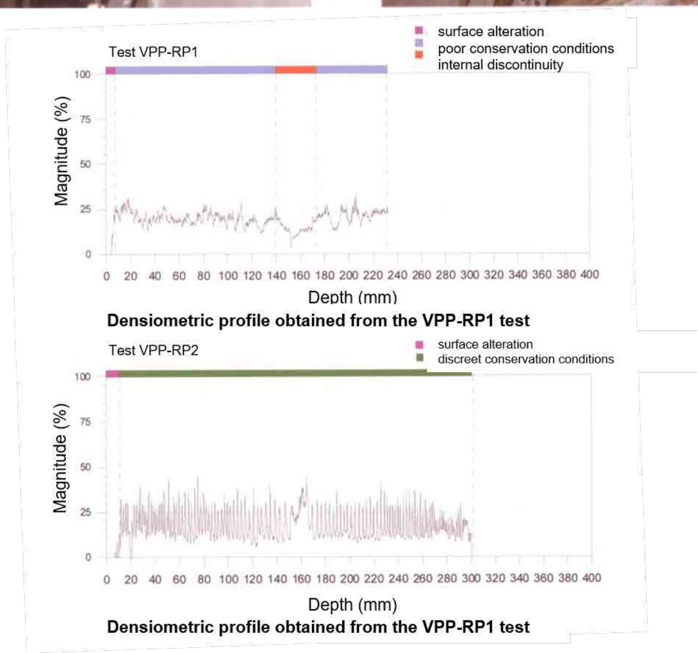


Fig. 64. Drilling depth-Resistance diagram for a degraded shelf.

Penetrometer tests on wood:

Fig. 65. Reading the humidity inside the beam. (Left). Performing the penetrometer test. (Right) (PP.MM. Laboratory, Politecnico di Milano). From F. Doglioni, G. Mirabella, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011.



NOTES

About general philosophy: Test for masonry and wood

On remembering the pioneristic study on wood, by Paolo MORA,

1) The study should seriously deal with the most varied problems attached to the life of the monuments and covers many fields (perharps unforeseen). Therefore a complete study should be provided, organized in a global and organic way and that can be adapted to the infinite number of monumental variations. In DE ANGELIS d'OSSAT G., *Guide to the methodical study of momuments and causes of their deterioration*, Roma 1972, p. 5;

2) Simple structural monitoring has being done by Susana Mora before, during and after the restoration of the church of San Bartolome in Tarazona de la Mancha, Albacete, Spain, directed by her as architect, for the "Junta de Comunidades de Castilla-La Mancha" (1995-The follow-up must be done during some periods of climate changes as from winter to spring and from summer to autumn);

3) On the conservation of wood, see the historical study by TAMPONE. G., *Il restauro delle strutture in Legno*, Milano 1996; to the numerous studies launched within ICCROM: by Paolo Mora e all'Istituto Centrale del Restauro. Untill the 19th century, wood was the only material that was resistant to both compression and to traction and that was readily available in structural sizes. The products that were available led to standardisation, with modular structures and prefabricated building parts, created according to a set constructive procedure related to structural typology. From TAMPONE G., *The slow progress of the conservation of wooden structures and wooden architecture, in Proceedings of the international conference Conservation of Historic Wooden Structures*, Florence 22-27 february 2005, vol. 1, Alter Ego Ing Arch, Firenze 2005, p. XIII. See also: PIAZZA M., CARABONI M., DE MARIA A., *Strutture in Legno*, Milano 2005;

4) This drawing form part of a collection of the sketches of all the wooden trusses of the roof structure of the church of Santa Maria de los Reyes in Grijalba, Burgos (Spain), and were done before the Restoration project designed by S. Perez Arroyo and Susana Mora, for the Junta de Comunidades de Castilla-Leon, 1995;

5) BRUNETTI G., *Tecniche non distruttive per la diagnosi*, in *Tecniche della Conservazione*, a cura di A. Bellini, Milano 1986, pp. 228-274.

ABBASI J., *Consolidation of historical woods using polyvinyl butyral/zinc oxide nano-composite: investigation of water absorption, wettability, and resostamce to weathering*, in International Journal of Conservation Science, Vol. 11, n. 1, 2020, pp. 15-24.

CEN, EN 338, *Structural timber – Strength classes. Technical report,* European Union, 2016.

DEFUS A., POSSENTI E., SANSONETTI A., TEDESCHI C., *The effectiveness of di-ammonium hydrogen phosphate (DAP) consolidation treatment on lime-based mortars weathered by freeze-thaw cycles*, in Journal of Cultural Heritage, Vol. 50, 2021, pp. 1-12.

MOUTON B., *Méthodes d'analyse destructives et non-destructives pour les structures historiques. Avantages et limites*, in *Stable – Unstable?*, pp. 141-146.

VANNUCCI P., *A study on the structural functioning of the ancient charpente of Notre-Dame with a historical prospective*, in Journal of Cultural Heritage, Vol. 49, 2021, pp. 123-139.

CHAPTER 6. ARCHAEOLOGY AND STRATIGRAPHY

Within the family of historical science, archaelogy qualifies, according to the most widespread definition – and that in which archaeologists recognize themselves most – as the discipline that studies past societies starting from material sources, or rather from objects that they have left. The evolution of archeology, over the last few decades, has led to a continuous expansion of the number of objects considered possible sources: even in the middle of the past century a university manual could state that “archaeological studies aim to reconstruct on the basis of historical ancient art”, already thirty years later not even the most traditionalist of scholars, still imbued with Crocianism, would at least publicly subscribe to this definition. Today we are perfectly aware that archaological sources can be shards, animal bones, seeds, and even pollen invisible to the naked eye, or post holes and dirt tracks, or entire landscapes that preserve traces of the different phases of settlement, as well as statues, monuments and painted vases. (1)

At the moment in which a construction operation is concluded, the intervention of several factors that deteriorate its results begins; the most common are the following:

1. Degradation. The loss of qualities is inevitable because of the simple and unavoidable impact of environmental factors; this “simple aging” will begin to manifest itself in what we call “patina”, which is a mixture of deposits and chemical alterations that cushion the differences in color and texture.

2. Deformations. The actions that affect the architecture, which we usually reduce to that of gravity, produce deformations that are normally compatible with general or sectorial stability, although sometimes they cause collapse; among such deformations we include cracks, crashes, arrows and seats.

3. Weathering. The passage of time and the use of a building lead to the acceleration and concentration of degradation in specific areas, causing the disappearance of part of the building’s material. The extreme case of wear will be ruin.

4. Deposits. It is evident that diverse circumstances (accidents, obsolescence, reforms, ruins, destructions… can contribute to the deposit on the forms of variable amounts of materials either as part of a natural or anthropic process.

5. Reforms. In all periods of history the reforms have been integrated, to a greater or lesser extent, with the pre-existing parts, reaching the case of intentionally hiding all appearance of antiquity, and archaeology studies them.

ASPECTS OF ARCHAEOLOGICAL WORK

A. Excavation: With the passage of time there is an accumulation of material and objects over the ruins, of natural or anthropic origin. The elimination of these deposits allows to discover the objects, deposits, remains, ruins, etc. that were hidden.

B. Archaeological survey: An important part of archaeology is the graphic description of the findings, both in drawings and photographs.

C. Protection of the remains found. When discovering the remains, they are left unprotected and exposed to the conditions of weather, humidity, rain, solar radiation, etc.

D. Interpretation of the remains. In the archaeological campaigns are remains that, besides being conserved, must be studied and analyzed. In many cases, these remains are part of a set that can be recovered, such as the skeleton of an animal or columns that can be reassembled by anastylosis.

E. Dissemination of the findings. This may consist of exposing the remains found in museums or interpretation centers adjacent to the site, but also in generating routes that allow the public to see the site itself.

Fig. 1. Tower of Hercules, La Coruña, Coruña. Photo by P. Latorre.

A. EXCAVATION

Over time there is an accumulation of material and objects over the ruins, of natural or anthropic origin. The elimination of these deposits allows us to discover the objects, deposits, remains, ruins, etc. that were hidden. (2)

Figs. 2, 3. Archaeological works at St. Mary of Carracedo monastry, 1985-2000.

Figs. 4, 5. Archaeological excavations with protection and consolidation of remains. Organization of routes and accesses. Puebla de Almenara Castle, 1990. Photo by Susana Mora.

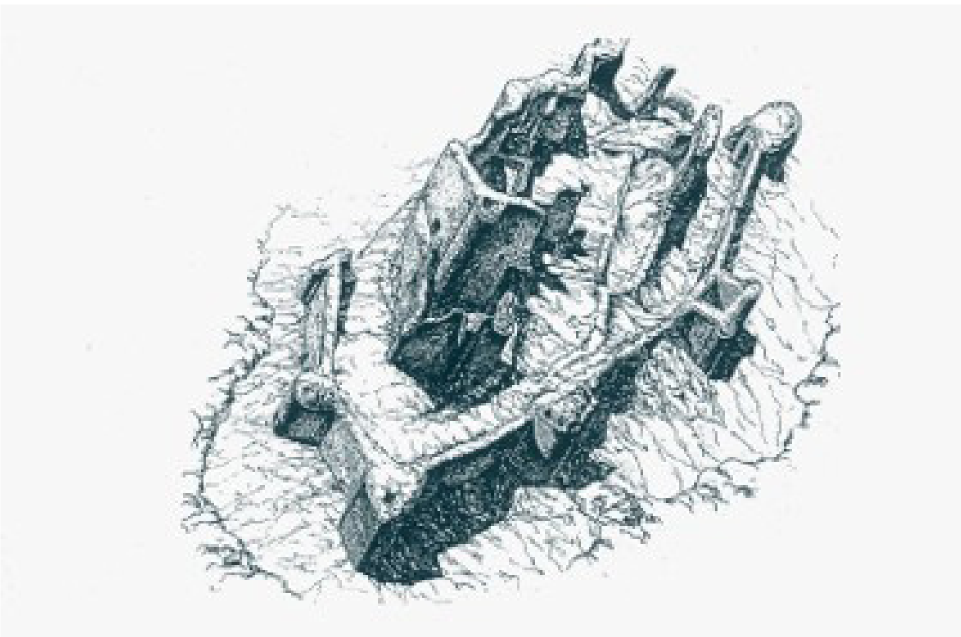


Fig. 6. Puebla de Almenara Castle, Cuenca.
Drawing by Susana Mora.

Fig. 7. Archaeology on the walls. Villalba del Rey Parish Church, Cuenca. Photo by Susana Mora.

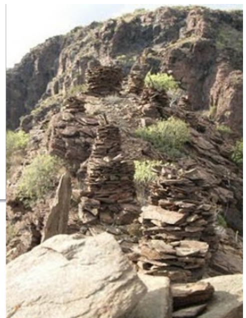
Fig. 8. Archaeology, Puebla de Almenara Castle, Cuenca. Photo by Susana Mora.

Fig. 9. Church of Santa María de Los Reyes. Grijalba. Burgos. Exterior paving. Photo by Susana Mora.

B. ARCHAEOLOGICAL SURVEY

An important part of archaeology is the graphic description of the findings, both in drawings and photographs. This drawing may involve different scales, from territorial to local and detail. (3)

Fig. 10. Excavation of Lavinium. From Cairoli Fulvio Giuliani, *Archeologia. Documentazione grafica*, Roma 1987, p. 74.



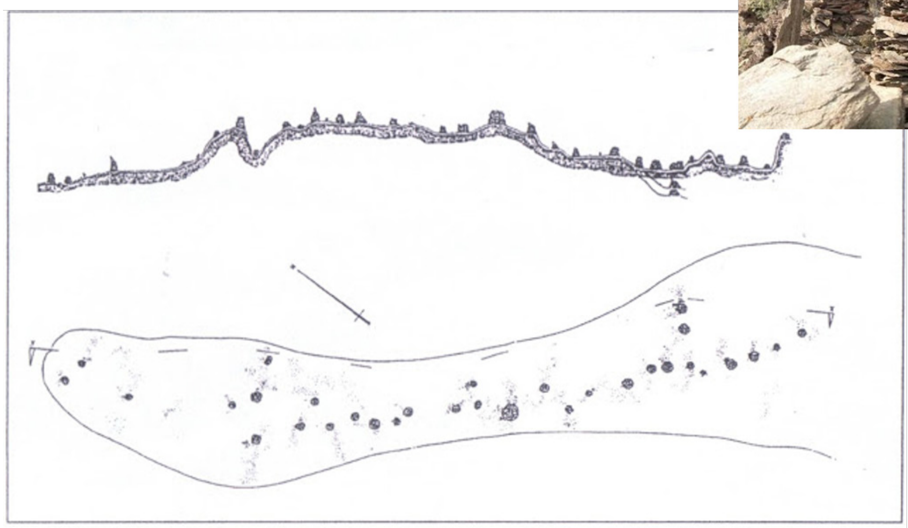


Fig. 11. Plant and section Archaeological Joint High Crown. Canarian Museum Archeology Service, 1992, in SBT Archaeological Letter.

C. PROTECTION OF THE REMAINS FOUND

The remains must be conserved and protected.

Fig. 12. From *Copertura delle aree archeologiche*, ICR, p. 106.

Fig. 13. From *Copertura delle aree archeologiche*, ICR, p. 107.

Figs. 14, 15. From *Copertura delle aree archeologiche*, ICR, pp. 105, 108.

D. INTERPRETATION OF THE REMAINS

In the archaeological campaigns are remains that, besides being conserved, (4)
must be studied and analyzed. In many cases, these remains are part of a set that can be recovered, such as columns that can be reassembled by anastylosis.

Fig. 16. Archaeological site. Palatino, Roma. Photo by Susana Mora, 2010.

Figs. 17, 18. Interpretation of the ancient monument. Roman theatre in Cartagena, Spain. Photo by Susana Mora, 2014.

Fig. 19. Memorial memory and adequacy of its environment. Uzquiza reservoir. Burgos. Photo by Susana Mora, 2000.

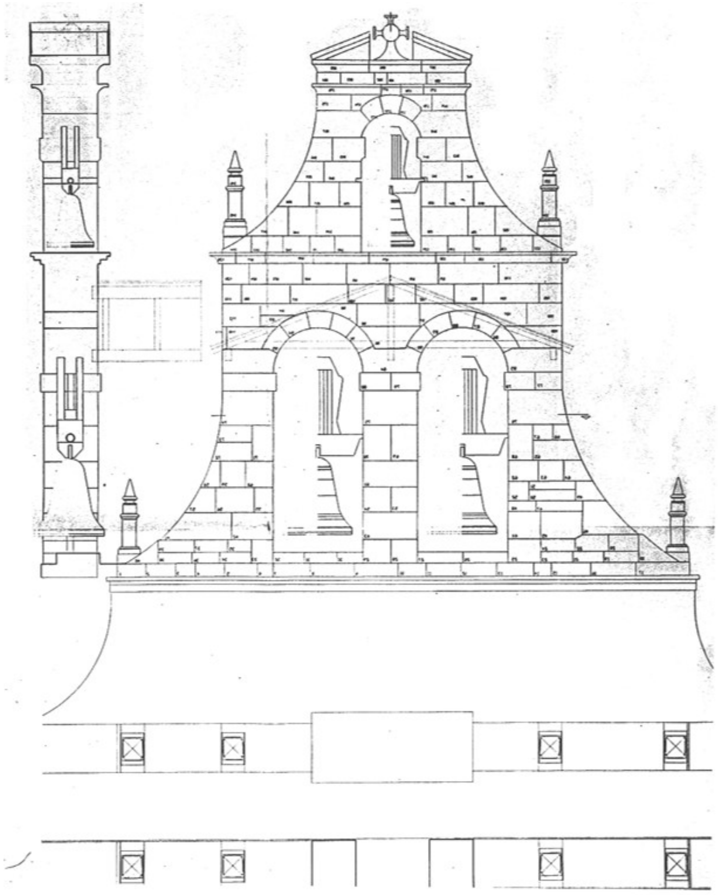


Fig. 20. Adaptation, through anastylosis, of the existing remains of cattails and cover, coming from demolitions, due to the construction of the Uzquiza reservoir. Elevation by Susana Mora, 2000.

E. DISSEMINATION OF THE FINDINGS

(5) For example by books, expositions…

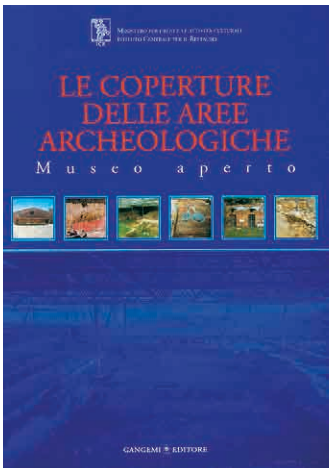


Fig. 21. Cover of Maria Concetta Laurenti, *Le coperture delle aree archeologiche. Museo aperto*, Gangemi Editore, Roma 2006.

ARCHEOLOGY OF ARCHITECTURE

Archeology of architecture: reading of the phases that make up a building. Without using invasive methodologies you can only know the visible surface of the building, which is why readings of vertical walls are frequent. You can also read horizontal paraments, read sections and plants and axonometric views or perspectives.

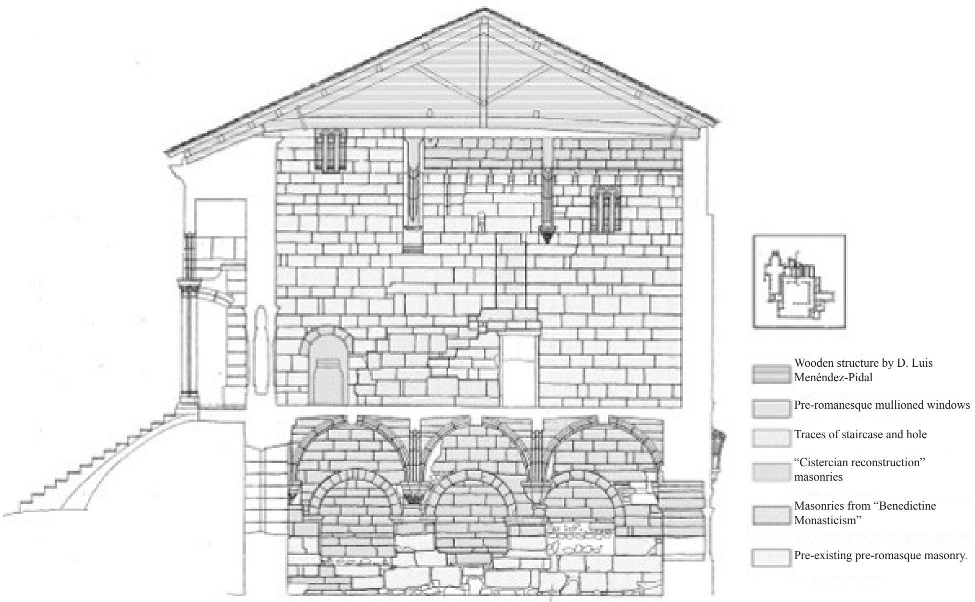


Fig. 22. Supposed stratigraphy of Santa María de Carracedo Monastry. Elevation by Susana Mora, 2015.

Fig. 23. Santa María de Carracedo Monastry. Photo by Susana Mora.

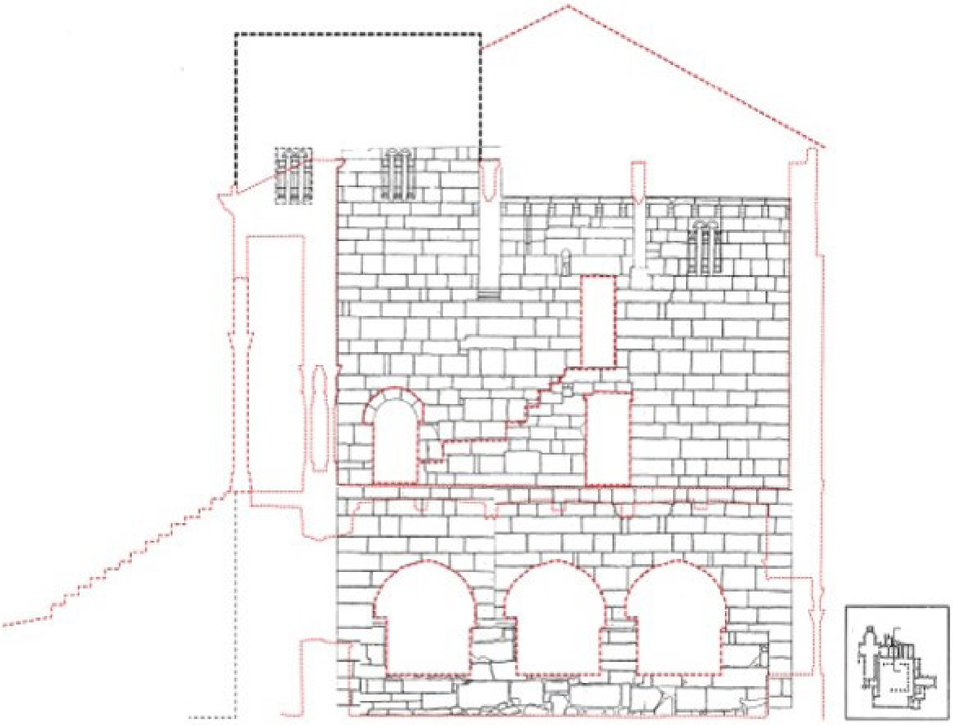


Fig. 23. Santa María de Carracedo Monastry. Elevation by Susana Mora, 2015.

SUPPOSED STRATIGRAPHY

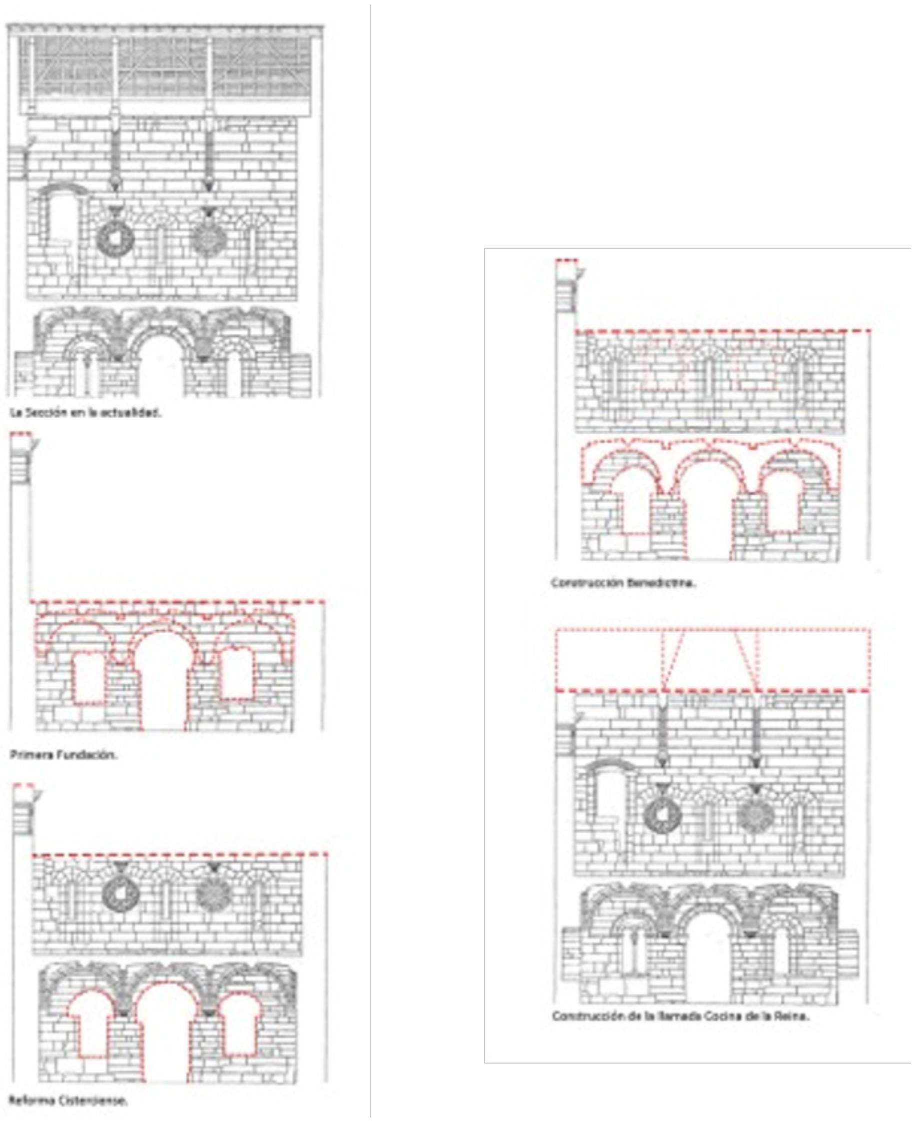


Fig. 24. Santa María de Carracedo Monastry. Elevation by Susana Mora, 2015.

STRATIGRAPHY

A. STRATIGRAPHIC MAPS AND MATRIX OF HARRIS

B. PHASES / STAGES

C. RELATION BETWEEN PHASES

A. STRATIGRAPHIC MAPS AND MATRIX OF HARRIS

STRATIGRAPHY

We begin by remembering and specifying the idea of a stratum, as a region of a building. or associated with it, which enjoys a perceptive unity, extended to each and every one of its attributes, starting with the figure, with which colour and texture overlap; it is considered in principle indivisible; they also characterize its size, position with respect to a reference system; it is possible to detect spatial relationships: they link them to others and perhaps infer temporal ones.

A problem in the practice of the reading of walls is the reduction of the study to the visible parts of the walls, since in this way the three-dimensionality of the architecture is ignored. A broader view should think of the stratigraphic units as elements with volume.

Fig. 25. Portico di Ottavia, Rome. Photo by Susana Mora, 2016.

The stratigraphic investigation applied systematically after a first graphical survey, comprehensive and reliable, helps, not always successfully, to distinguish, relate and, sometimes, date the different concurrent initiations, so that, in an optimal case, the Harris diagrams would describe the construction stages of the building.

STRATIGRAPHIC MAPS

The drawing of stratigraphic maps starts with a material survey. The aim is to distinguish different constructive or stratigraphic unit, this is, elements that are homogeneous in composition, construction, period of time, etc. Over the material survey there should be drawn the interphases or lines that separate one unit from the other.

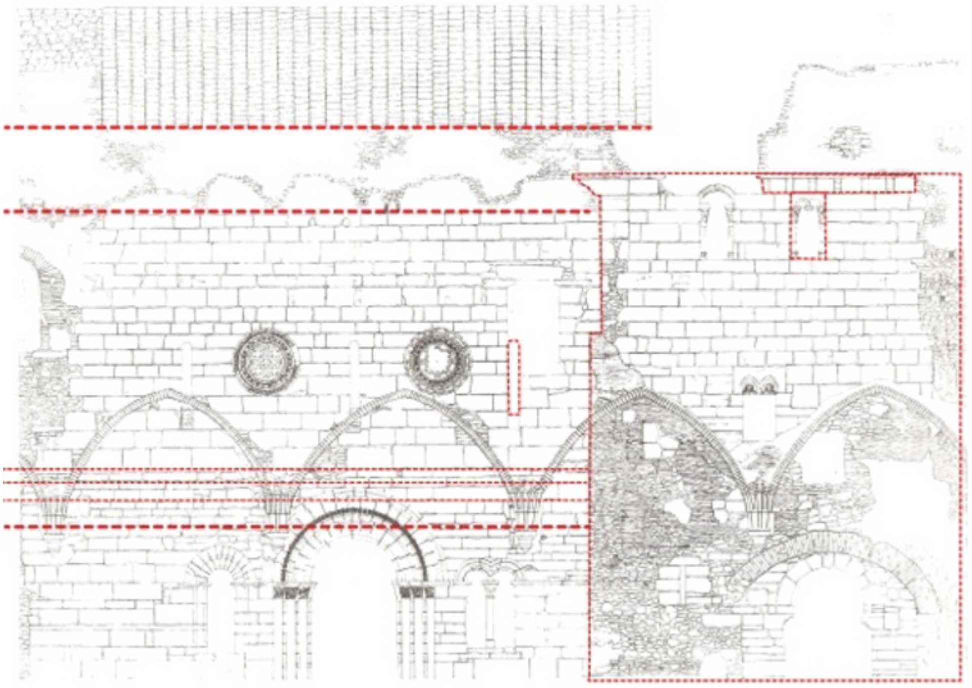


Fig. 26. Stratigraphic analysis and ortophotography from the studies at Santa María de Carracedo Monastry, 2015.

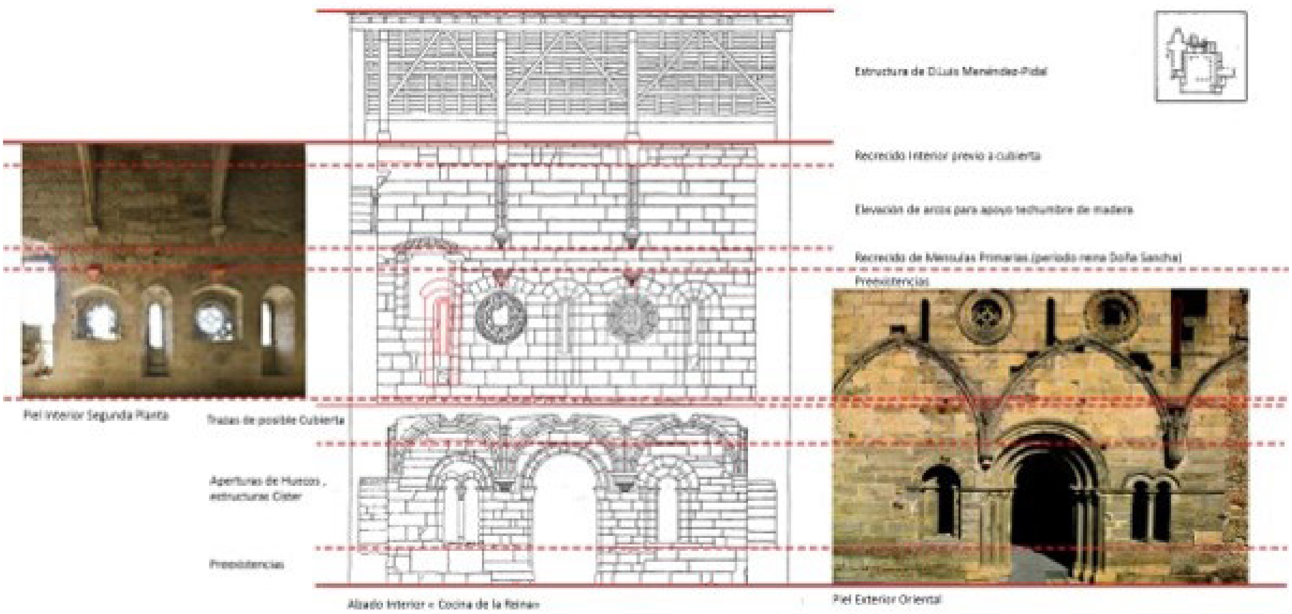


Fig. 27. Stratigraphic analysis and ortophotography from the studies at Santa María de Carracedo Monastry, 2015.

Fig. 28. Material survey and Phase-delimitating lines of Santa María la Real Church, Sasamón, 2014. (6)

Fig. 29. Stratigraphic map of Santa María la Real Church, Sasamón, 2014.

Fig. 30. Stratigraphic units map. From F. Doglioni, *Nel restauro. Progetti per la architettura del passato*, (IUAV Documenti), Marsilio, Venezia 2008.

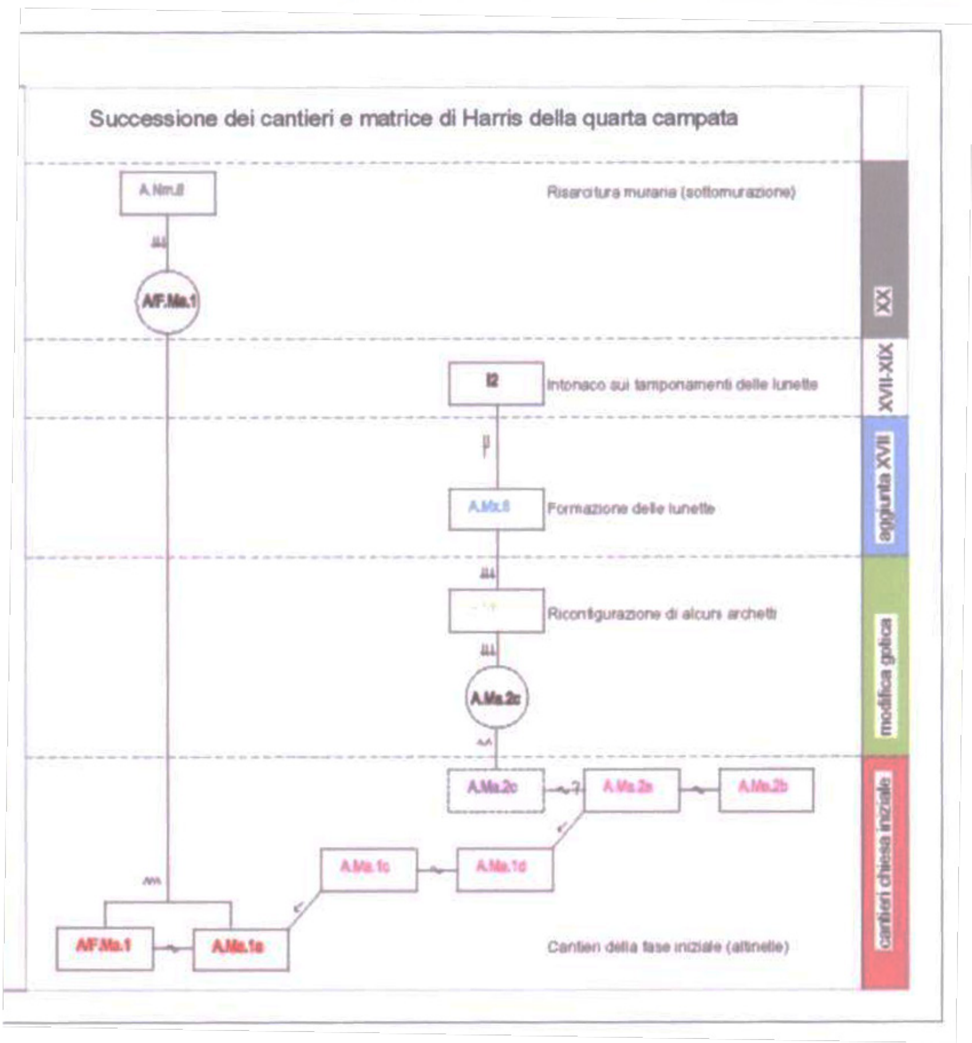


Fig. 31. Matrix of Harris. From F. Doglioni, *Nel restauro. Progetti per la architettura del passato*, (IUAV Documenti), Marsilio, Venezia 2008. (7)

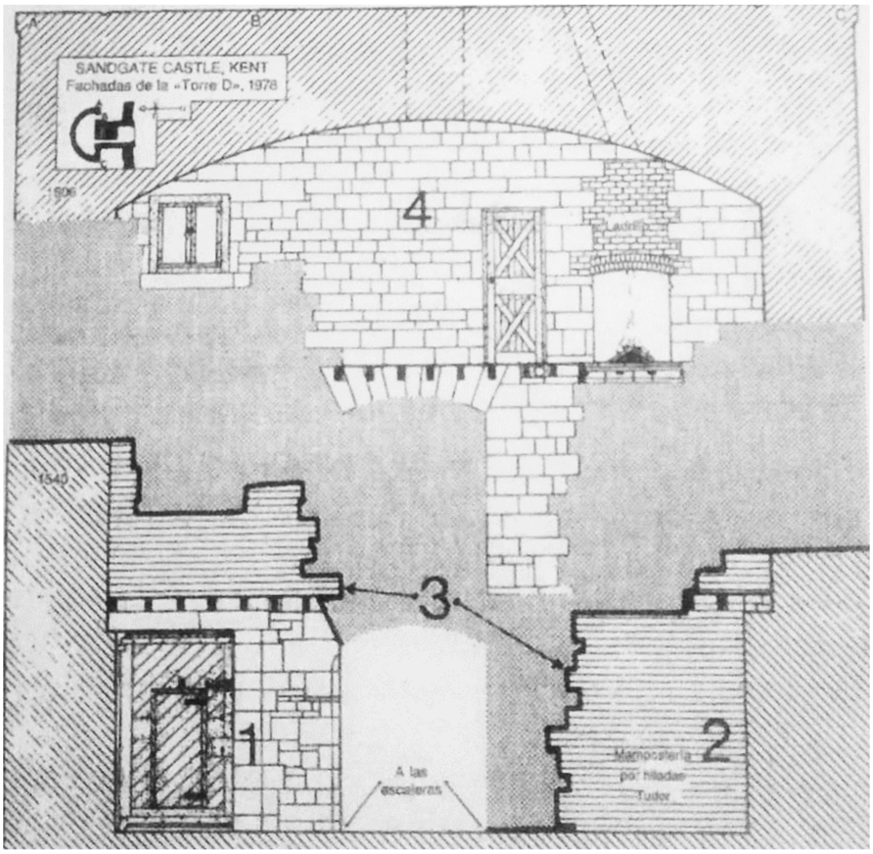


Fig. 32. Example of a stratigraphic units map. From F. Vela, "La arqueología en restauración" en *Tratado de rehabilitación*, DCTA (UPM), Editorial Munilla-Leria, Madrid 1999, p. 212.

When a date is known with certainty, other units can be referred to that one.

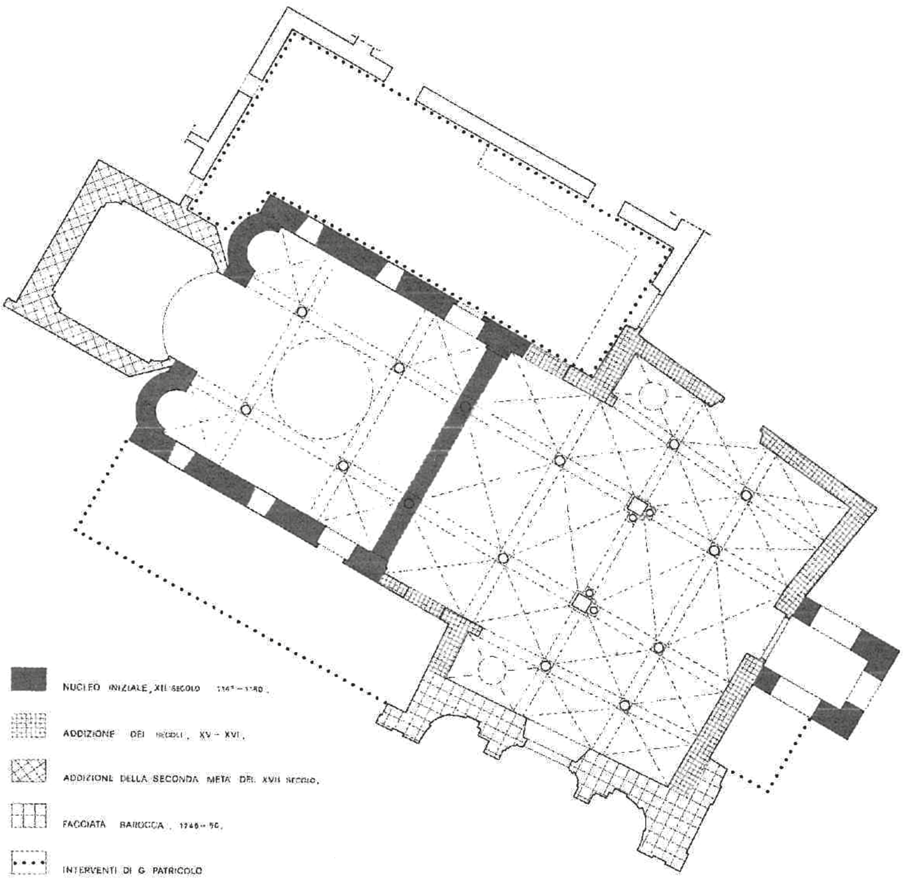


Fig. 33. Sintesi delle fasi costruttive della fabbrica. From C. Bellanca (editor), *Una didattica per il restauro*, Atena Editrice, Roma 2008, p. 58.

B. PHASES / STAGES

STRATIGRAPHIC UNITS OR PHASES

1. Stratigraphic unit. The stratigraphic element or stratigraphic unit is the smallest unit stratigraphically identifiable from those around it, equivalent to the geological stratum. It differs from the constructive unit in its stratigraphic and non-formal homogeneity. There are two types of stratigraphic elements, those that they have volume and materiality, for which 'element' is specifically reserved, and those that only have a surface, which we call surface or interface.

2. Interface. They are each and every one of the figures that stand out for their perceptive autonomy at the border of a stratum. They have perceptual characteristics that individualize them and spatial relationships with the stratigraphic elements, especially with the one that sustains it, and also with other interfaces.

There are three classes of phases or regions: one massive, genetically autistic, another spatial, muted by the loss of movable content and that only offers indications of relative chronology, and a third superficial, something more loquacious, because it provides information on the constitutive stage and also from later times.

- When we are analysing tectonic that is, constructed, forms, the masses remain equally mute, because we have forbidden the possibility of investigating their interior, since it would oblige us to destroy them, but they offer, like the spaces in the previous example, information about relative chronology.

- The spaces will give information that complements that of the masses, as it corresponds to the dialectical relationship that links them.

- The superficial phases, will be the ones to provide more information: on the one hand, they will tell us about their own vicissitudes, all derived from the daily or occasional use of the spaces of which they are frontiers.

1. Material. The architectural masses appear constituted by simple and compound materials, in a chemical sense, of organic origin, natural or artificial, that we generically denominate materials. In most cases, visual identification is sufficient; in others it may be necessary to characterize its composition.

2. Format. Some materials arrive at the work conformed, that is to say, the constitutive unit is typified in size and figure, while others must be so in the process of assembly.

3. Masonry. The intrinsic characteristics and format of one or several materials offer a few specific ways of association. according to precise rules, thanks to which they constitute. These are supposed generic virtues of resistance and durability and are given a name, based on the main material or dominant format (brick work, ashlar, wall…).

4. Bonding. The structures can be mounted on site according to different geometric patterns, chosen according to their meaning, formal appearance. performance, workability, stability or resistance, geometric ordering that we call rigging, because rigging consists in arranging formats of a structure in space, to constitute the masses.

5. (Constructive) elements. The architectural masses, to form spaces, are articulated through elements of structures or specific structure. They are characterized by their constructive mission according to their structure, enclosure or installation, their techniques and means used and their formal appearance.

6. Spaces. The construction elements are associated, following the geometric guidelines of a regulatory layout, and according to their respective construction missions, to form groups that contain habitable spaces and that we call plants.

C. RELATION BETWEEN PHASES

RELATION BETWEEN STRATIGRAPHIC UNITS

The analysis of stratigraphic / constructive relationships is undoubtedly the most delicate part of the process. In it three different readings are mixed: that of the spatial situation of the elements – in contact or not, above, below, to the alphas – that is paired with the constructive action that created them – cover, fill, support, attach, cut, join, etc. – that concludes with a temporal sequence of contemporaneity or of antero / posteriority. As you can see, the constrictive actions can be of many types, although to facilitate the analysis they are reduced to half a dozen; while the possible temporary relationships are only two.

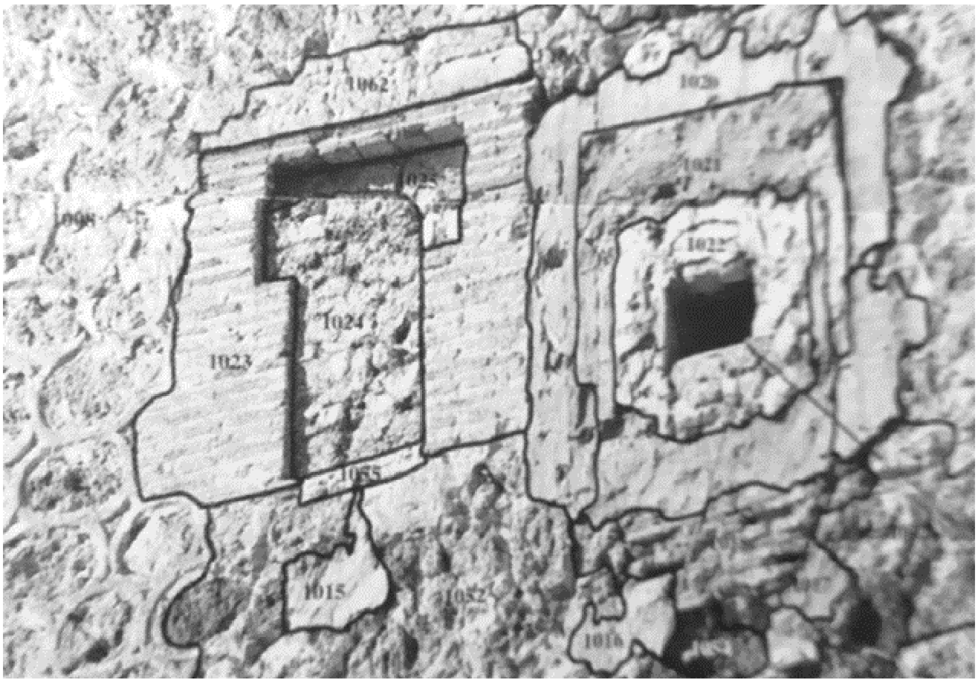


Fig. 34. From F. Vela, "La arqueología en restauración" en *Tratado de rehabilitación*, DCTA (UPM), Editorial Munilla-Leria, Madrid 1999.

Experts offer definitions of what the columns mean and the relationships that link them to the ranks. R. Parenti mentions two relations of contemporaneity ("equal to" and "unites"), four relations of anteriority ("it is supported", "covered by", "cut by" and "filled by") and its inverse of posteriority; C. Mileto uses almost the same words to designate two of contemporaneity ("equal to" and "is linked to"), four of anteriority ("supports-" "covers", "cuts and fills in") and their inverses of later, while Caballero summarizes his list in the following table.

	JOIN	SUPPORT	ATTACH	COVER	CUT	FILL
Previous to		X	X	X	X	X
Contemporary to	X					
Posterior to		X	X	X	X	X

Fig. 35. Temporal relationships transformation table. Susana Mora.

1. Relations of contemporaneity whose casuistry is quite captious.

– "Equal to", which is a consequence of admitting that we have exceeded our suspicion by identifying elements or interfaces because other constructive elements concealed continuity or because we did not detect that the elements were "matched" (linked) by a missing section, which we now identify as a virtual element.

– "Joins to", which the author reserves for the corners of walls and is based on interpreting that the correct locking of formats and a unitary rig does not convert the jog in an interface, but only in an angle of those that form the lines of the regulatory path.

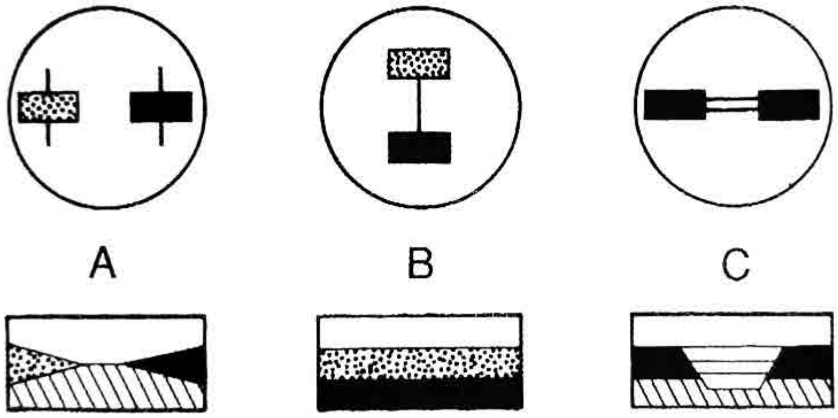


Fig. 36. From F. Vela, "La arqueología en restauración" en *Tratado de rehabilitación*, DCTA (UPM), Editorial Munilla-Leria, Madrid 1999, p. 213.

Relations between units of archeological stratification:

A. Units without direct stratigraphic connection.
B. Superposed units.
C. Interrelated units as parts separated from the whole.

- It leans on / is supported, "is when you notice differences in materials and matching equipment in a continuous surface, an interface, hall is a line followed in the face".

- "Covers / is covered by", is a relationship similar to the previous one, but reserved for relations between a wall and its coverings; It is therefore a purely dimensional nuance: one element has "two dimensions and peak" and the other three.

- "Cut to / is cut by", based on the interpretation of the surfaces of the elements as cut interfaces (thanks mainly to the fragmentary shape of formats), it is understood that an element or interface has been cut. To this relationship Parenti devotes more attention than any other, although it is perceptually the least ambiguous.

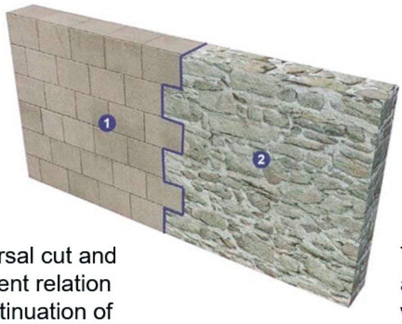
- "Fill in / is filled by", relationship observed. "when it is built inside an interface or surface itself, whether it is an opening (the windows, a door), or a removal of material", which is the previous case.

Support relation

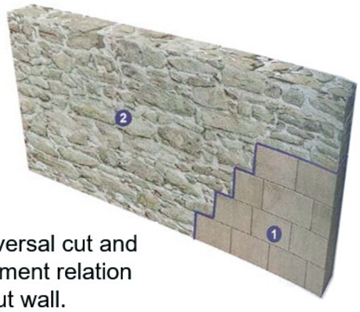
Longitudinal cut and attachment relation

Transversal cut and attachment relatior

Complete attachment relatior

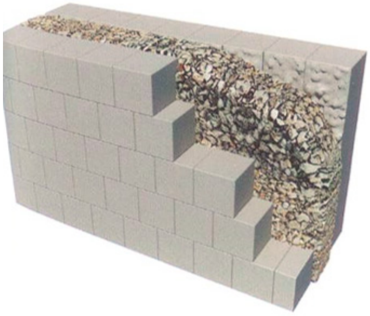


Transversal cut and attachment relation with continuation of work.

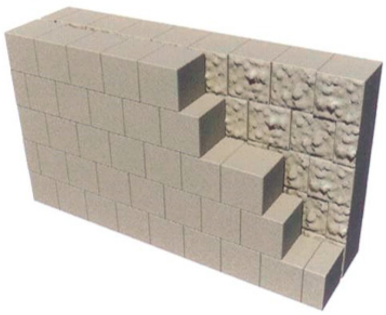


Transversal cut and attachment relation with cut wall.

Partial attachment relation



Two faces ashlar stone masonry wall with internal filler



Two faces ashlar stone masonry wall without internal filler

Two faces stonework masonry wall with internal filler

Two faces wall (one on stonework masonry and another on ashlar stone masonry) with internal filler

NOTES

It is necessary an introduction, when we speak on archaeological field: the protection will be necessary.

The protective Shelters for Archaeological Sites, Proceedings of a Symposium Herculaneum, Italy, 23-27 september 2013, ed. by Z. Aslan, S. Court, J.M., Teutonico, J. Thompson, London 2018;

1) See SANTANGELI VALENZIANI R., *Città ieri e di oggi, archeologia di ieri e di oggi*, in "Materiali e Strutture, Problemi di conservazione", n.s. a.VII, n. 13, 2018, p. 9. For a historical profile, see: BONI G., *Scavi del Foro Romano, Aedes Vestae*, in "Nuova Antologia", 1, agosto 1900, pp. 425-444; ID., *Il metodo nelle esplorazioni archeologiche*, in " Nuova Antologia", 36, 16, 1901, pp. 312-322; MUSTILLI D., *Storia degli studi archeologici*, Napoli 1943 and again MANACORDA D., *Prima lezione di Archeologia*, Roma-Bari 2004;

2) "The things he (the excavator) finds are not his own property, to treat as he pleases. Or neglect as he chooses. The are a direct legacy from the past to the present age, he but the privilegied intermediary through whose hands they come; and if, by carelessness, slackness or ignorance, he lessens the sum of kwnoledge yhat might have been obatained fro them, he knows himself to be guilty of an archaeological crime of the first magnitude. Destruction of evidence is so painfully easy, and yet so hopelessly irreparable". From H. Carter and A. C. Mace, *The tomb of Tutankhamun*, vol. 1924, in N. STANLEY PRICE, *Excavation and Conservation*, in *Conservation on Archaeological Excavations*, ICCROM, Roma 1985, p. 1;

3) The importance of making good records of Archaeological excavations hardly needs to be stated. in COLES J., *The site record and publication, in Conservation on Archaeological Excavations*, Roma 1985, p. 59;
   "The unpardonable crime in archaeology is destroying evidence which can never be recovered, and every discovery does destoy evidence unless it is intelligently recorded". From PETRIE F., *Methods and aims in Archaeology*, London 1904;

4) "It is only all right to raise material f you know how to conserve it". In PEARSON, *On site Conservation Requirements for marine Archaeology* in "ICOM Venise" 1975;

5) On the spread of archaeological discoveries: in the last years it has being a great change in the diffussion of the researchs or studies in monuments or archeologic places, and so there have being a great number of expositions, books and other publications about the advances in new discoveries. For example see: MENEGHINI R., SANTANGELI VALENZIANI R., *I Fori Imperiali, gli scavi del Comune di Roma (1991-2007)*, Roma 2007. But in last year we must remember: PILUTTI NAMER M., *Giacomo Boni, storia memoria e archeonomia*, Roma 2019; and a cura di A. Russo, R. Alteri, A. Paribeni, *Giacomo Boni, l'alba della modernità*, Milano 2021;

6) This work has being done during the workcamp that took place in april 2014 and april 2015 in Santa Maria la Real de Sasamon, Burgos, Spain, with students of ETSAM UPM in collaboration with DIDA of Florence, and Andrea Arrigheti as archeologist. During the previous studies for the Restoration Project of the church directed by Susana Mora, for the Junta de Castilla Leon;

7) HARRIS. E. C., *The stratigraphic Sequence; a question of time*, in "World Archaeology", 1975, pp. 109-121; ID, *Principles of Archaeological Stratigraphy*, 1979, ed.it., *Principi di Stratigrafia archeologica*, trad. it . Roma 193. See also: PARENTI R., *Una Proposta di Classificazione tipologica delle murature post-classiche*, in *Conoscenze e sviluppi teorici*

per la conservazione di sistemi costruttivi tradizionali in muratura, Acts of Convention of Bressanone 23-27 June 1987, ed. BISCONTIN G. and ANGELETTI R., Padova 1987, pp. 49-61; ID, *Sulle possibilità di datazione e di classificazione delle murature*, in FRANCOVICH R., PARENTI R., *Archeologia e Restauro dei monumenti*, Firenze 1988, pp. 280-304. DOGLIONI F., *Stratigrafia e Restauro*, Trieste 1997.

HARRISON R. (editor), *Manual of Heritage management*, Oxford (UK) 1994.

RUFFOLO A.S., *New insights to assess the consolidation of stone materials used in built heritage: the case study of ancient graffiti (Tituli Picti) in the archaeological site of Pompeii*, in Heritage Science, Vol. 8, n. 1, 2020.

PART II

HERITAGE PROBLEMS, CAUSES AND SOLUTIONS

The aim of this part of the book is to familiarize the lecturer with a set of criteria and architectural intervention techniques, to expand their theoretical knowledge of construction systems, analysing the causes that produce the different damages and the possible compatible consolidation solutions.

They will represent graphically the proposed intervention, developing a final intervention project, and describing and defending it with arguments from the culture of restoration.

Previous page.
Carracedo Monastry,
Spain. Salvador Pérez
Arroyo and Susana Mora.
Photo by Susana Mora.

CHAPTER 7. FOUNDATIONS: CONSTRUCTIVE SYSTEMS, PROBLEMS, CAUSES AND SOLUTIONS. SOIL MOISTURE

INTRODUCTION

Reminder of what we have written in Part I: Methodological Approach to Conservation.

First of all, we must study, to know the "monument" and its problems, after the "libraries and archives survey".

SURVEY

1. Geometrical Survey

2. Constructive Systems Survey

3. Stratigraphy. Phases

4. Constructive Survey

5. Map of Damages

6. Damage Monitoring

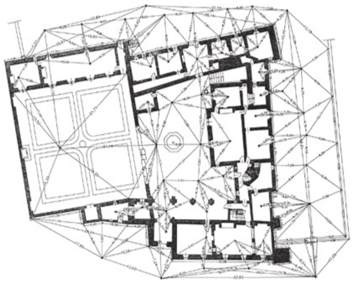


Fig. 1. Geometrical Survey. From F. Vella, E. Viganò, "Final Degree Project", *Manuale del restauro architettonico*, Mancosu, Roma 2001, Section H. Approcci metodologici, rilievo geometrico, 12.

Fig. 2. Architectural Survey. Elevation by P. F. Cueto.

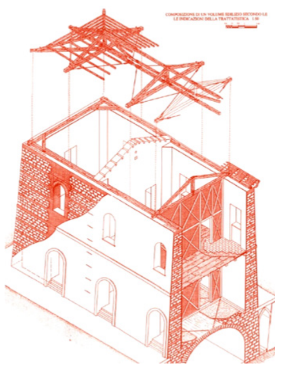


Fig. 3. Mechanical and Constructive Survey. From Carlo Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001.

CONSTRUCTIVE SYSTEMS

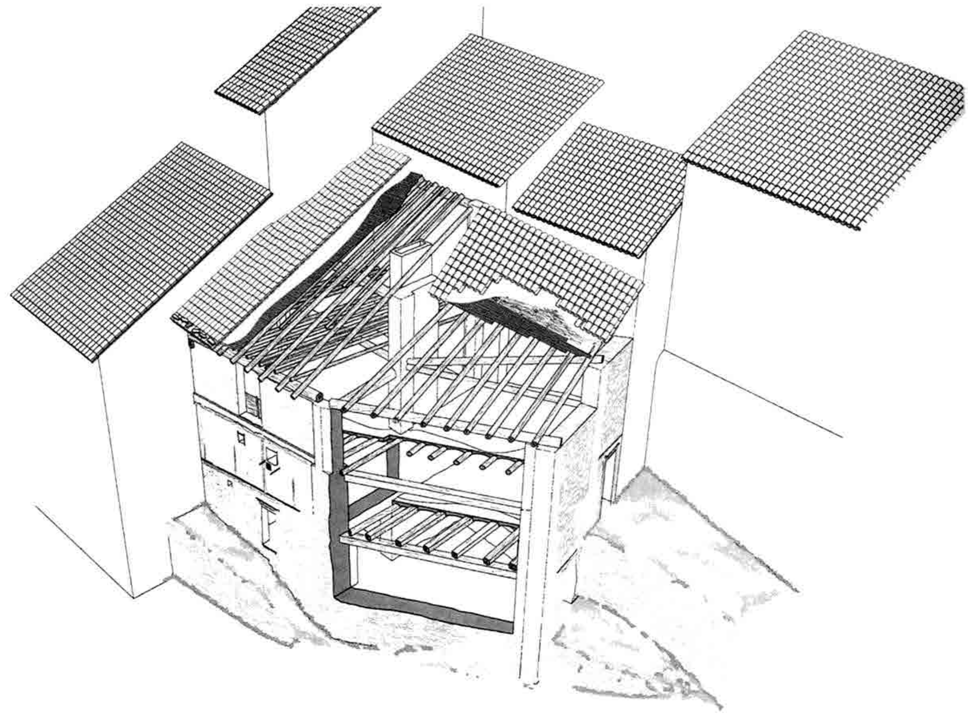


Fig. 4. Constructive Systems Survey. From F. Vegas, C. Mileto, *Aprendiendo a restaurar*, in *PH: Boletín del Instituto Andaluz del Patrimonio Histórico*, year n. 26, n. 93, 2018.

MAP OF DAMAGES

Using as a basis a cartographic architectural survey on which is portrayed the perimeter of the areas subject to some typical aspects of degradation, such as surface deposit, cracking, cracking, fracturing, scaling, alveolization, black crusts, pitting, corrosion, spotting, efflorescence, detachment, etc.

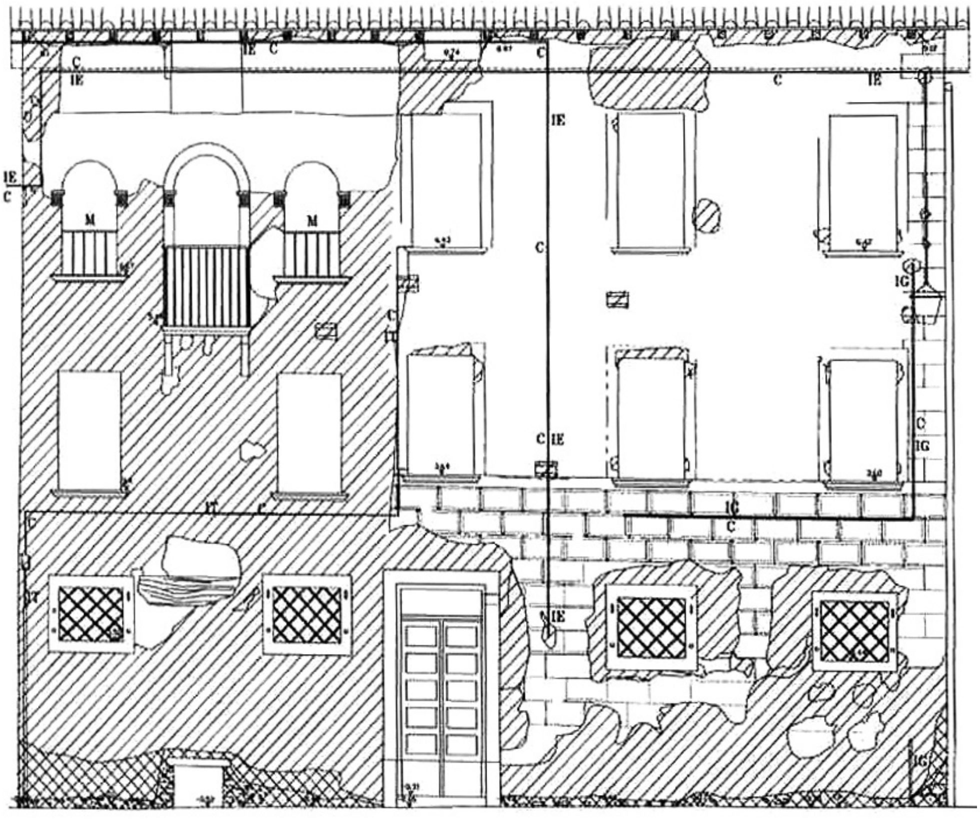


Fig. 5. Map of Damages. From F. Doglioni, *Nel restauro. Progetti per la architettura del passato*, (IUAV Documenti), Marsilio, Venezia 2008, p. 228.

First of all, we must know the principal “historic” constructive systems.

CONSTRUCTIVE SYSTEM

ELEMENTS

- Vault
- Lintel
- Foundations
- Walls
- Floors
- Roofs
- Other Traditional Structures

CRITERIA

- Compatibility
- Minimal Intervention
- Reversibility

The interventions on the “structures” must be decided after having identified their values, degradation, and the causes, the current conditions and the type of material and constructive system that constitutes the construction.

Fig. 6. Santa Maria di Collemaggio, L’Aquila. Photo by Susana Mora, 2012.

GENERAL CAUSES OF PROBLEMS: GROUND

Soil settlements belong to the category of indirect actions that induce movement at the boundaries. Soil deformation is one of the major causes of damage to buildings and therefore it is essential to understand the main concepts with a general view of the various problems and solutions.

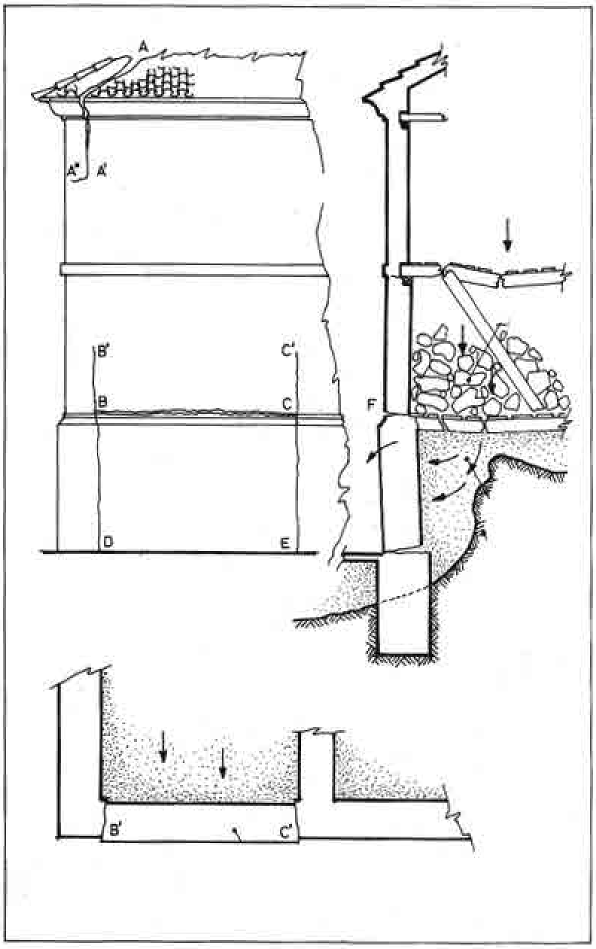


Fig. 7. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1985.

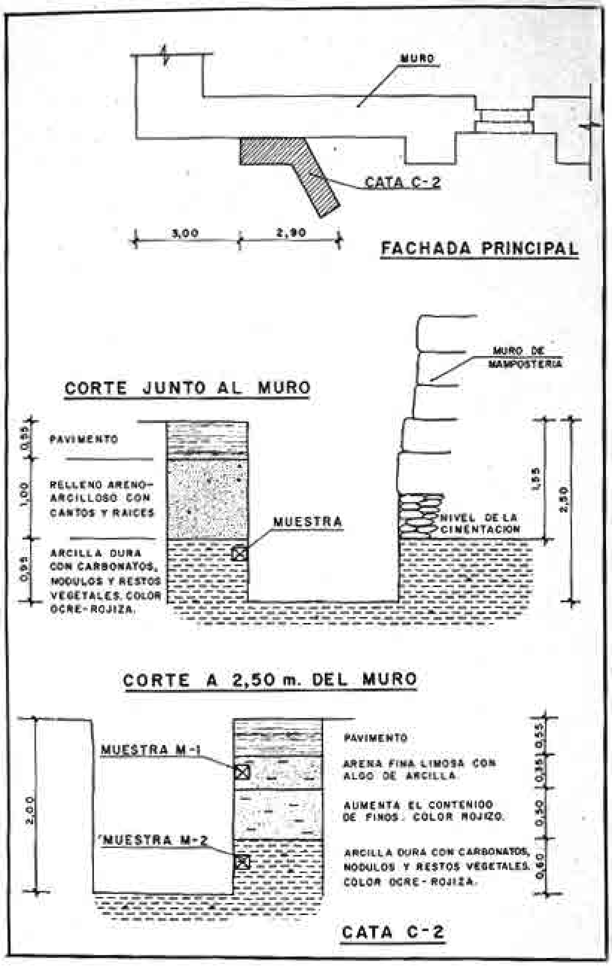


Fig. 8. Geological study. San Bartolomé, Tarazona de la Mancha. Project by Susana Mora.

GENERAL CAUSES OF PROBLEMS: WATER

The penetration of moisture into the walls is one of the main causes of deterioration in the structures. This humidity can come from:

- A. Condensation of water vapor
- B. Rainwater that penetrates through the roof or external surface
- C. Soil moisture that rises through the foundation and the walls by capillarity

FOUNDATIONS

> “Foundations are that part of a building that distributes the loads from roofs and walls on to the earth bellow. This is generally done by a widening of the wall into a footing which bears on the soil under the building; however, in many early building no such widening was practised. The main factor in the permanence of architecture is the sufficency of its foundations and, when this is lacking, there is no sense in spending large sums of money elsewhere on superficial restoration work. Ground movement is not at all uncommon. Geologically, it occurs continuously and, when extreme, causes earthquakes. It can be induced by manmade activities such as mining and underdrainage. Heavy rain can also induce landslides, while underground streams, especially in chalk and gravel, can cause potholes and caves under buildings. Conversely, blocked underground watercourses may cause the water table to rise. The absolute movements of a building -with the exception of earthquakes-are of less concern than differential or relative movements which may be caused by different types of ground under the building or uneven loading of different parts of the preexistence”.
>
> From FEILDEN B. M., *Structural elements IV: Foundations in Conservation of Historic Buildings*, Oxford 1982, revised edition 1994, third edition 2003, p. 79.

1. DAMAGES AND BACKGROUND

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

CAUSES:
Excavations, paving, sanitations, wells, cellars…

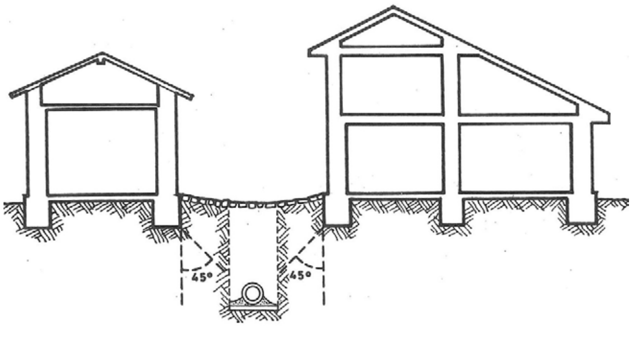


Fig. 9. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Madrid 1985, p. 144.

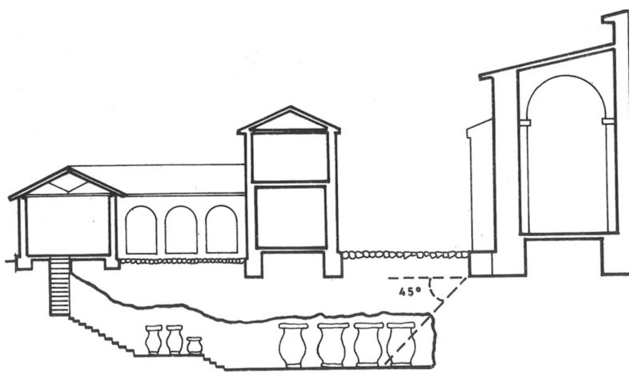


Fig. 10. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1985, p. 151.

2. ANALYSIS OF OBSERVED PATHOLOGY

– VERIFY THE ORIGIN OF DAMAGES
– TYPOLOGY OF FOUNDATION AND GROUND DAMAGES:
  · EDGE MOVEMENTS
  · INTERNAL MOVEMENTS
  · GENERALIZED MOVEMENTS
  · TWIST
  · COLLAPSE

PROBLEMS

- Damages and deformations in a masonry structure:

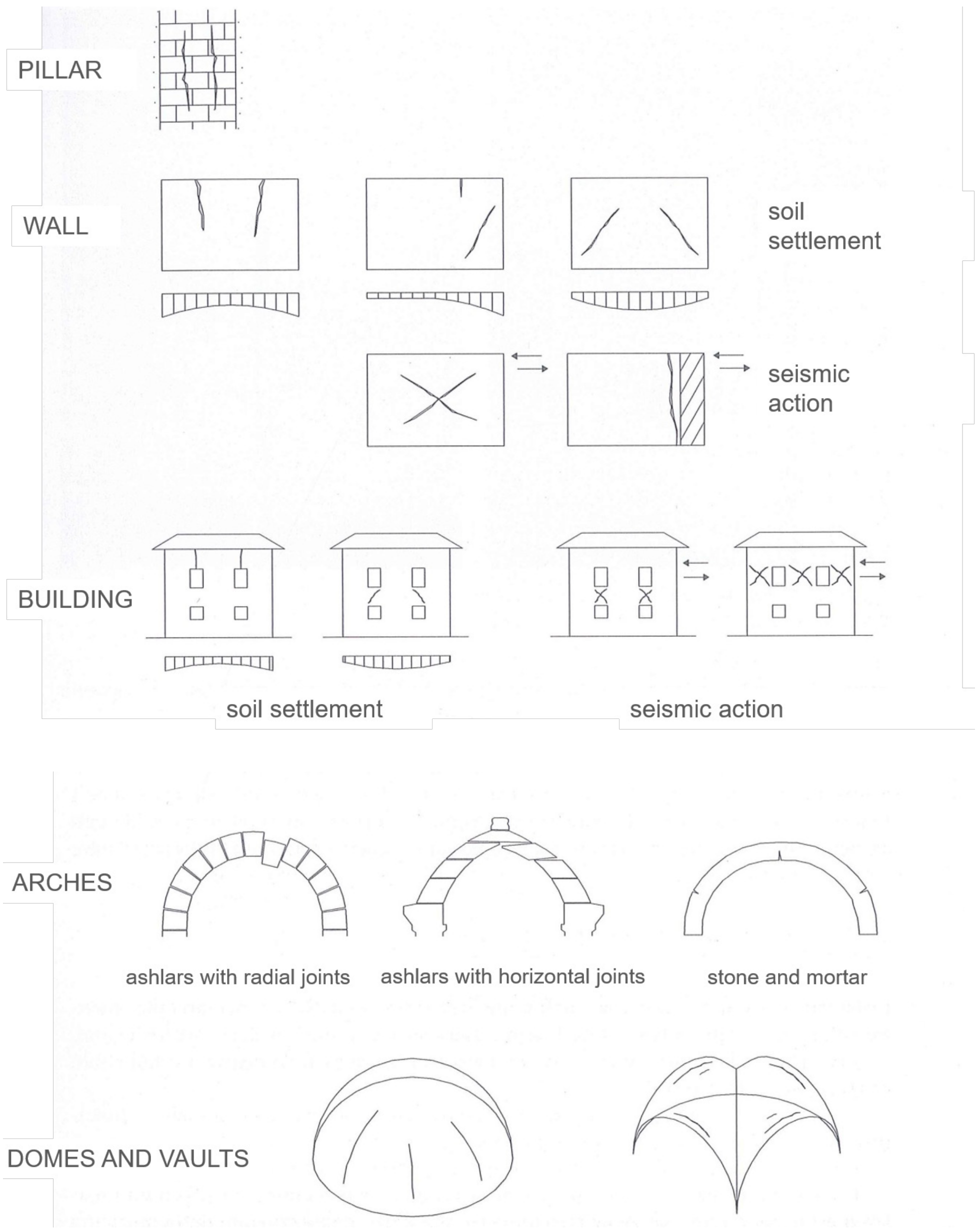


Fig. 11. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2001, p. 121.

- Foundation and ground damages: Edge movements.

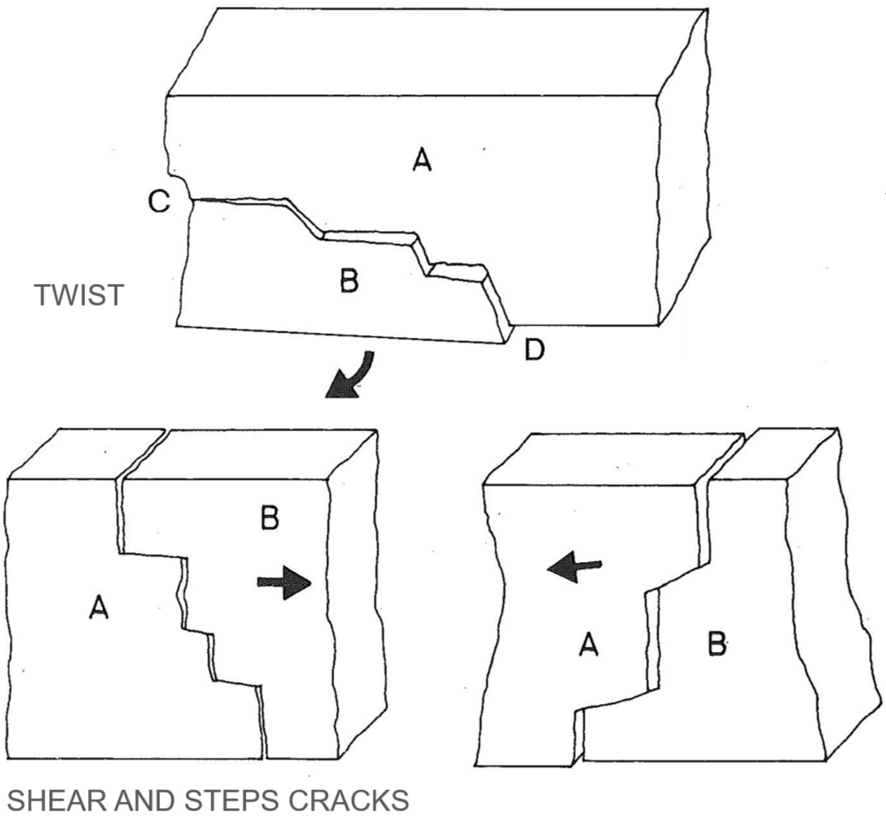


Fig. 12. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1985, p. 54.

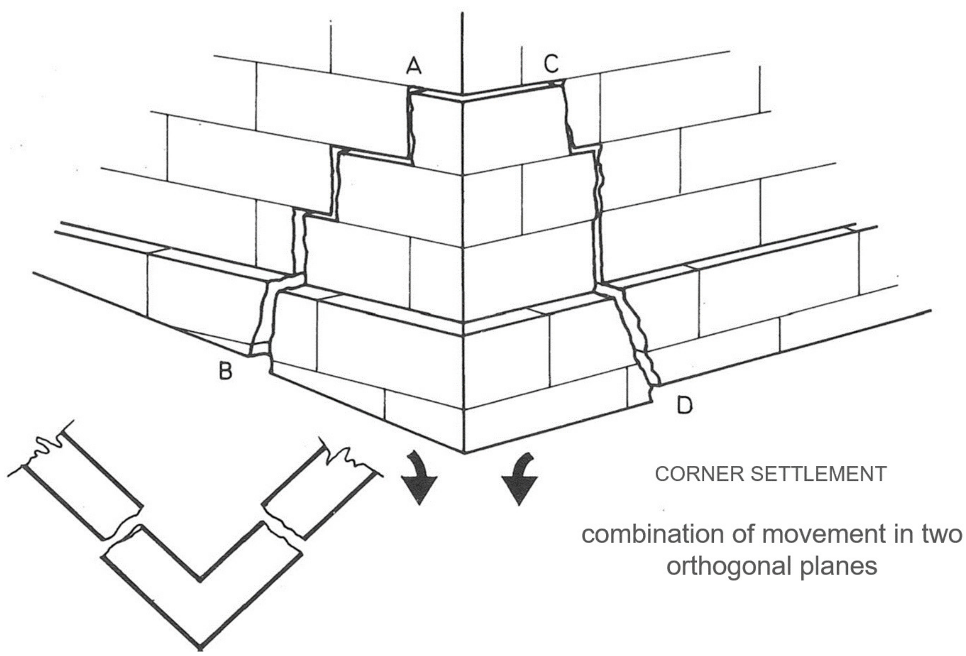


Fig. 13. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1985, p. 63.

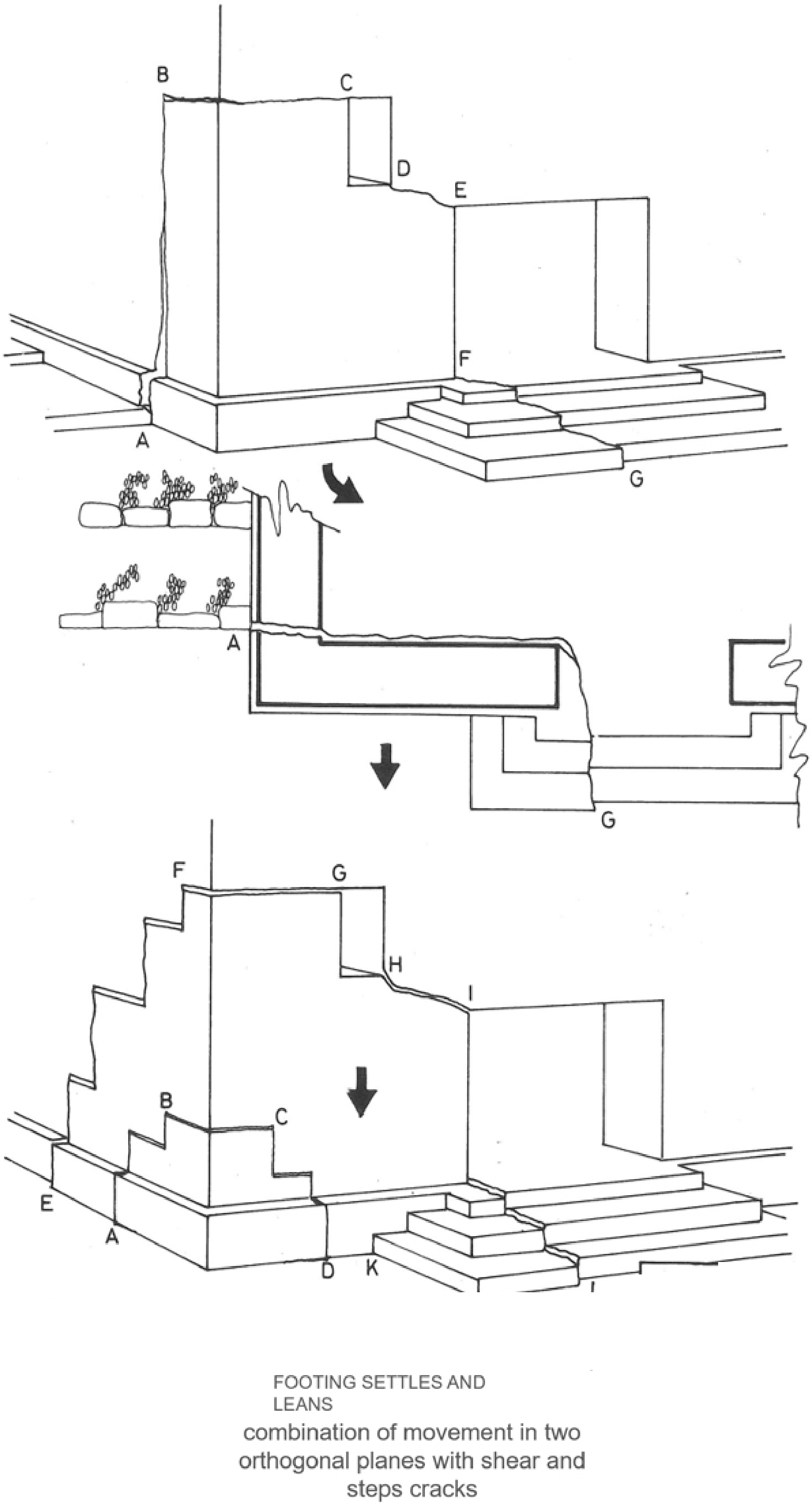


Fig. 14. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1985, p. 66.

- Foundation and ground damages: Internal movements.

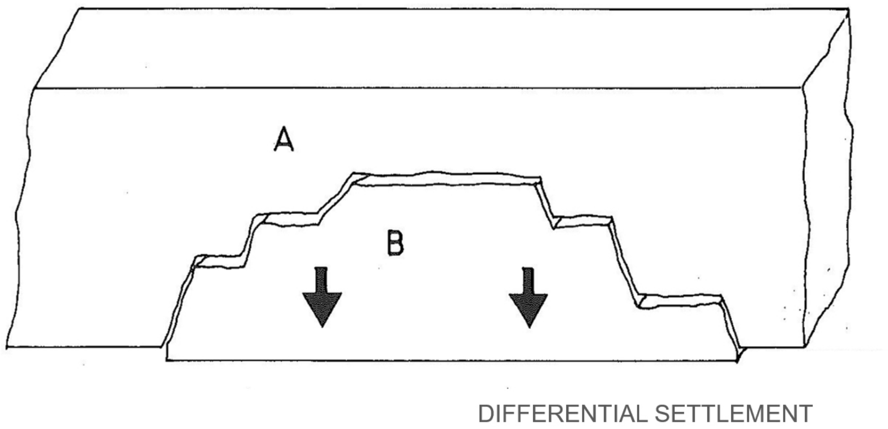


Fig. 15. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1985, p. 54.

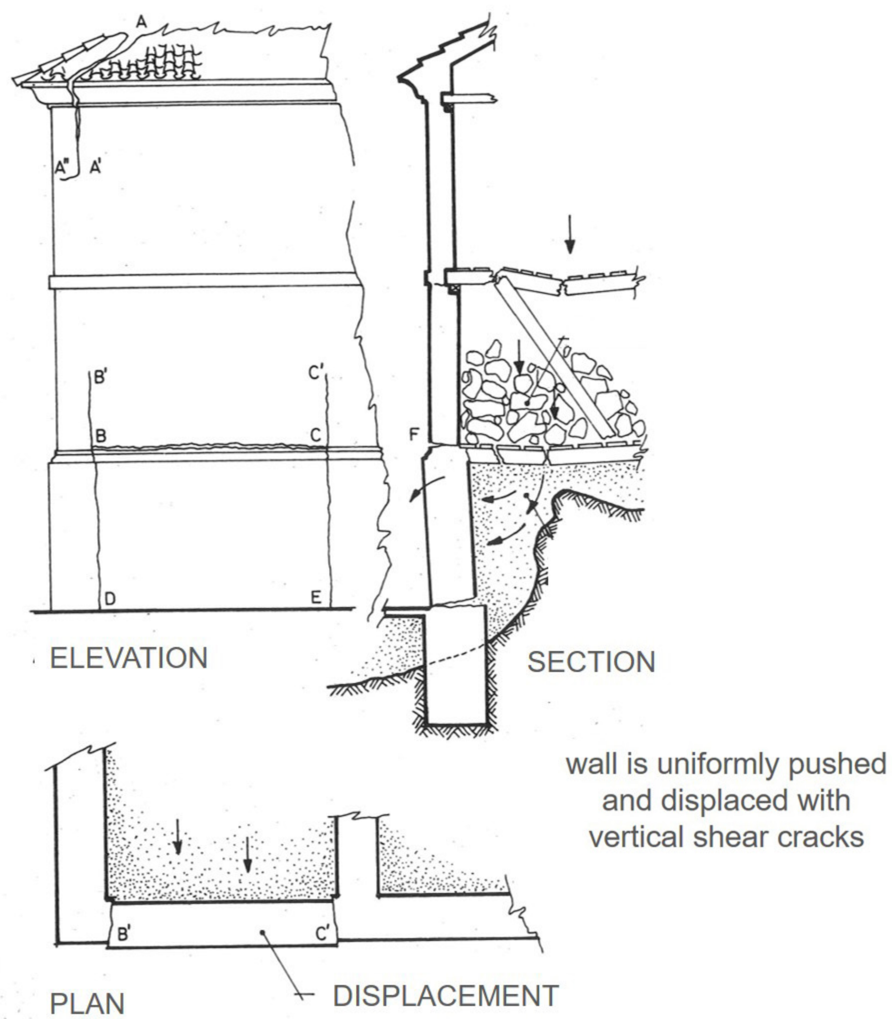


Fig. 16. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1985, p. 56.

3. VERIFICATION OF THE HYPOTHESES

- STRUCTURAL ANALYSIS
- SURVEYS AND PROSPECTIONS
- GEOTECHNICAL INTERPRETATION

4. SELECTION OF REPAIR SOLUTIONS

1. REINFORCEMENT
2. BRIDGING AND ENLARGE FOOTINGS
3. NEW FOUNDATION OVER THE PREVIOUS
4. MICROPILES
5. REPLACEMENT
6. INJECTIONS
7. EXTERIOR REINFORCEMENT
8. JET GROUTING

(1) Work of consolidation, repair or reconstruction that is made to the foundations of a wall or a building, without damaging the superstructure.

1. REINFORCEMENT

Wider footings solutions

1. Original foundation
2. Grout
3. Perimeter ring or concrete tie beam
4. Anchor bar
5. Drill
6. Cable-stayed perimeter ring
7. Wedge cutout
8. Pyramidal ring
9. Toothed joint

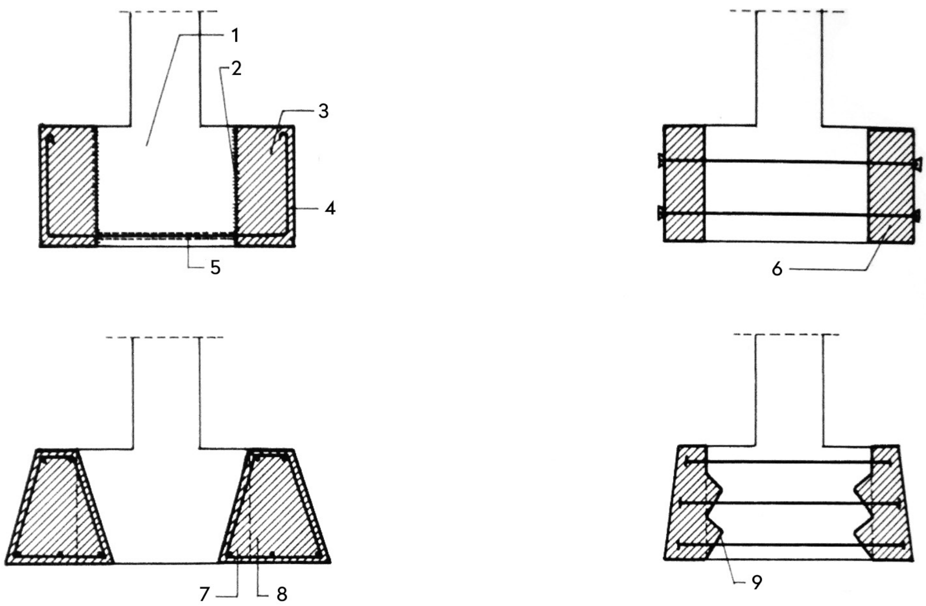


Fig. 17. From J.M. Rodríguez Ortíz, *La cimentación*, Curso COAM, Madrid 1984, p. 32.

2. BRIDGING AND ENLARGE FOOTINGS SOLUTIONS

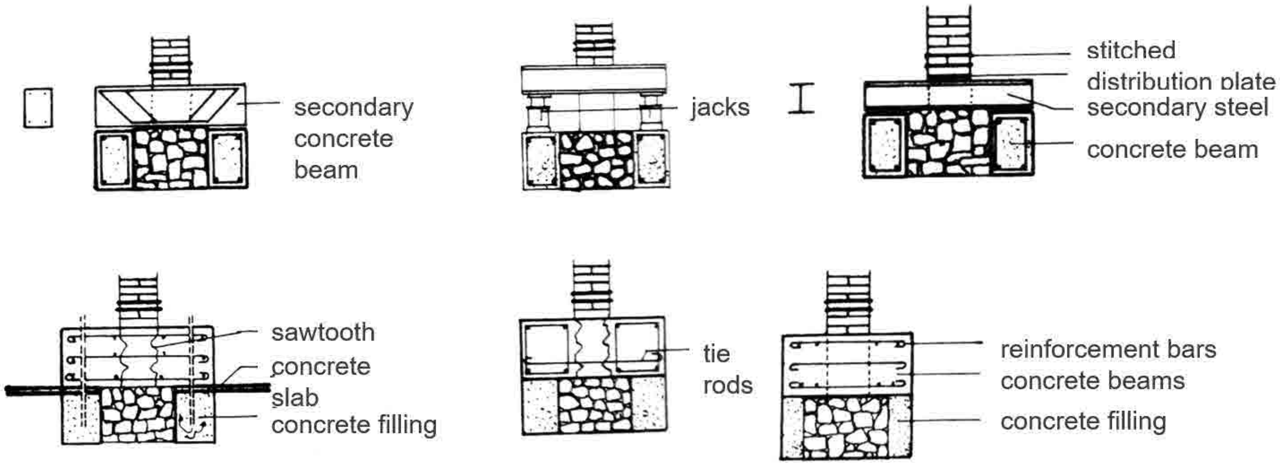
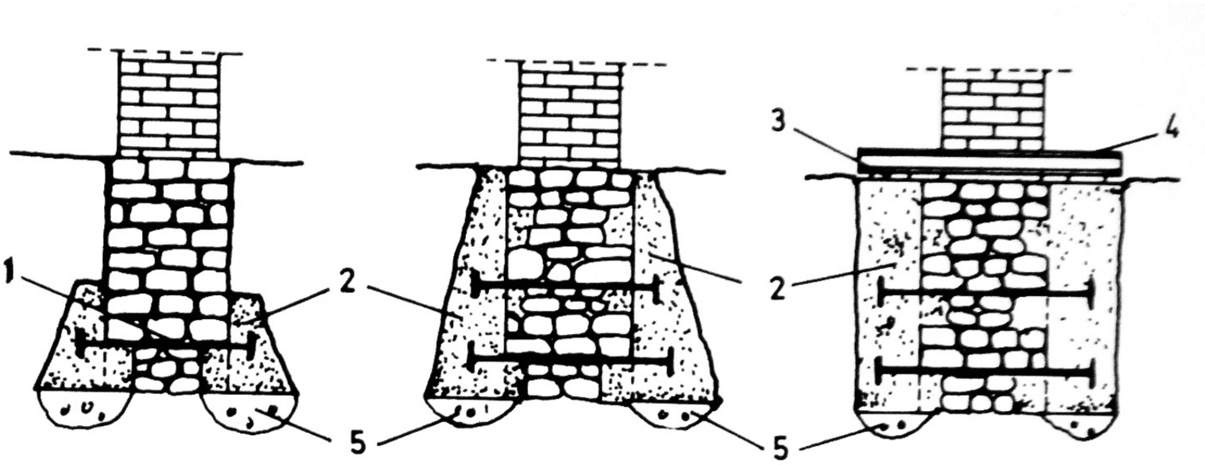


Fig. 18. From J.M. Rodríguez Ortíz, *La cimentación*, Curso COAM, Madrid 1984, p. 32.

Enlarge footings solutions with local ground improvement.



1. Tie rods; 2. Concrete; 3. Wedges; 4. Secondary beam; 5. Compacted or injectedsoil.

Fig. 19. From J.M. Rodríguez Ortíz, *La cimentación*, Curso COAM, Madrid 1984, p. 33.

3. NEW FOUNDATION PLACED OVER THE PREVIOUS

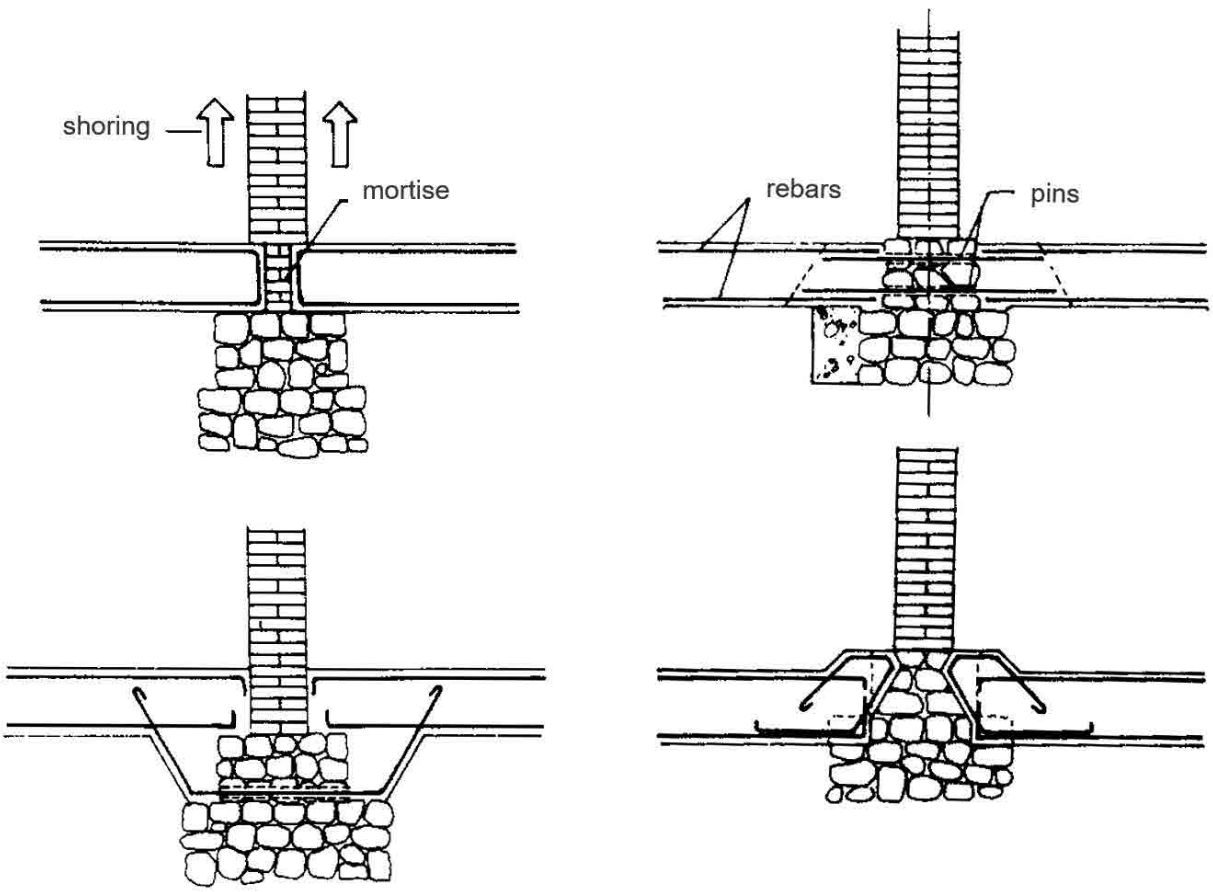


Fig. 20. From J.M. Rodríguez Ortíz, *La cimentación*, Curso COAM, Madrid 1984, p. 35.

4. MICROPILES

(2) Micropiles are a deep foundation element constructed using high-strength, small-diameter steel casing and/or threaded bar.

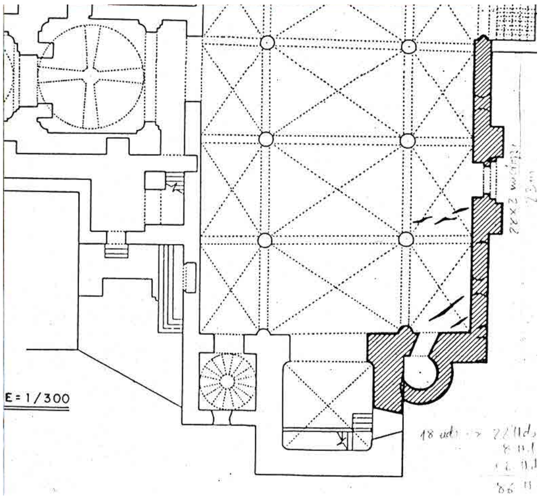
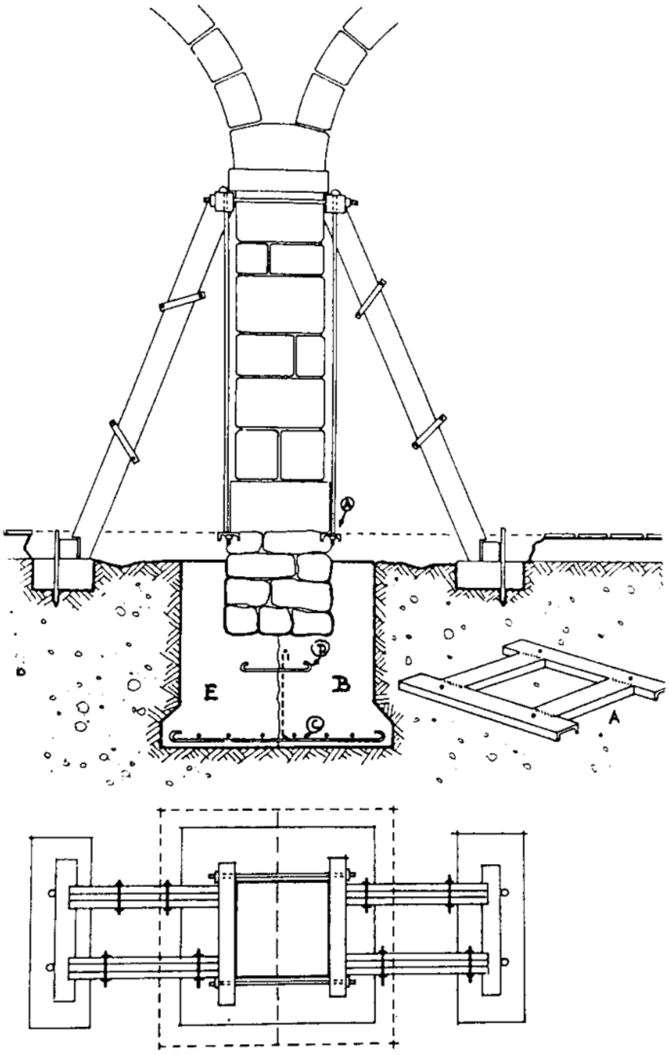


Fig. 21. Above left. San Bartolomé, Tarazona de la Mancha. Photo by Susana Mora.

Fig. 22. Above right. Floor plan by Susana Mora.

5. REPLACEMENT

Complete shoring of the pillar for replacement of the foundation with shoring and hanging of the pillar.



A. Metallic frame
B. Half the foundation trench
C. Footing reinforcement
D. Rebar nailed on the ground

Fig. 23. From J.M. Rodríguez Ortíz, *La cimentación*, Curso COAM, Madrid 1984, p. 37.

Complete shoring of the pillar for replacement of the foundation with shoring frames on hydraulic jacks.

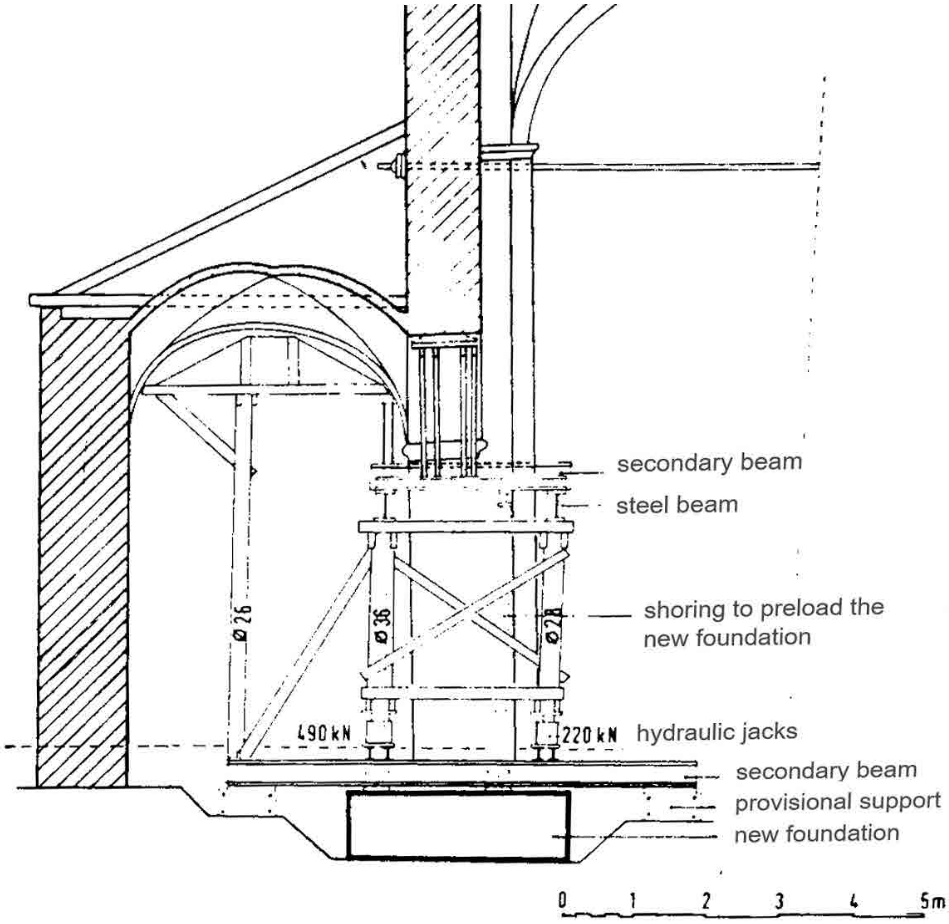


Fig. 24. From J.M. Rodríguez Ortíz, *La cimentación*, Curso COAM, Madrid 1984, p. 37.

6. 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, returning the mechanical capacity to the foundation.

INJECTIONS BY GRAVITY

- Injection control
- Grout density
- Washing inner leaf

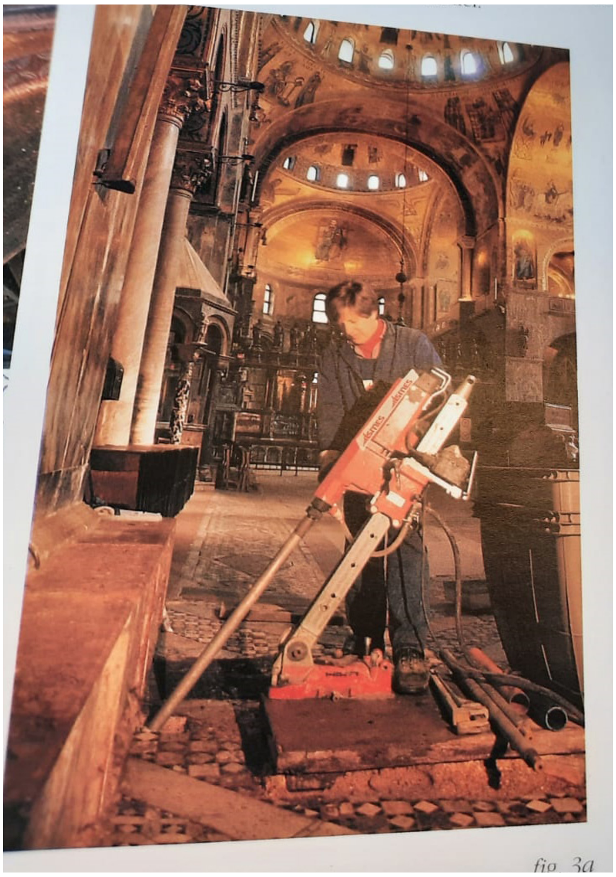


Fig. 25. Restoration of the crypt of San Marco, Venezia. From *San Marco la cripta e il restauro*, CM Vallardi & Associati, 1993, p. 83.

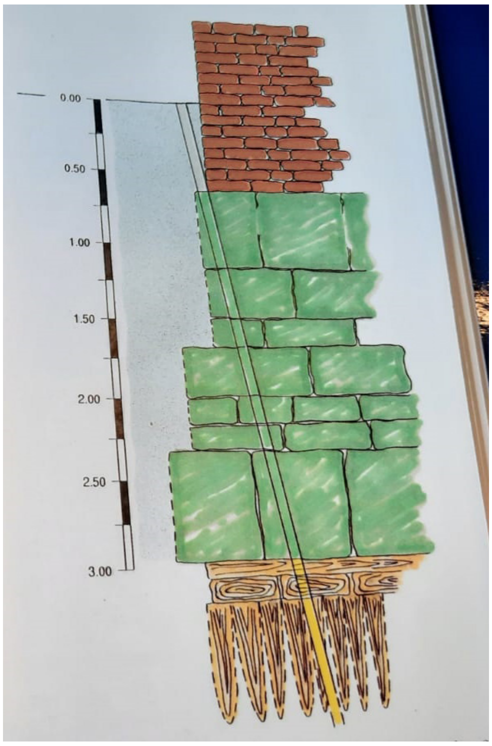


Fig. 26. Restoration of the crypt of San Marco, Venezia. From *San Marco la cripta e il restauro*, CM Vallardi & Associati, 1993, p. 83.

INJECTIONS BY PRESSURE

- Injection control
- Grout density
- Washing inner leaf

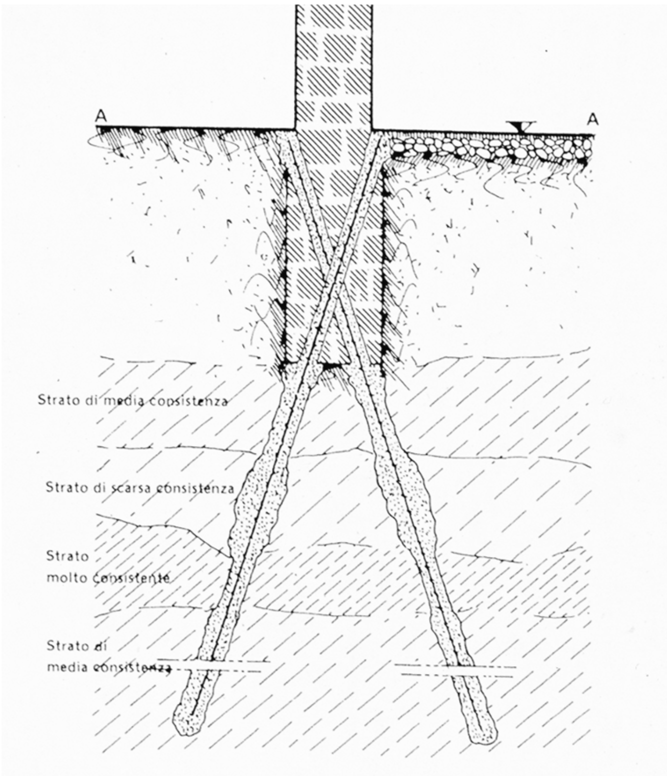


Fig. 27. From F. Lizzi, *The static restoration of monuments*, Sagep Publisher, Genova 1982, p. 29.

PROBLEMS

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

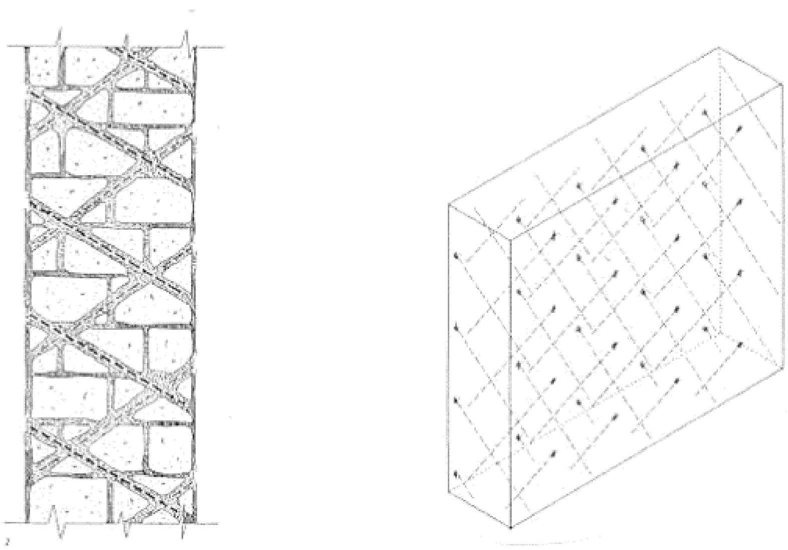


Fig. 28. From F. Lizzi, *The static restoration of monuments*, Sagep Publisher, Genova 1982, p. 18.

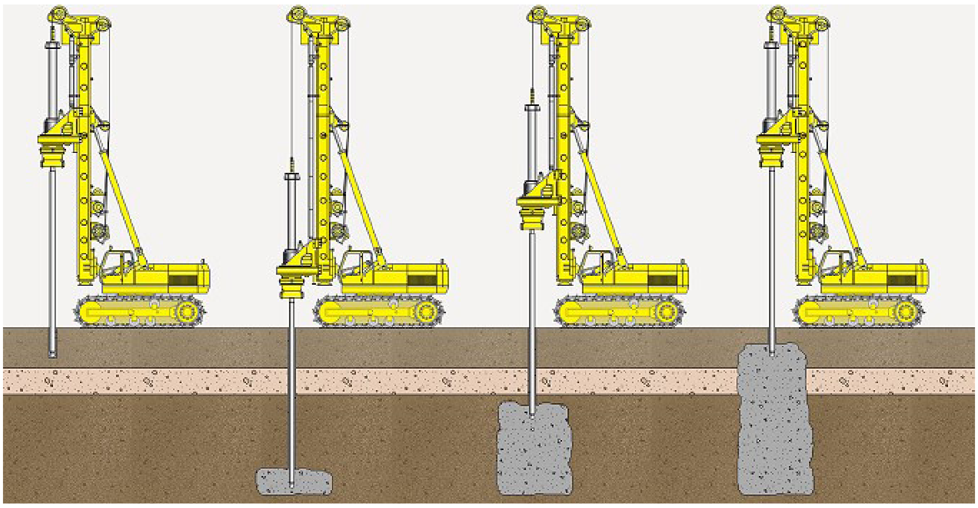
7. EXTERIOR REINFORCES

Fig. 29. Parish Church, Villalba del Rey (Cuenca). Restoration by Susana Mora. (3)

8. JET GROUTING

Jet grouting involves inserting a cement bond material (usually cement grout) using one or more high-speed jet pumps. The energy from the jets break up the ground and restructure it, mixing it with the injected material to produce an improved ground. Any surplus material rises to the surface as spoil return

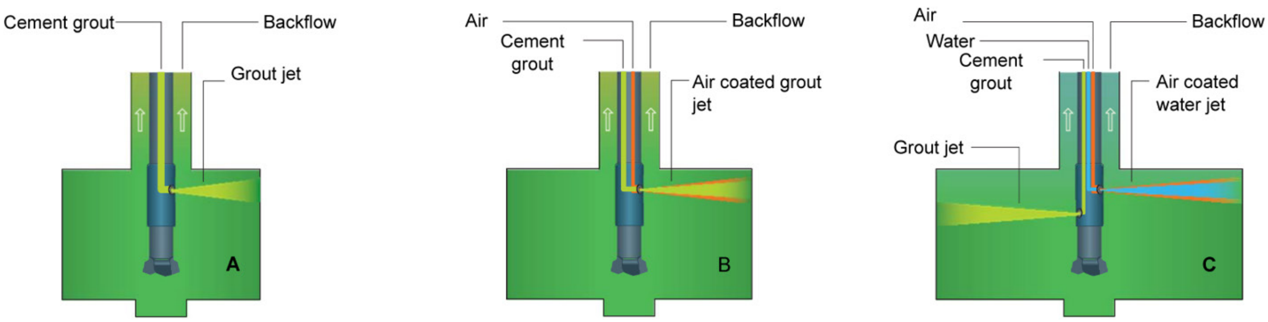
Fig. 30. Photo by F. Ripollés.



(4)

Fig. 31. Design by Fernando Ripollés.

Fig. 32. Design by Fernando Ripollés.



A. Single Fluid Jet Grouting
B. Double Fluid Jet Grouting
C. Triple Fluid Jet Grouting

Fig. 33. Design by Fernando Ripollés.

Application in restoration:

- Strengthening the foundation of existing buildings

- Treatment of the foundation of buildings near excavations

- Improving the ground foundation under increased loads or settlement

- Strengthening and consolidation of the bottom of excavations

- Strengthening of the soil

SOIL MOISTURE

(5) The objective is ensuring good ventilation and allowing for permeability in the wall surfaces.

1. CAVITY WALL / VENTILATION GALLERIES
2. WALL SECTIONS
3. SIPHONS
   WATERPROOFING
4. ELECTROOSMOSIS

1. VENTILATION GALLERIES

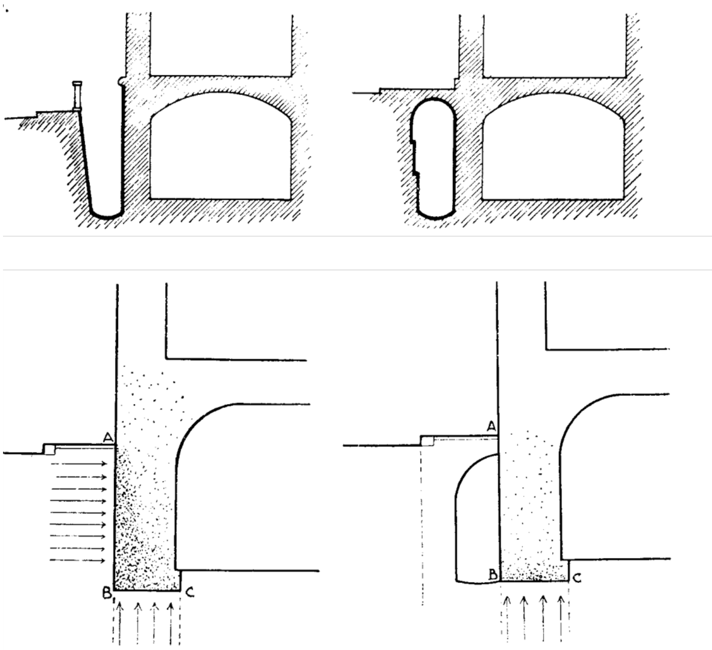


Fig. 34. From G. e I. Massari, *Risanamento igienico dei locali umidi*, Hoepli, Milano 1981, p. 111

2. WALL SECTIONS

INSULATING PLATES

Mechanical cutting of the wall for the insertion of insulating plates

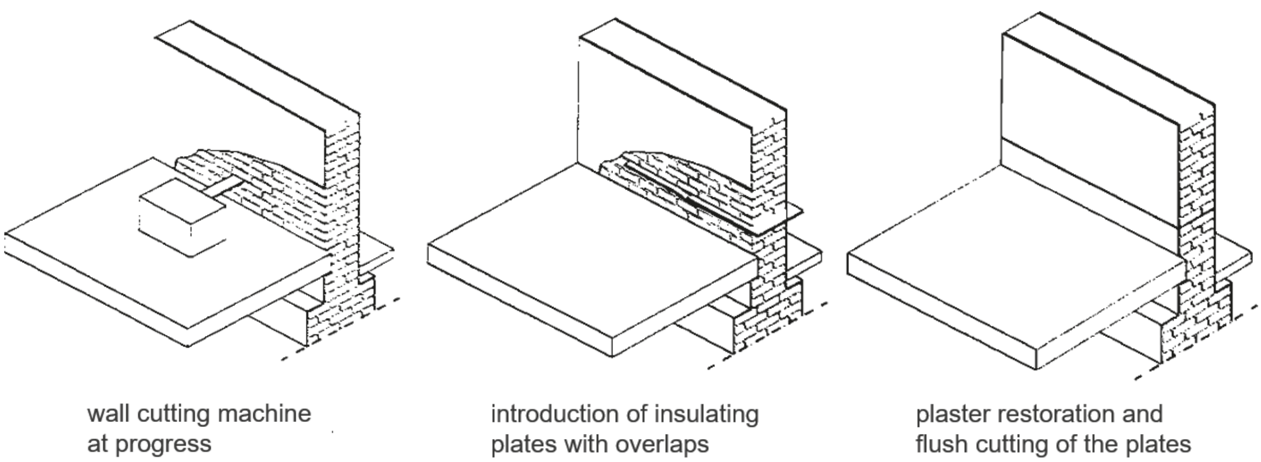


Fig. 35.

Method against the capillary rising of water: execution of a double series of partially overlapping holes for the insertion of insulating material.

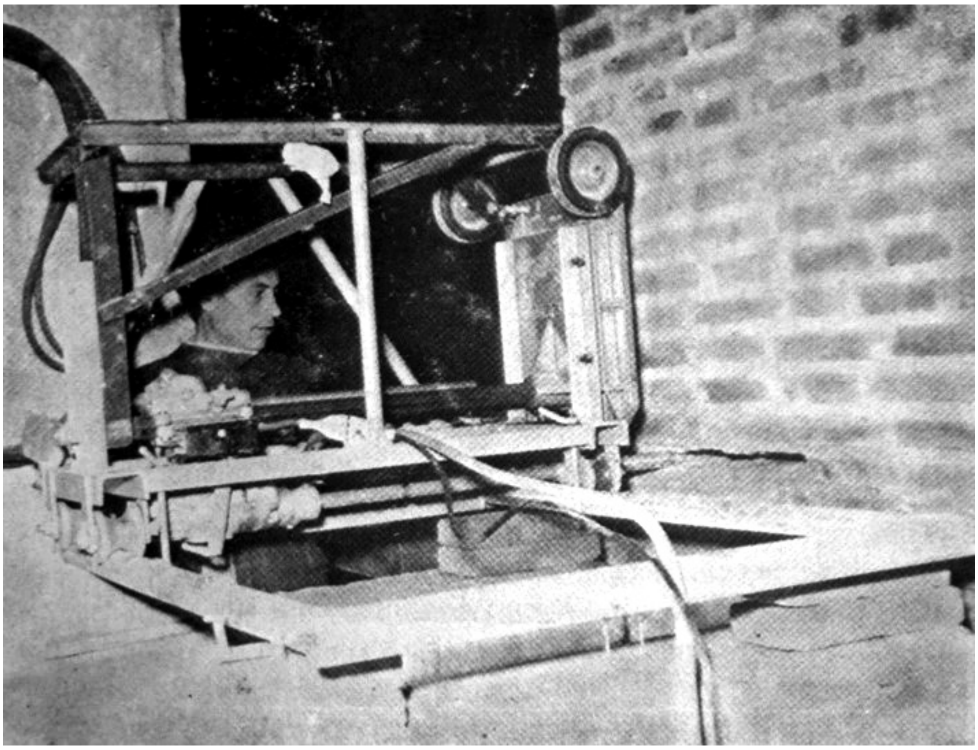


Fig. 36. Core drill in operation on a brick wall. From G. e I. Massari, *Risanamento igienico dei locali umidi*, Hoepli, Milano 1981, p. 107.

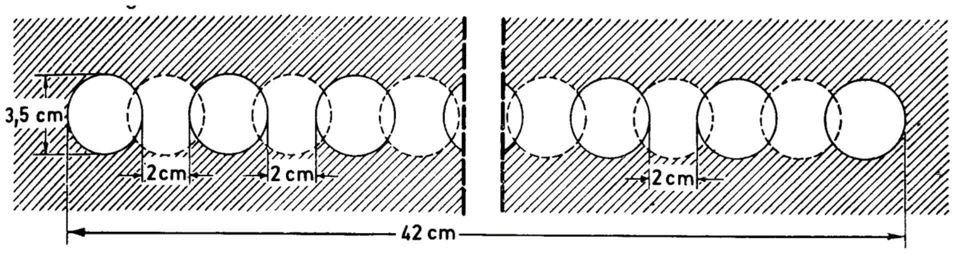
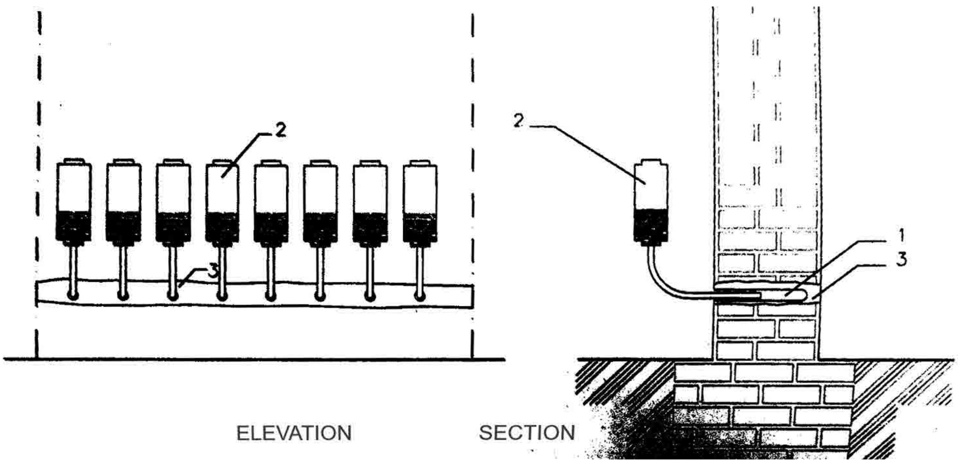


Fig. 37. Front view of the cut. From G. e I. Massari, *Risanamento igienico dei locali umidi*, Hoepli, Milano 1981, p. 107.

Horizontal barrier of slow diffusion waterproofing product



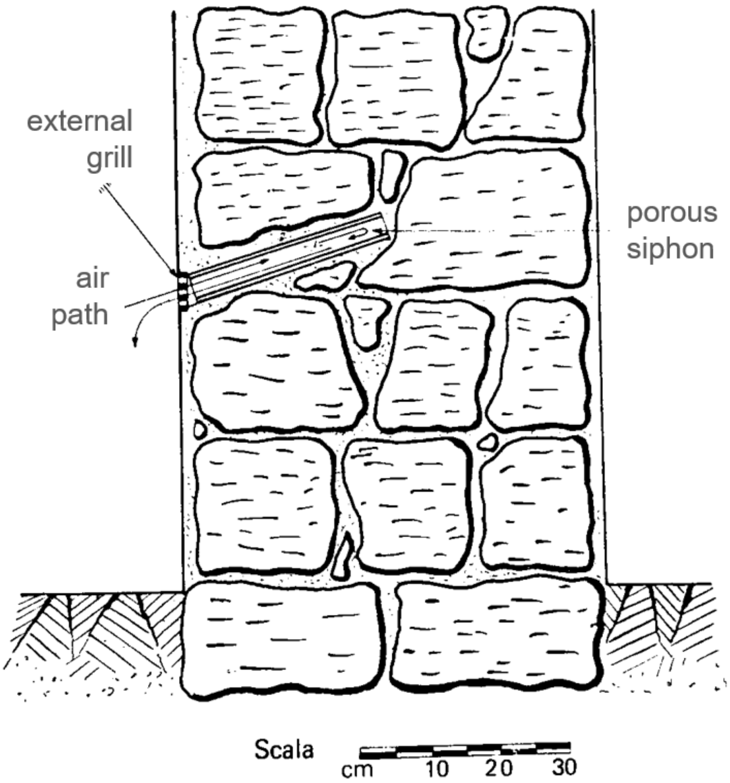
1. Hole
2. Containers of fluid resin
3. Spread of the waterproofing

Fig. 38. From G. e I. Massari, *Risanamento igienico dei locali umidi*, Hoepli, Milano 1981, p. 107.

3. KNAPEN ATMOSPHERIC SIPHON

The atmospheric knapen siphons, placed in the walls to be treated, attract humidity and evacuate it outside by an air circuit ensuring a permanent and effective functioning.

Each siphon, in its radius of action, attracts moisture, and this, impregnating its porous wall, saturates the drier outside air that enters the siphon channel.



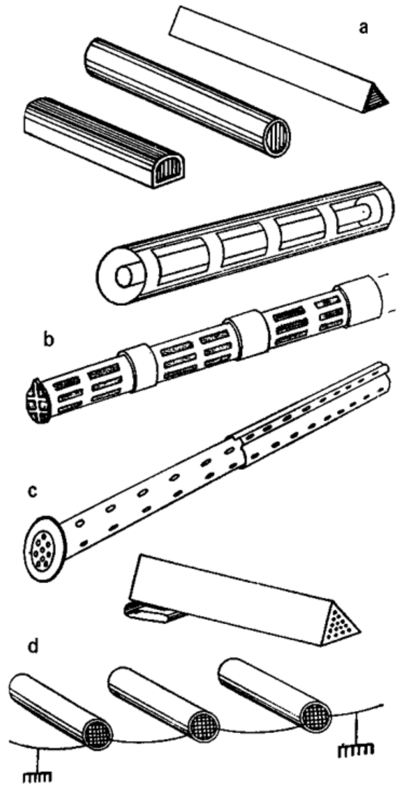


Fig. 39. Above left. From G. e I. Massari, *Risanamento igienico dei locali umidi*, Hoepli, Milano 1981, p. 113.

Fig. 40. Above right. From G. e I. Massari, *Risanamento igienico dei locali umidi*, Hoepli, Milano 1981, p. 115.

4. ACTIVE ELECTROOSMOSIS

The device emits small pulses from electrodes inserted in the wall to the ground. In this way the polarity between the soil and the wall is inverted, causing the ionized water to descend through the wall to the ground.

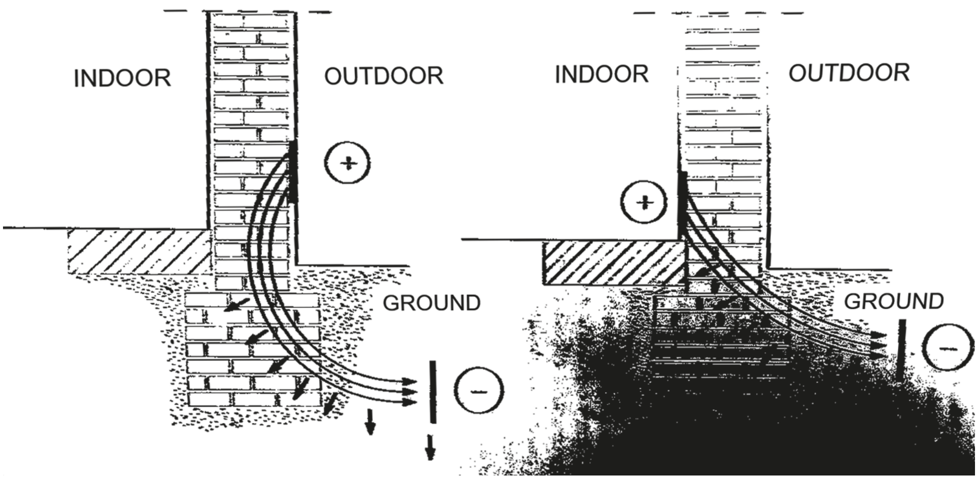


Fig. 41. From G. e I. Massari, *Risanamento igienico dei locali umidi*, Hoepli, Milano 1981, p. 119.

NOTES

For the study and restoration of architectural preexistence, it is necessary the knowledge of history of processuality of architecture.

For this is natural to remember some basilar books:

ALBERTI L., *De re Aedificatoria*, Firenze 1485, rist. anas. München 1976,
Francesco di Giorgio Martini, *Trattato di Architettura civile e militare (1456)*, I ed. a stampa C. Promis e C. Saluzzo 1841;
SERLIO S., *Trattato di Architettura*, i vari libri, da Venezia 1537, a 1584;
BARBARO D., *I dieci libri di Architettura di M. Vitruvio tradotti e commentati da mon. Barbaro*, Venezia 1556;
PALLADIO A., *I quattro libri di Architettura*, Venezia 1556-1570, numerose ristampe;
BORROMEO C., *Instructiones Fabricae et Supellectilis Ecclesiasticae*, liber. II Milano 1577;
SCAMOZZI V., *L'idea dell'Architettura Universale*, Venezia 1615;
BLONDEL F., *Cours d'Architecture enseingné dans L'Académie Royale d'Architecture, parte I*, Paris 1675;
CAPRA A., *La nuova Architettura civile e militare*, Bologna 1678;
DESGODETS A., *Les édifices antiques de Rome*, Paris 1682;
D'AVILER A.C., *Cours d'Architecture, qui comprend les ordres de Vignole*, Paris 1691;
BELIDOR B.F., *Architecture Hydraulique, ou l'art de conduire, d'eléver, et de menager les eaux*, 4 voll, Paris 1737-1753;
VITTONE B., *Istruzioni elementari per indirizzo de' giovani allo studio dell'architettura civile divise in libri tre*, Lugano 1760;
MASI G., *Teoria e pratica di Architettura, per istruzione della gioventù specialmente romana*, Roma 1788;
CHOISY A., *L'art de batir chez le romains*, Paris 1873;
CURIONI G., *Materiali da Costruzioni*, Torino 1872;
ANDREANI I., *Costruzioni lesionate, cause e rimedi*, Milano 1912;
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BREYMANN G. A., *Costruzioni in Pietra, e strutture murali*, Milano 1926;
RUSSO C., *Le lesioni dei fabbricati, sintomi, cause, effetti, rimedi*, Torino 1930;
MASTRODICASA S., *Dissesti Statici delle strutture edilizie*, Milano 1978, e successive edizioni;
GIANGRECO E., *Considerazioni ed esempi di restauro statico*, Milano 1971;
CROCI G., *Intuizioni e calcolo nella progettazione delle strutture*, Milano 1977;
DEFEZ A., *Il consolidamento degli edifici*, Napoli 1978, e successive, edizioni;
LIZZI F., *Restauro statico dei monumenti*, Genova 1981;
CARBONARA G., *Restauro e cemento in Architettura*, Associazione Italiana Tecnico Economica del Cemento, Roma 1981, vol. II, Roma 1984;
CROCI G., *L'origine dei dissesti, convegno di studio sul consolidamento delle costruzioni*, Udine 1982;
BINDA L., *Indagini per la valutazione dell'efficienza statica di strutture murarie*, in Ibidem,
ADAM J.P., *L'arte di costruire presso i romani, materiali e tecniche*, Milano 1988.

On foundations:

DAVEY N., *A history of building materials*, London 1961;
TORROJA E., *Rajon ser de los tipos estructurales*, ed it. *La concezione strutturale*, Torino 1966;
CESTELLI GUIDI C., *Geotecnica e tecnica delle fondazioni*, Milano 1980;
AA.VV., *San Marco, Basilica Patriarcale in Venezia, la cripta, il restauro*, Milano 1993;
DI PASQUALE S., *L'arte del Costruire, tra conoscenza e scienza*, Venezia 1996;
Structural studies, repairs and maintenance of historical buildings, edited by S.Sanchez-Beitia, C. A. Brebbia, vol. 3, Boston, Southampton, 1997.

IENTILE R., *Per un consolidamento consapevole dei beni architettonici*, Torino 2001.

1) To study historic types of foundations, problems and solutions dont forget Cap. V, LA REGINA F., *Sicurezza e conservazione del patrimonio Architettonico*, Liguori editore, Napoli 1995. See also, DI STEFANO R.C. *Il consolidamento strutturale nel restauro architettonico*, Edizioni Scientifiche Italiane, Napoli 1990, pp. 156 e sgg; CARTAPATI E., *Fondazioni*, in sezione c1, in *Atlante del Restauro*, vol. VIII, tomo II, diretto da Carbonara G., Torino 2004, pp. 159-175; ID., *Interventi sulle Fondazioni*, sezione G1, *Atlante del restauro*, vol. VIII, tomo II, diretto da Carbonara G., Torino 2004, pp. 487-507;

2) Micropiles used in the consolidation of the foundations of the church of San Bartolomé in Tarazona de la Mancha, Albacete, Spain. Project and direction of Restoration by Susana Mora, architect, for the Junta de Comunidades de Castilla La Mancha (1990-95).

3) Exterior reinforces for the parish church of Villalba del Rey, Cuenca, Spain. Project and direction of restoration by Susana Mora, architect, (2000-) for Junta de Comunidades de Castilla La Mancha.

4) For jet grouting, see DI STEFANO R.C., *Il consolidamento,* Napoli 1990, pp. 176-186; LA REGINA F., *Sicurezza e conservazione,* Napoli 1995, pp. 132,146;

5) See also CIGNI G., *Murature degradate*, 1977, pp. 48-76; MASSARI G., I. *Risanamento*, in particolare, cap. VII, Milano 1981, pp. 101-124; VITIELLO V., CASTELLUCCIO R., *Il risanamento delle murature affette da umidità da risalita capillare*, *il metodo CNT*, Napoli 2019; AGLIATA R., MOLLO L., *Sulle tecnologie per il monitoraggio non invasivo dell'umidità nelle murature*, in *Technologies for the recovery of built heritage*, 4-5 aprile, Matera 2019, Napoli 2019.

But for the thematic relative to the study of disturbances and the remerdies for structures see some texts that are classic in the structural sector: from the volumes of Carlo CESTELLI GUIDI. To the studies by Giorgio MACCHI, and Giorgio CROCI.

ASHURST D.N., *Practical Building Conservation*, Vol. 2, Brick Terracotta e Earth, Hampshire, Gower Technical Press, 1988.

LOURENZO P.B., ROCA P., *International Journal of Architectural Heritage. Conservation, Analysis and Restoration*, Vol. 15, Philadelphia P1, 2021.

STANLEY RABUN J., *Structural analysis of Historic Buildings Restoration, Preservation, and Adaptive Reuse Applications for Architects and Engineers*, edit by John Wiley and sons, York (UK), 2000.

VAN GEMERT D., *The use of grouting for the consolidation of historic masonry constructions. Advantages and limitations of the method*, in *Stable – Unstable?*, pp. 265-276.

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

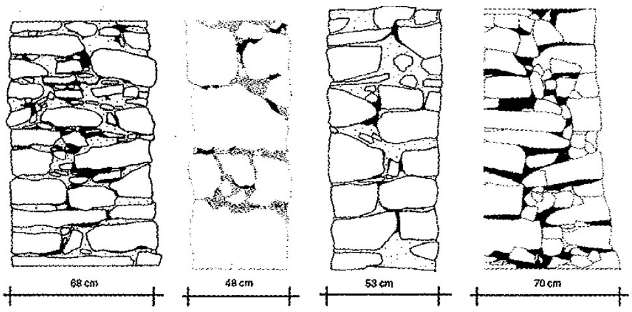


Fig. 1. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 109.

PROBLEMS

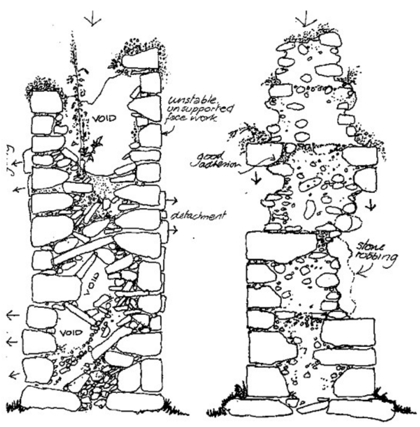


Fig. 2. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 109.

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.

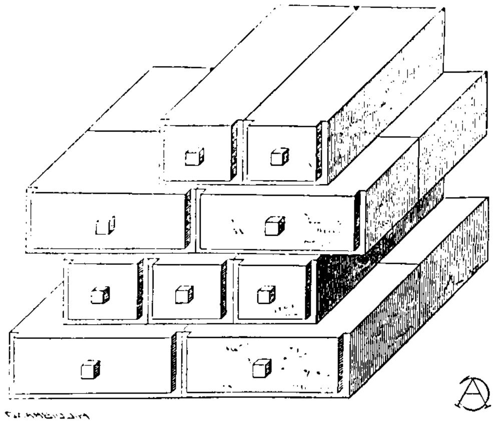


Fig. 4. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 81.

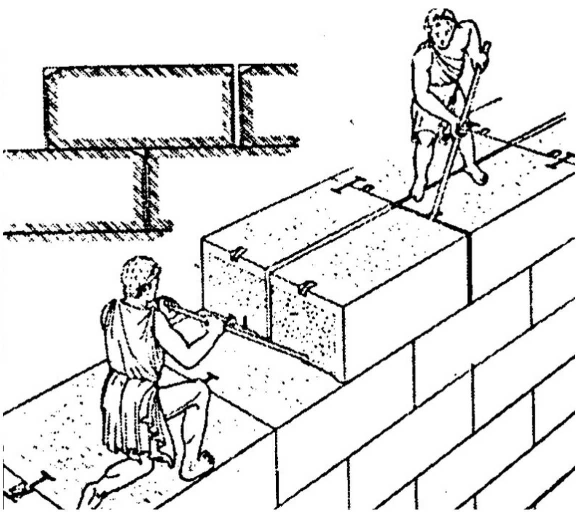


Fig. 5. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 82.

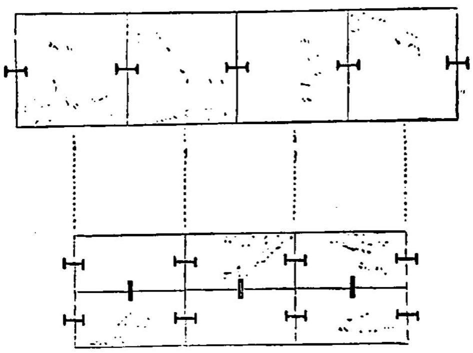


Fig. 6. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 82.

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.

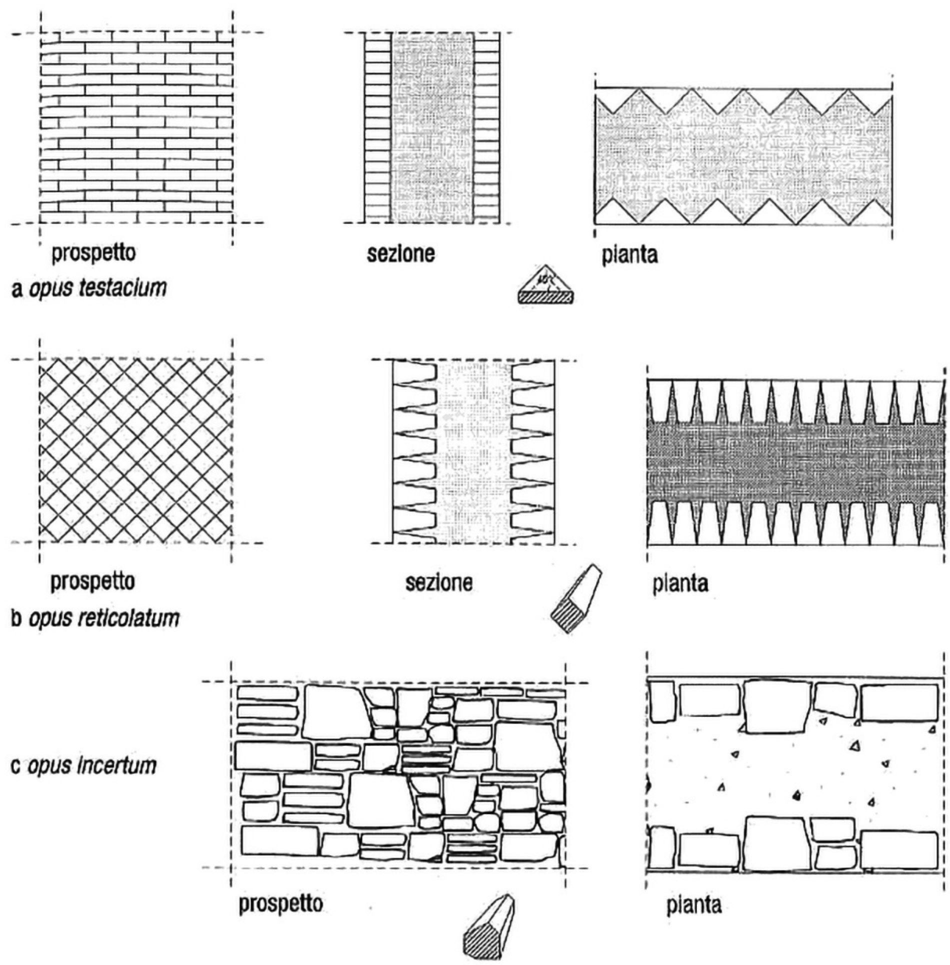


Fig. 7. Three types of opus cementicium: opus testacium, opus reticolatum, opus incertum. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011, p. 19.

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.

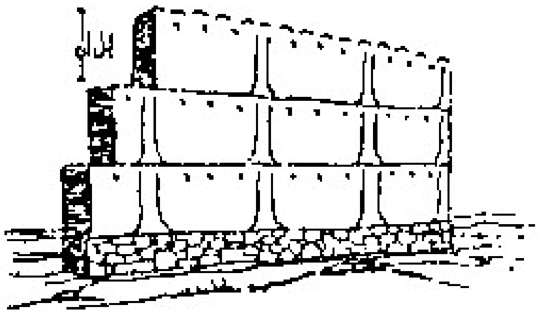
BRICK MASONRY

(2)

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

RAMMED EARTH WALL

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



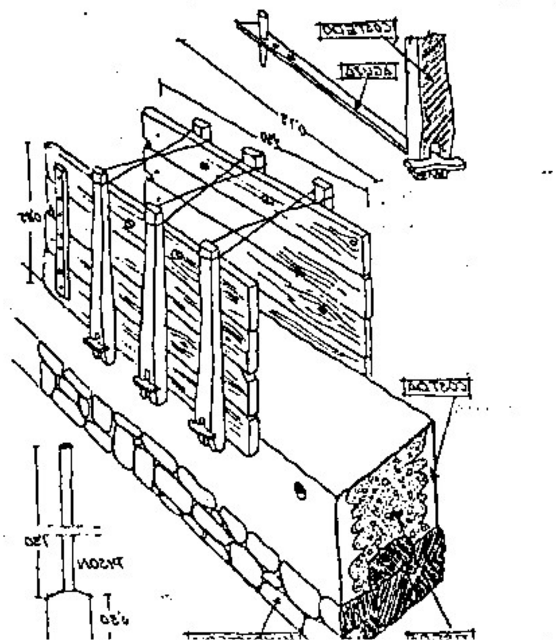


Fig. 11. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 115. (3)

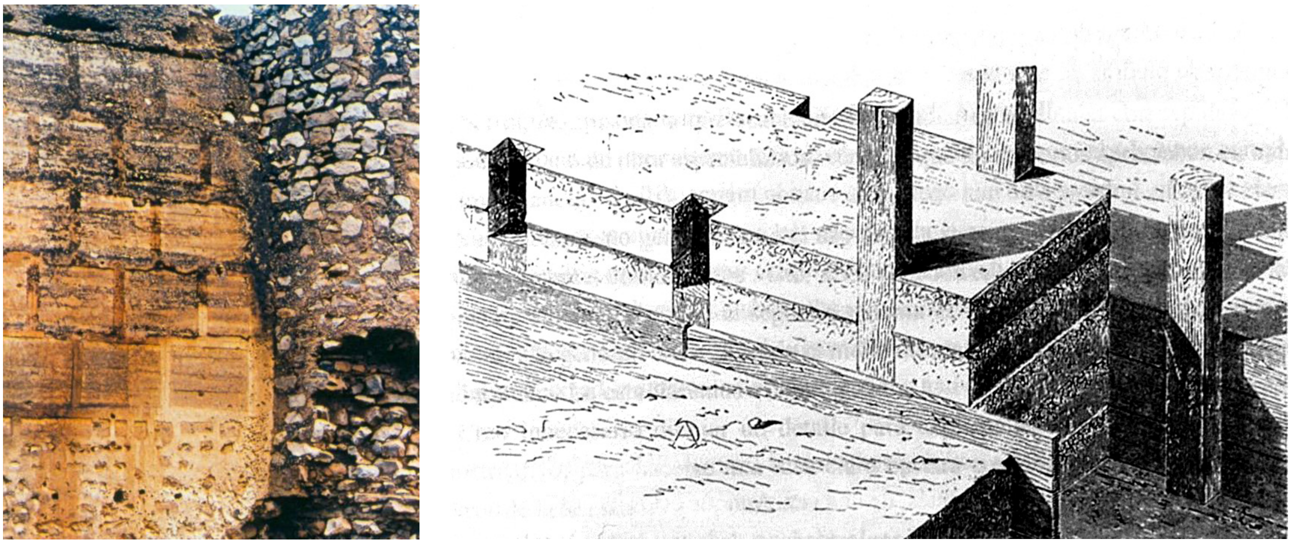


Fig. 12. Alcázar, Guadalajara. Photo by Susana Mora.

WOODEN FRAME WALL

- ADOBE (MUD BRICK)
- BRICK

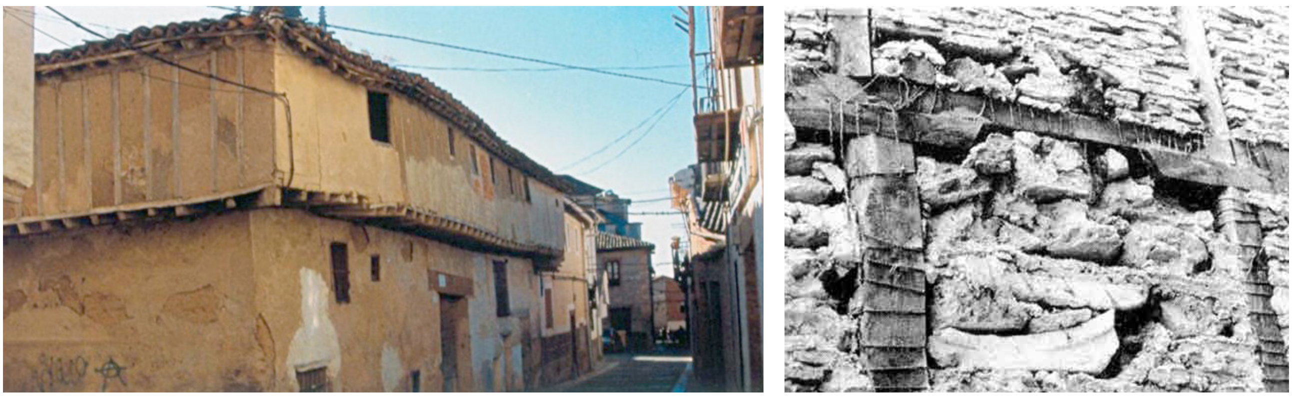


Fig. 13. Alhondiga, Torrelaguna, Madrid. Photos by Susana Mora, 1991.

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

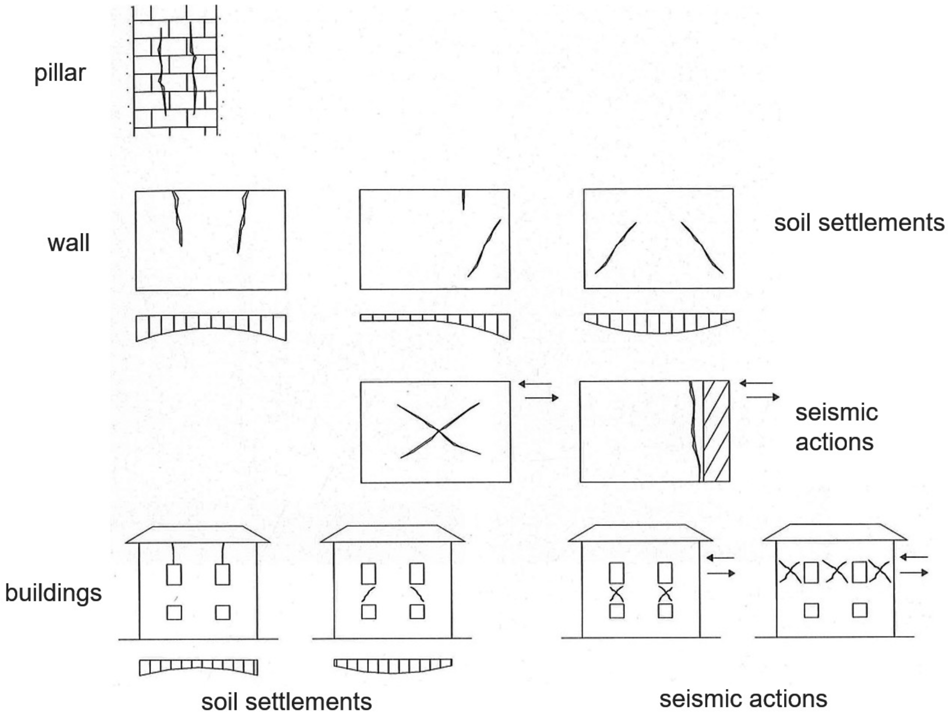
- Historical references:
    - · Photographs, documents, testimonies
- Existence of previous buildings
- Structural or architectural modifications
- Damages: earthquakes, flooding…
- Modifications of the environment:
    - · Excavations, paving, sanitation, wells, cellars…

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

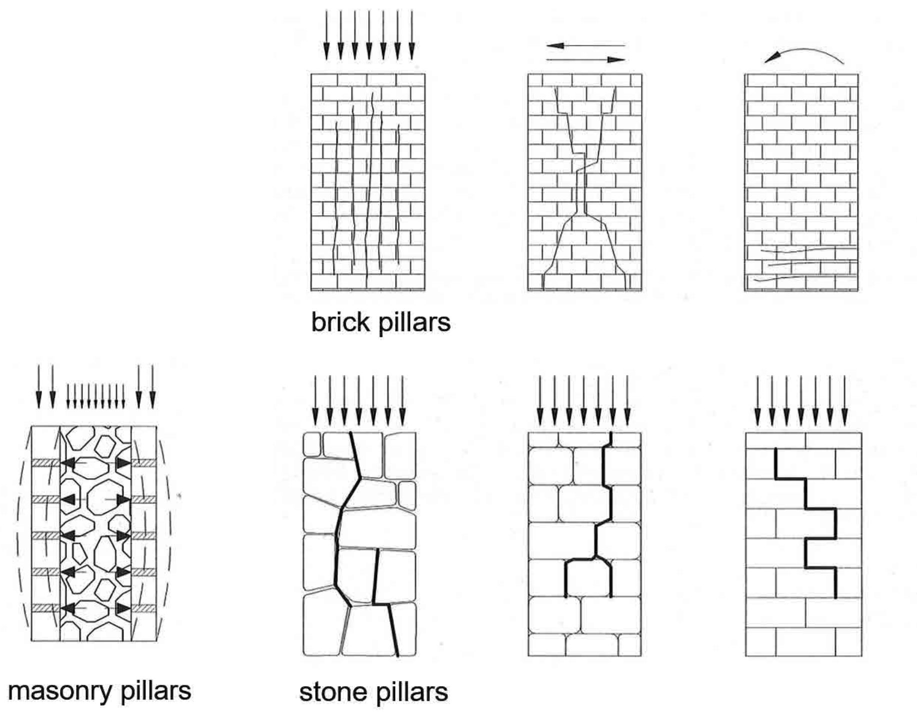
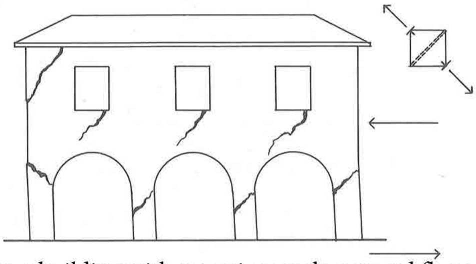
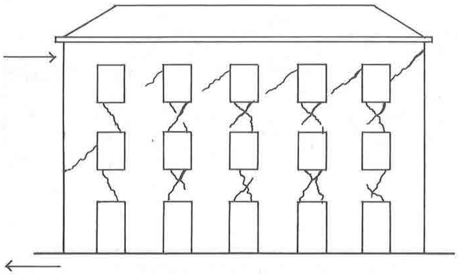


Fig. 15. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011, p. 123.



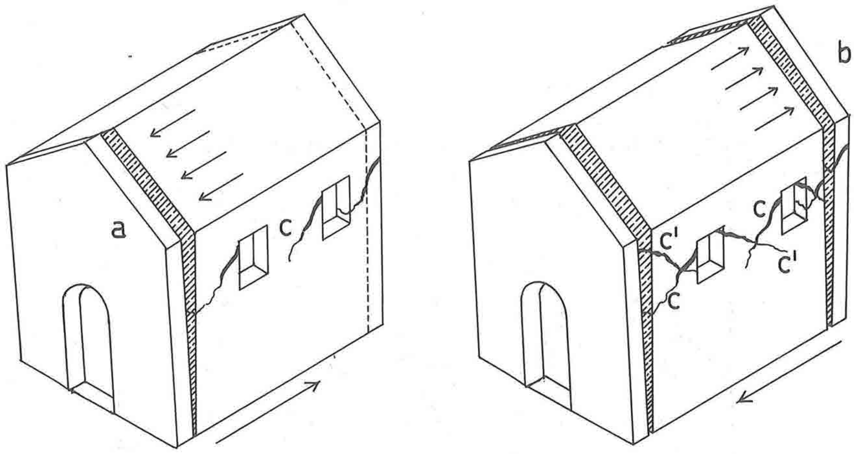
Damage in a building with a portico on the ground floor.



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

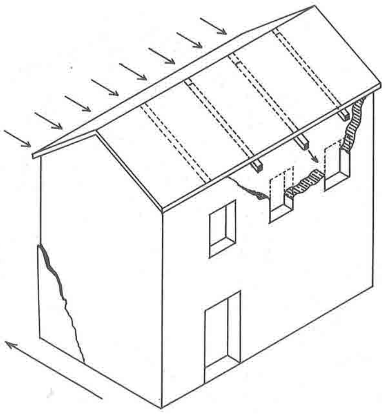
(5)

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

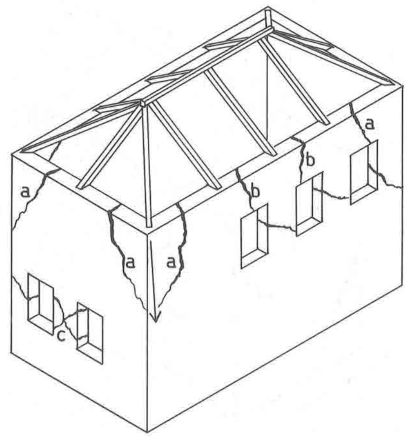


Thrust in one direction: detachment of the facade ***a*** and formation of fractures ***c***.
Thrust in the opposite direction: detachment of the wall ***b*** and shear cracks ***c'***.

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:

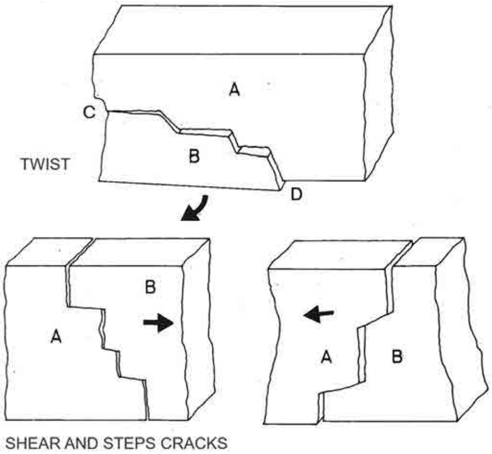


Fig. 19. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Madrid 1985, p. 54.

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

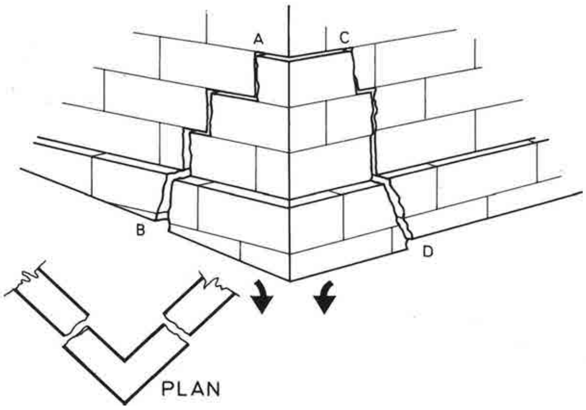


Fig. 20. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Madrid 1985, p. 63.

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

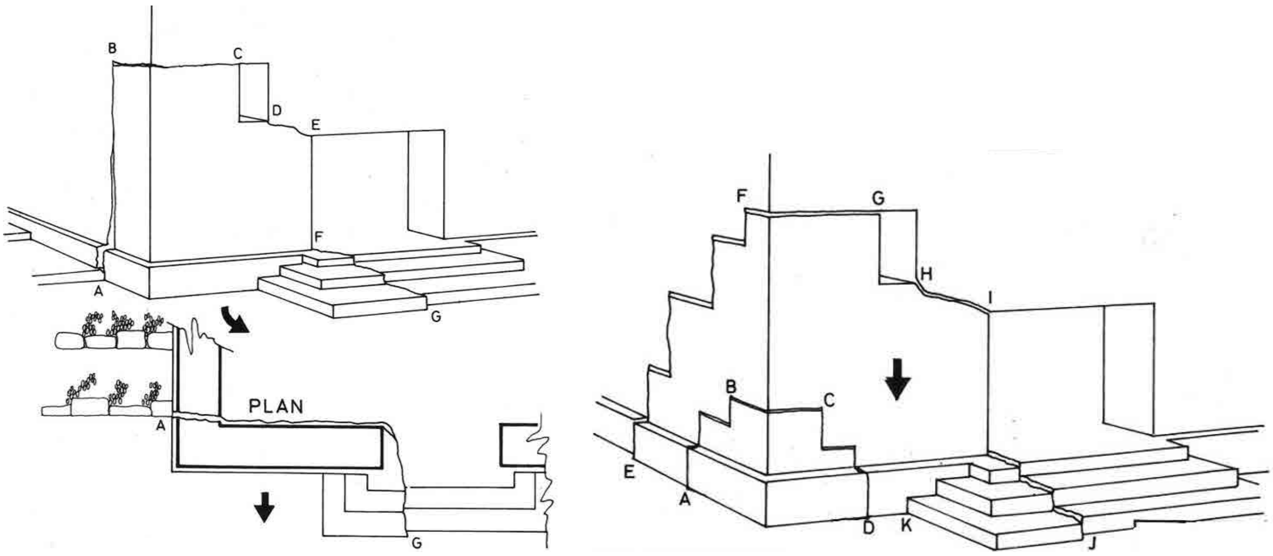


Fig. 21. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Madrid 1985, p. 66.

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

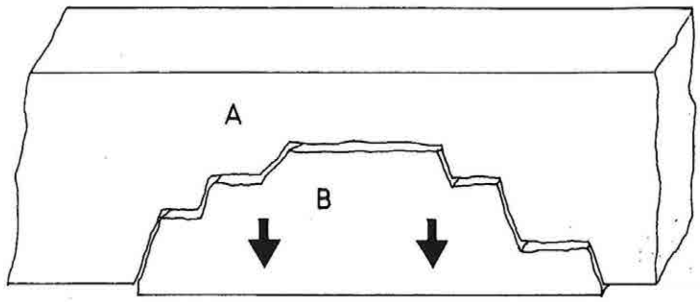


Fig. 22. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Madrid 1985, p. 54.

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

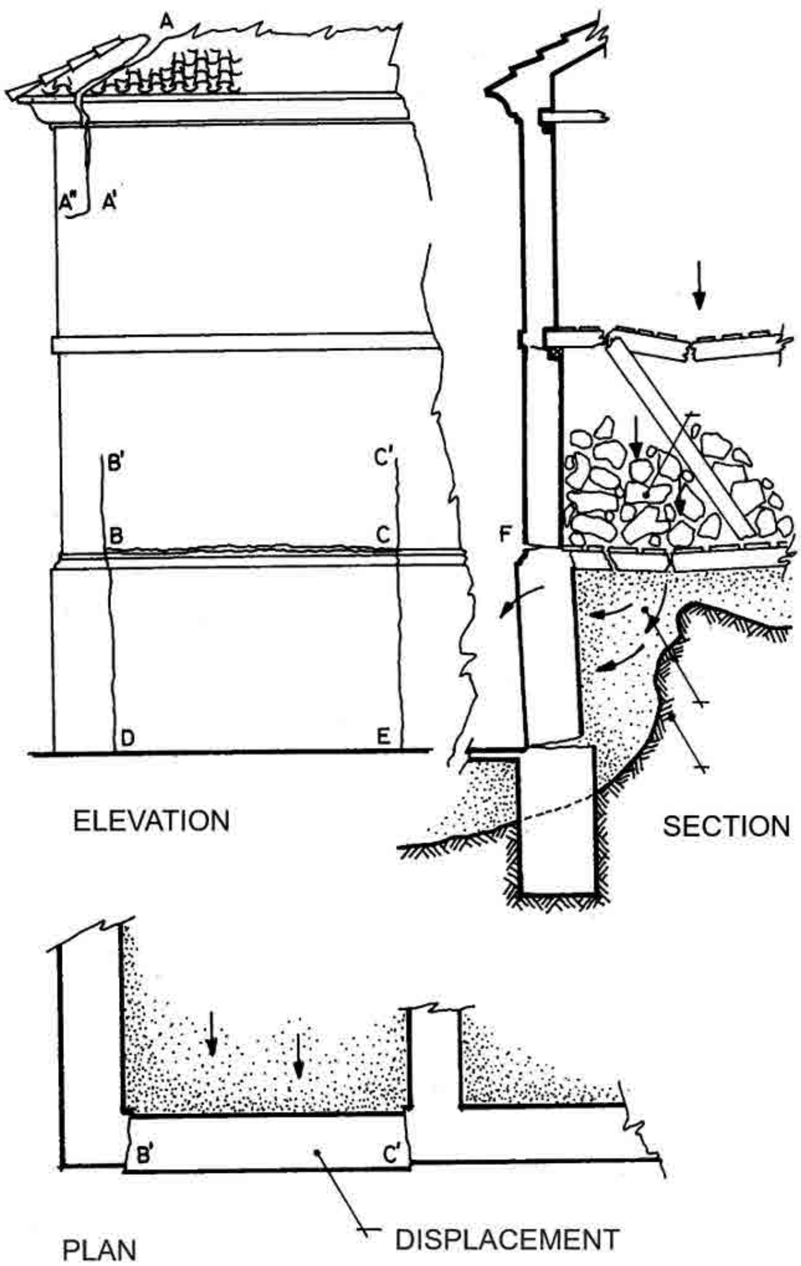


Fig. 23. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Madrid 1985, p. 56.

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:

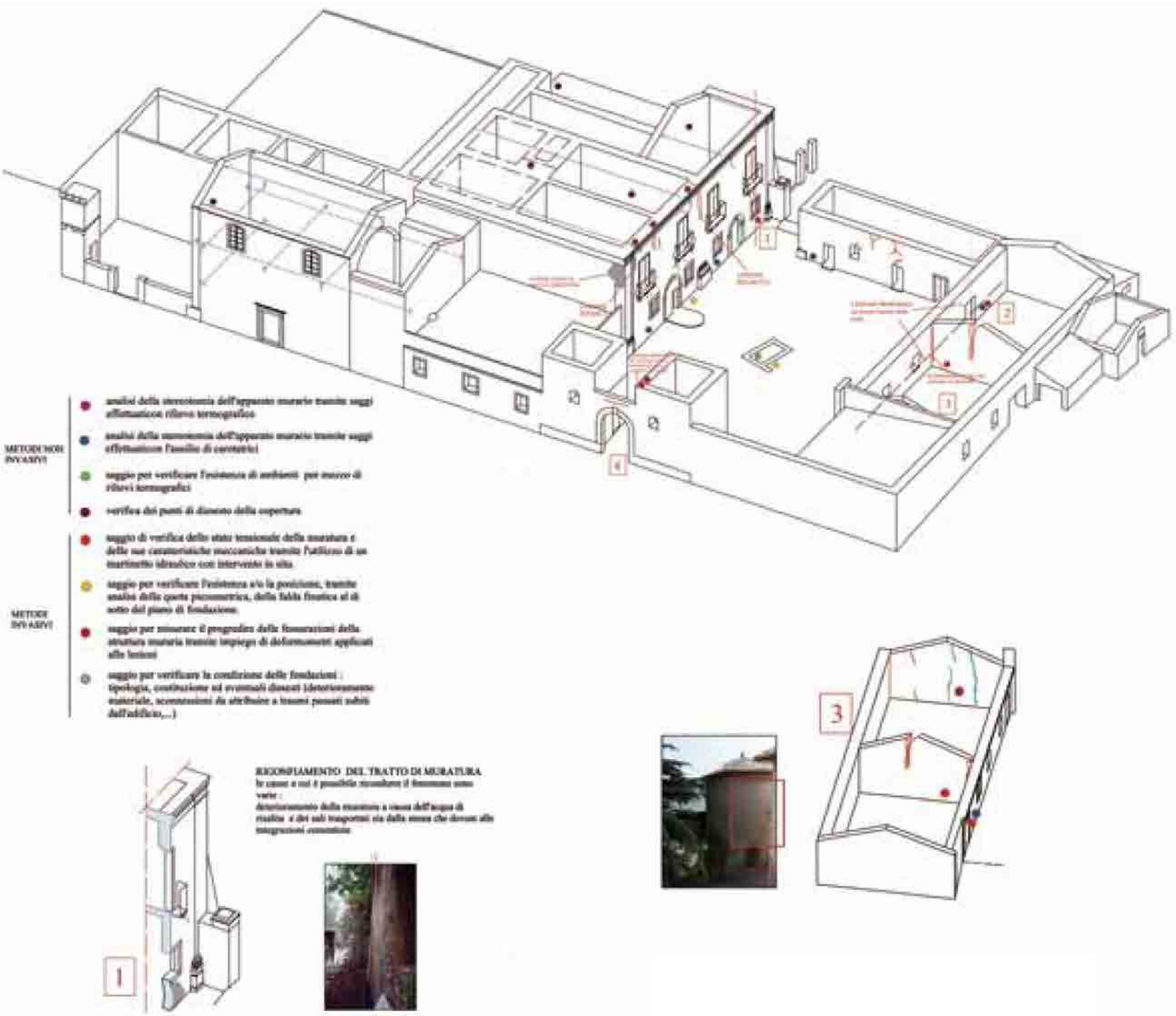
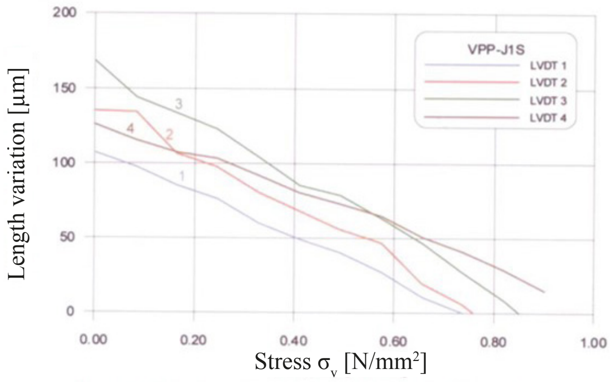


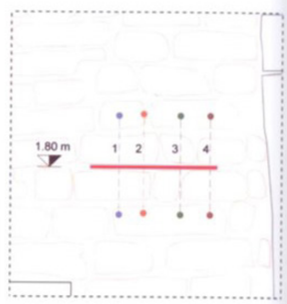
Fig. 24. Structural analysis of Palazzo Spadafora, Milazzo. From C. Bellanca, *Methodical Approach to the restoration of Historic Architecture*, Alinea Editrice, Firenze 2011, p. 249.

– 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.





Disposition of the meassurement bases

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

Fig. 25. 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)

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

· Double Flat-Jack

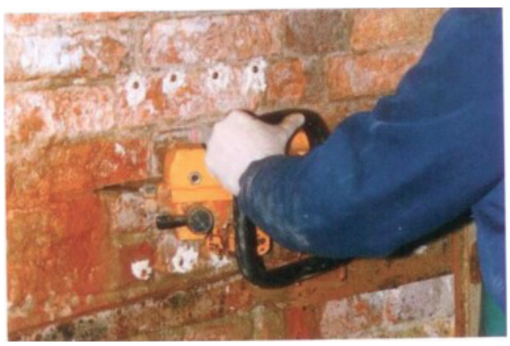


Fig. 27. From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011, p. 209.

· 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

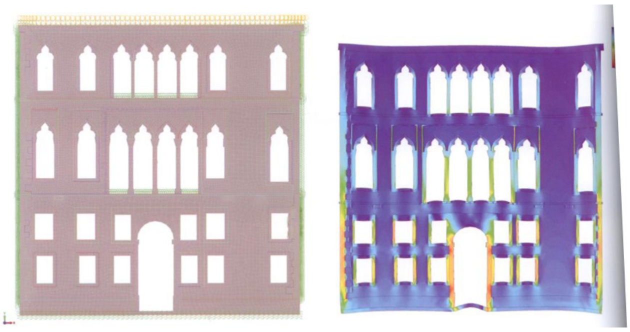


Fig. 29a. Stress in vertical direction. From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011.

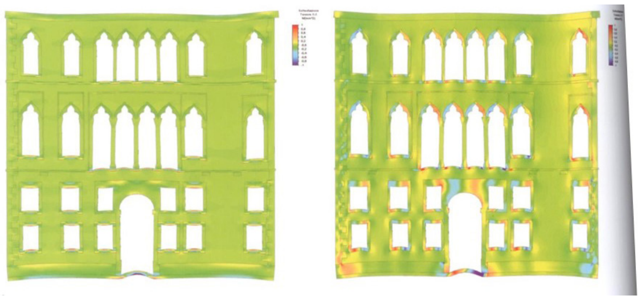


Fig. 29b. Stress in horizontal direction. From F. Doglioni, G. Mirabella Roberti, *Venezia. Forme della costruzione, forme del dissesto*, Libreria Cluva Editrice, Venezia 2011.

 · 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.

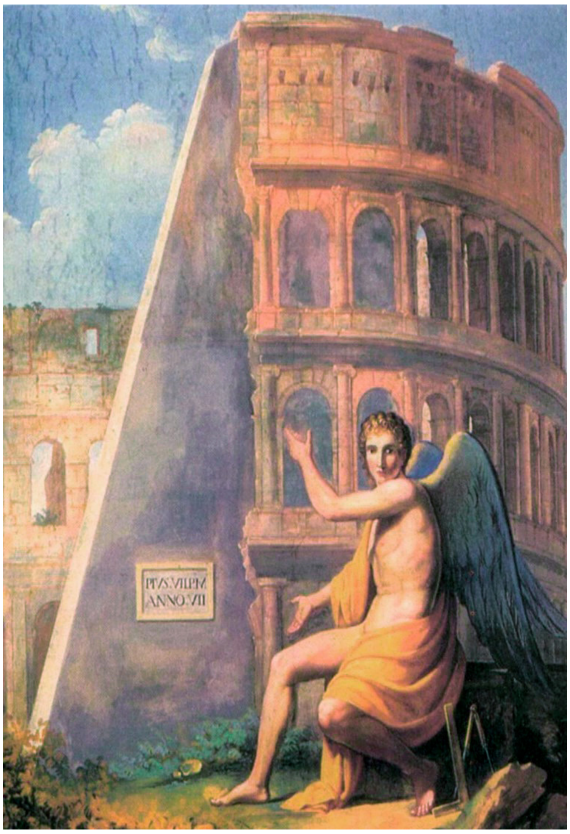


Fig. 40. Colosseo Buttress. From S. Casiello, *Verso una storia del restauro*, Alinea Editrice, Firenze 2008.

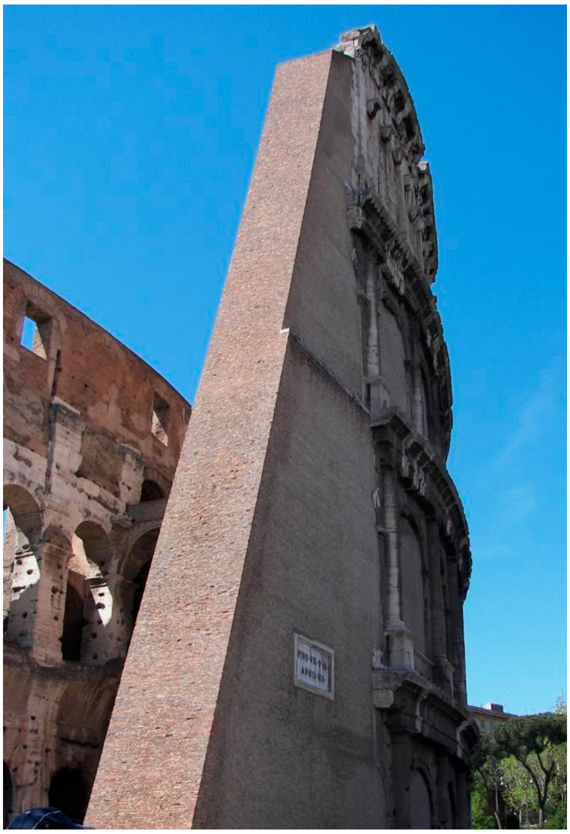


Fig. 41. Colosseo Buttress, Rome. Photo by Susana Mora, 2015.

CLADDING

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

ANASTYLOSIS // BRACING

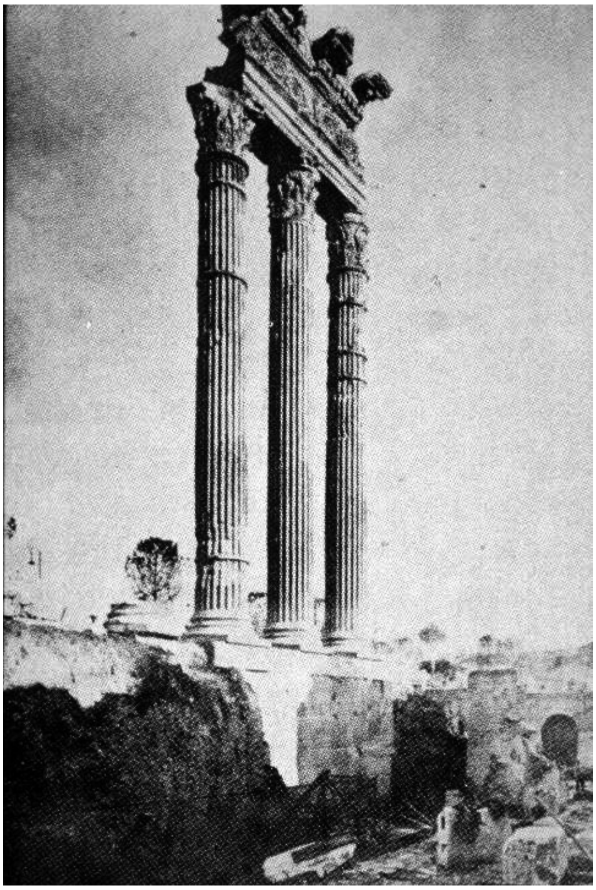


Fig. 43. Fori Imperiali, Roma. From C. Ceschi, *Teoria e storia del restauro*, Bulzoni, Roma 1970, p. 120.

HIDDEN REINFORCEMENTS // CABLE-STAYED

Restoration has insert reinforcements and still acts inside the columns.

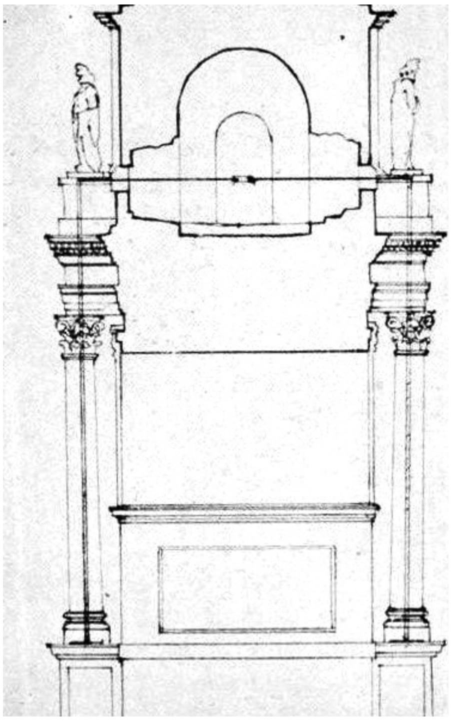


Fig. 44. Costantino Arch, Rome. From C. Ceschi, *Teoria e storia del restauro*, Bulzoni, Roma 1970, p. 129.

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

CLADDING

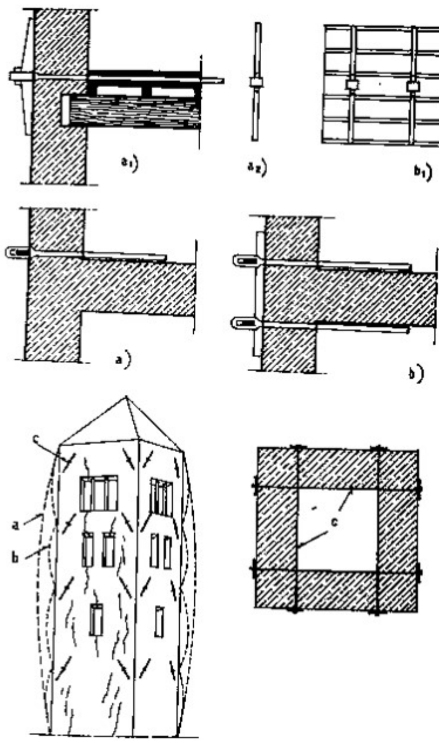
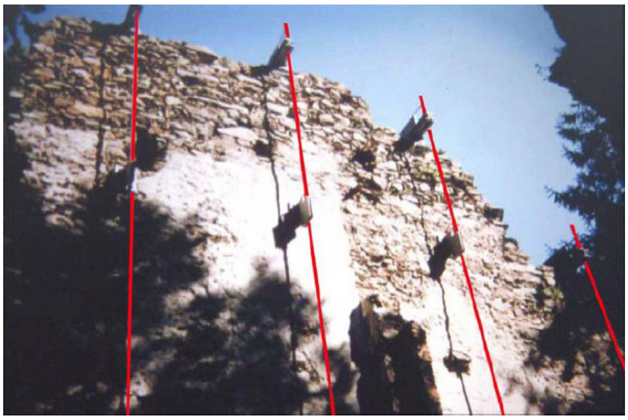


Fig. 46. From G. Cigni, *Il consolidamento murario*, Edizioni Kappa, Roma 1975.

AUXILIARY ELEMENTS // CABLE-STAYED



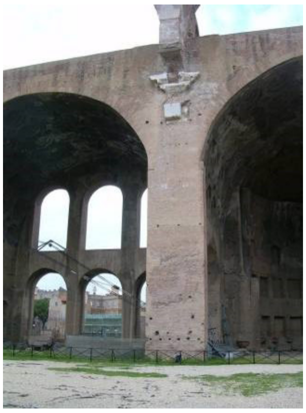
(9)

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.

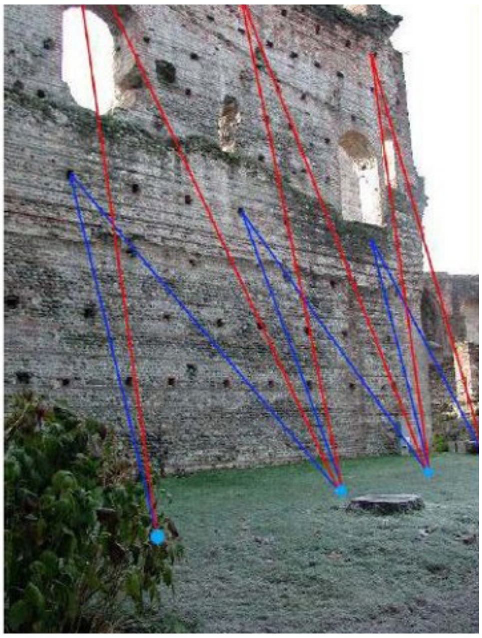
CABLE-STAYED



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.

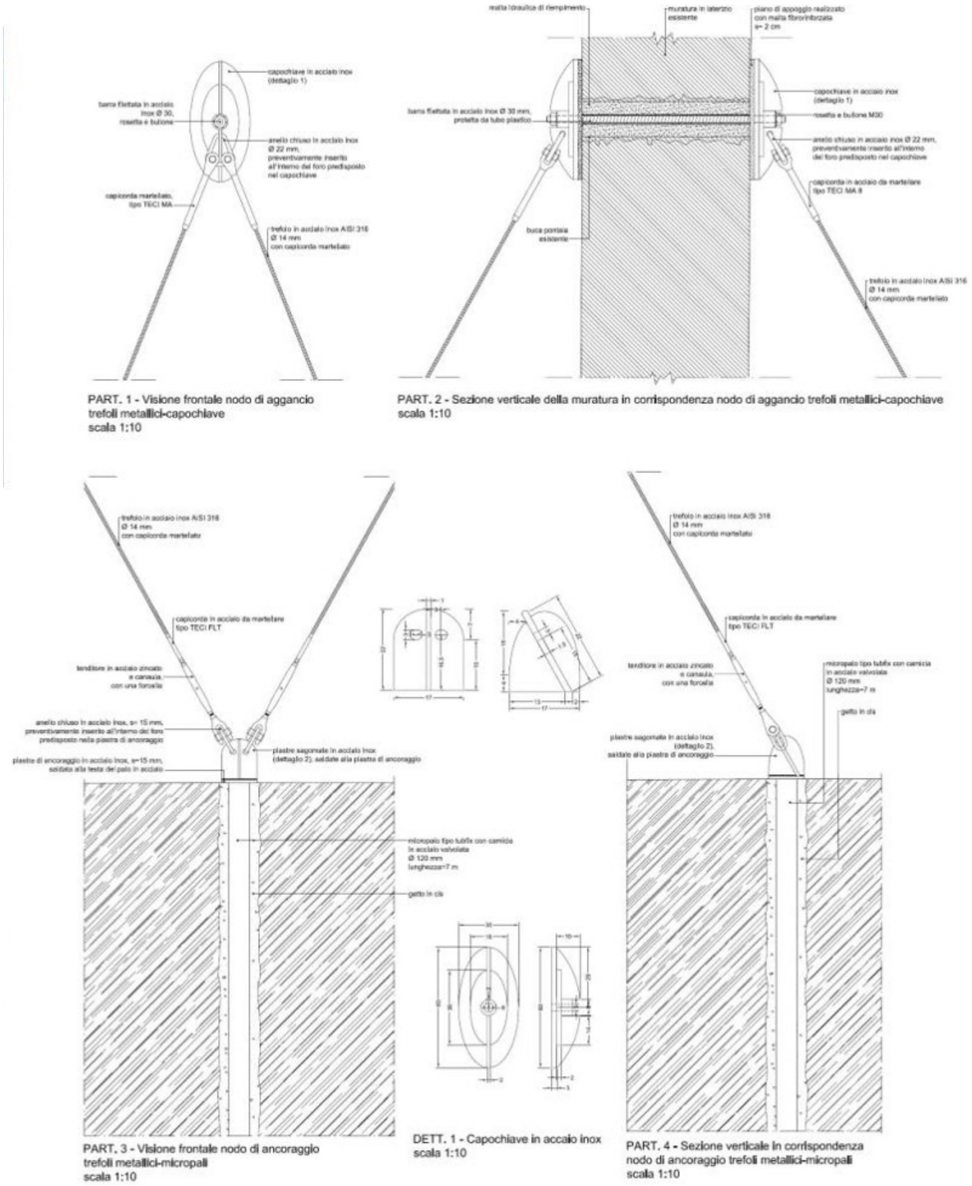


Fig. 55. Designs by Lorenzo Jurina.

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.

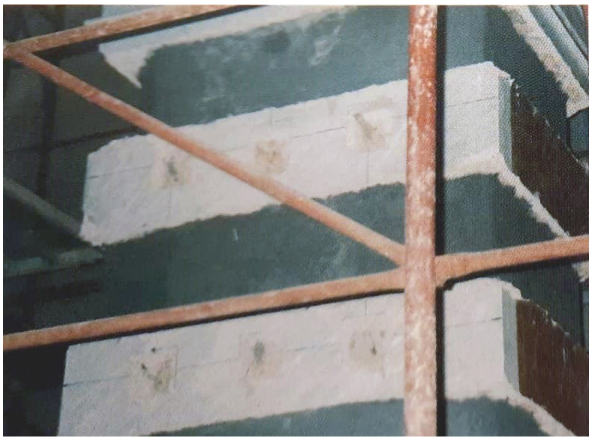


Fig. 59. Cathedral of Palestrina, Rome. From F. Marmo, *Materiali fibro-rinforzanti a matrice polimerica*, "Materiali e strutture", Anno 2, n. 34.

Reinforcement of beams and plates

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

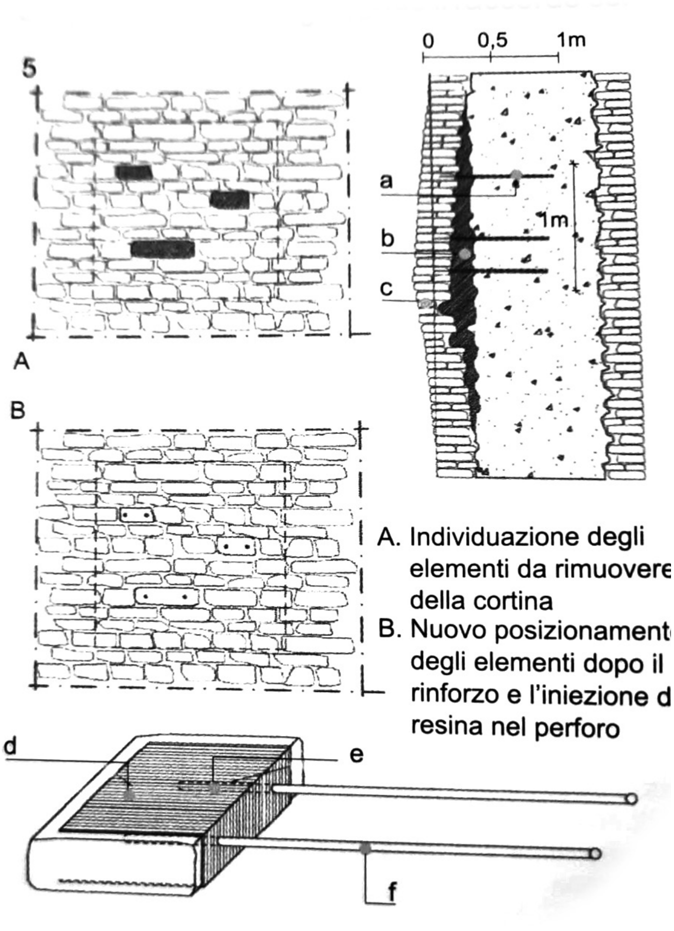


Fig. 61. Design by D. Fiorani. From G. Carbonara, *Atlante del restauro architettonico,* vol. II, Utet, Torino 2004, p. 530.

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.

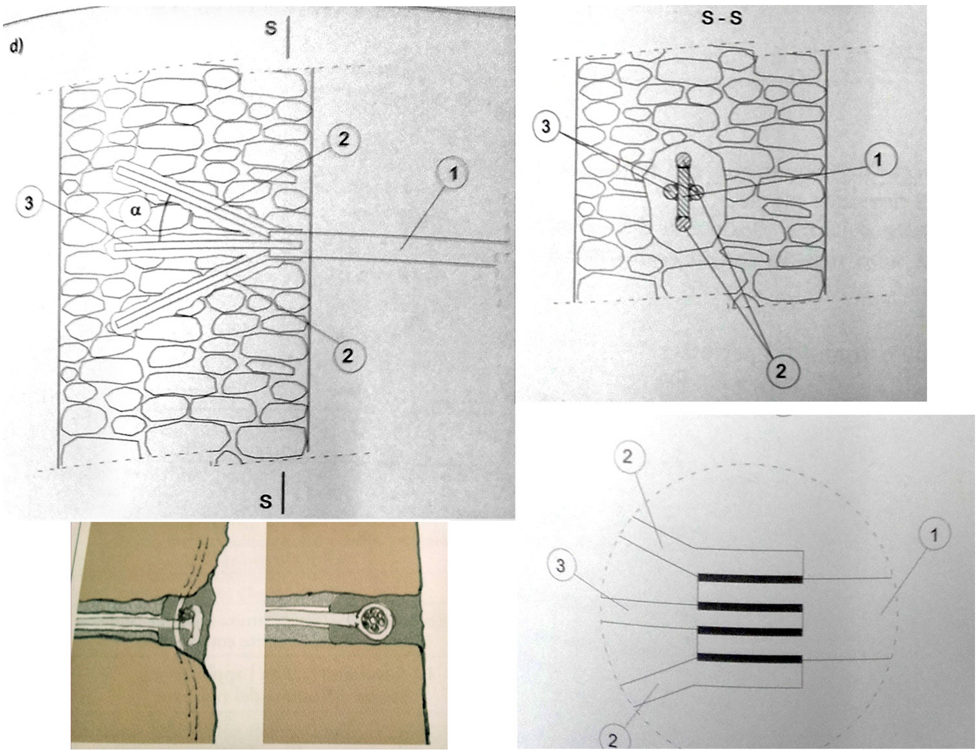


Fig. 65. Redesigned by Susana Mora.

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

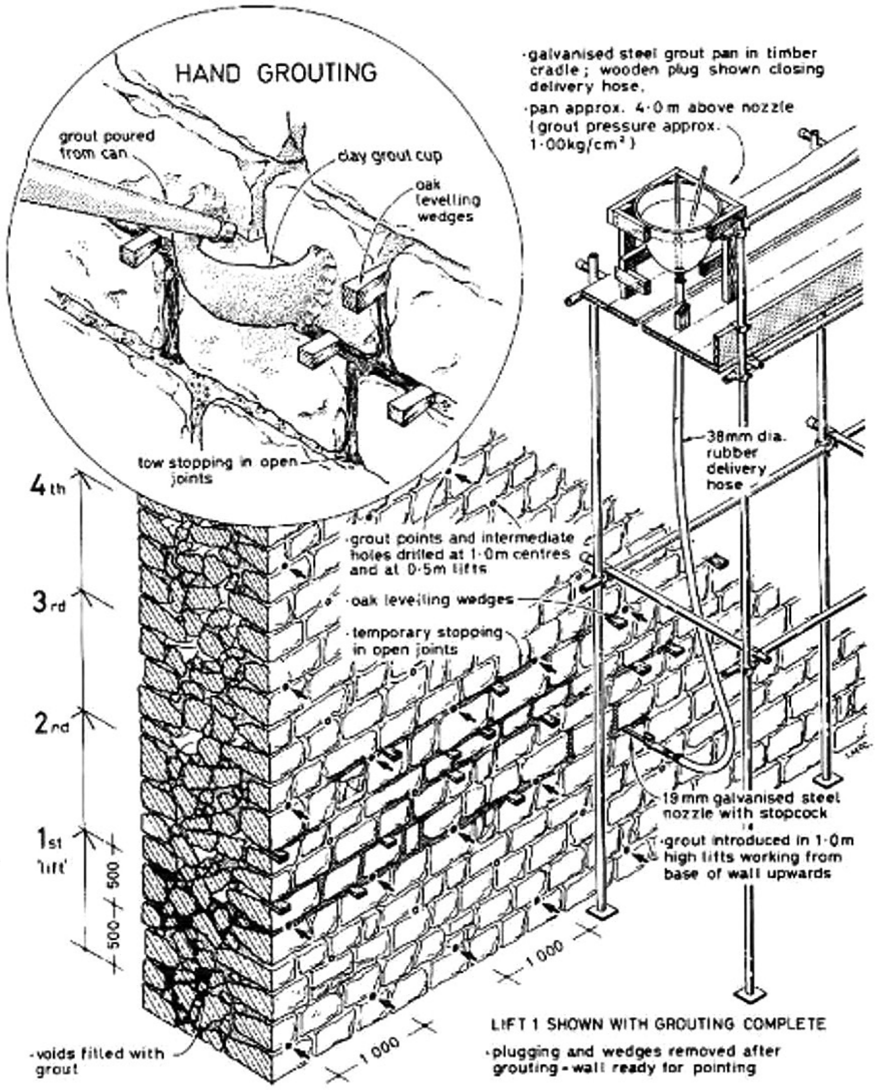


Fig. 66. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 175.

By Pressure:

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

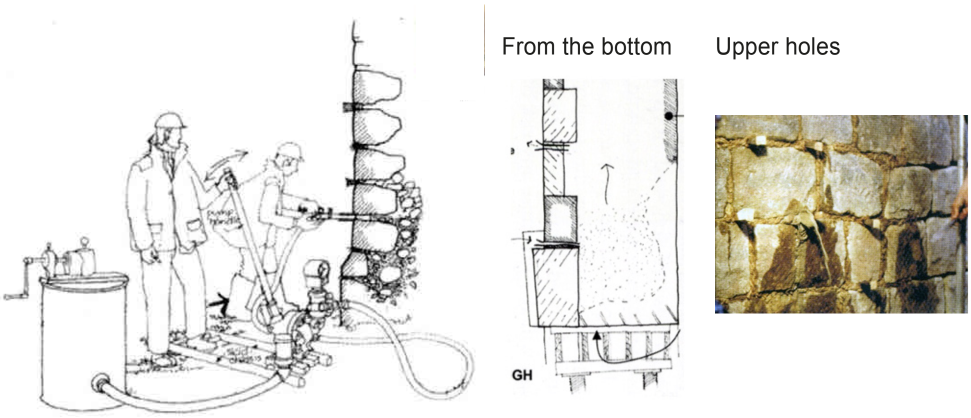


Fig. 67. From J. Ashurst, *Conservation of Ruins*, Routledge, Oxford 2006, p. 187.

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

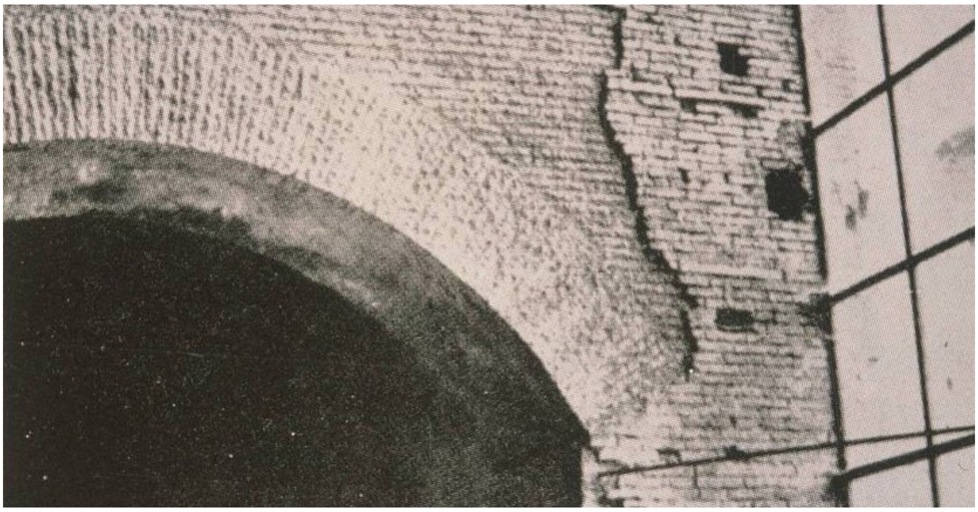


Fig. 70. Santa Maria Antiqua, Rome. Photo by Susana Mora, 2010.

Different Material

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

Cuci-Scuci

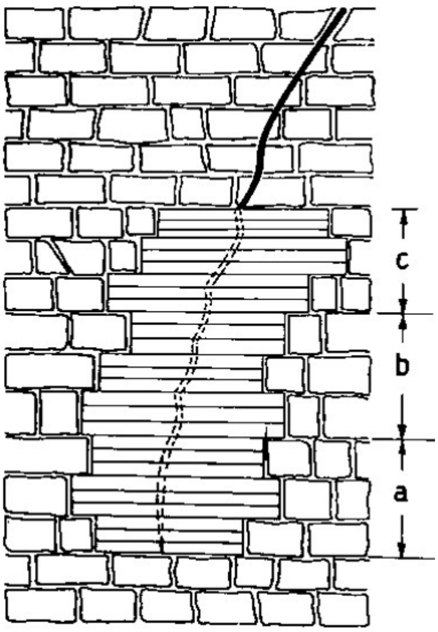


Fig. 72. Design by Susana Mora.

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.

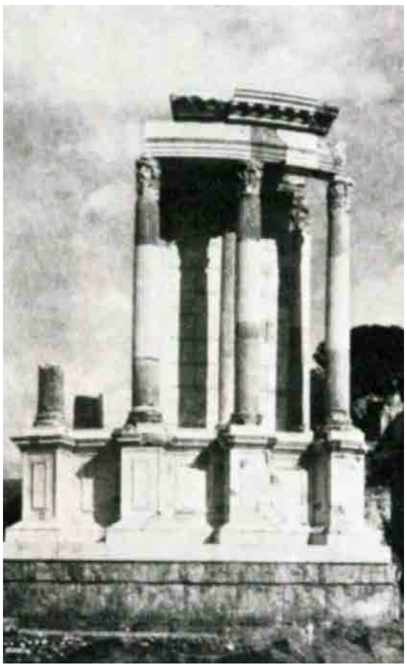


Fig. 75. Tempio di Vesta, Rome. Photo by Susana Mora, 2010.

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;
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LIZZI F., *The static restoration of monuments*, Sagep Publisher, Genova 1982;
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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.

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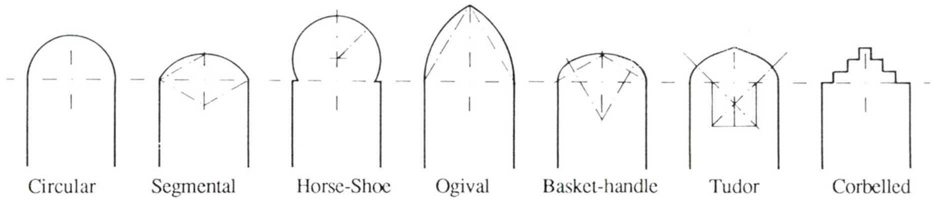
CHAPTER 9. VAULTS: CONSTRUCTIVE SYSTEMS, PROBLEMS, CAUSES AND SOLUTIONS

"Vaults are usually constructed of stone or brick masonry, as these are good materials when used in compression, but other materials such as timber and plaster can be used. The ceilings of York Minster are an interesting example of a stone vault reproduced in laminated timber. Vaults such as Neuman used at Baroque Neresheim were constructed of tufa reinforced with iron tie bars. The complex cutting of stones with two curves to form vaults was avoided in Roman construction by the use of mass concrete. Later, brick ribs were introduced into the groin, as in the Baths of Diocletian where clear spans of up to 20 m were achieved. Such heavy construction demanded heavy centring, which was overcome by building the ribs first and then filling in the webs vistually freehand with a light curved centring".

From FEILDEN, B. M., *Conservation of Historic Buildings*, Butterworths, London, 1982, p. 40.

FORM OF ARCHES

There are many shapes of arches. These are mainly characterized by the curve of the intrados and the ratio of height to span. Most arches are connected to the wall by the extrados. The corbel arch, built using courses gradually jutting further out, and monolithic arches, whether poured, tamped or cut out, have no extrados and continue directly on from the wall.



TYPES OF VAULTS

– Formal
– Constructive

There are a great many forms of vault. The simplest are barrel vaults which in fact consist of a succession of identical arches. Barrel vaults can have steeper or flatter profiles: semicircular, segmental, ogival, etc. The catenary vault is very common as its form gives maximum stability for a minimum use of material.

Combining two barrel vaults with the same profile allows two other types to be defined: the "groined vault" and the "dominical vault". By prolonging one of the two barrel vaults, the "dominical vault" becomes a "trough vault". Combining barrel vaults with different profiles forms a "lunette vault".
A "dominical vault", the ribs of which are rounded in the form of cones starting from the corners, becomes a "squinch vault". Similarly the "trough vault" can evolve into a "boat vault".

FORMAL

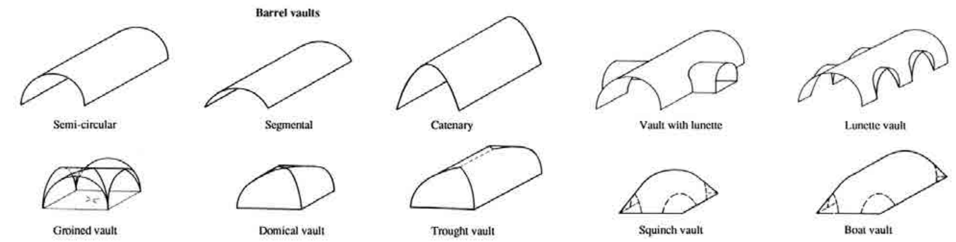


Fig. 1. Design by Susana Mora.

CONSTRUCTIVE

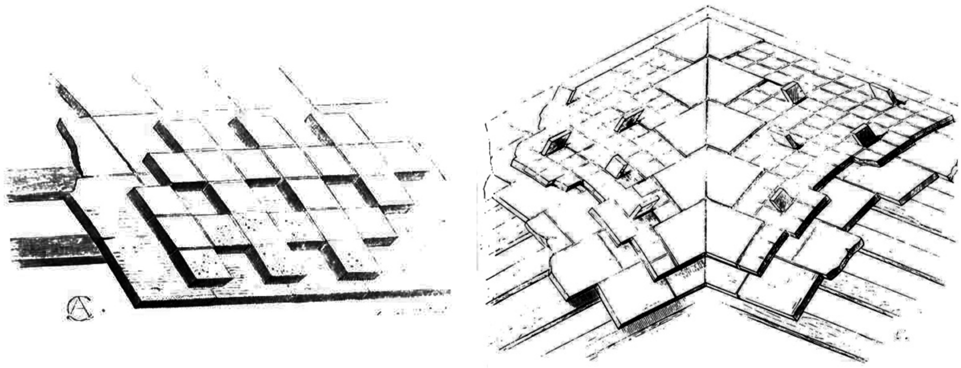


Fig. 2. On the left: Bonded. On the right: Poured. From G. Giovannoni, *L'Arte di costruire presso i romani*, 1925. Reprinted: Roma 1994.

Fig. 3a. Roman vault. Fori Imperiali, Rome. Photo by Susana Mora, 2017.

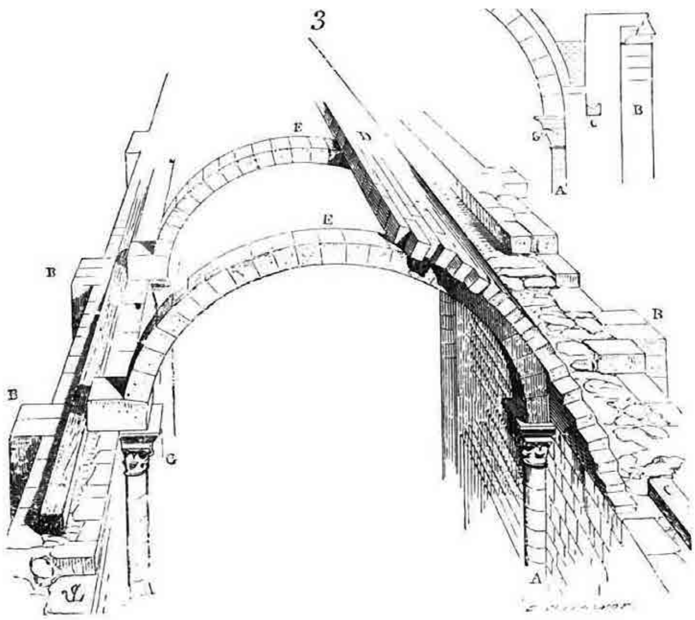


Fig. 3b. Medieval vault. From L. Palaia, E. Abdilla, *Técnica de intervención en arcos*, *bóvedas y cúpulas,* UPV, 1996.

FORMS OF DOMES

Domes are obtained by rotating an arch, except for faceted domes which more closely resemble the Dominical vault. A dome can be semi-circular, segmental, ogival, conical, etc.

Domes are circular in plan. They can, however, be used to cover square or rectangular rooms by using pendentives or squinches. Domes on pendentives can be used to cover any kind of polygonal shape in plan.
It is possible to combine several cupolas or to combine domes with vaults.

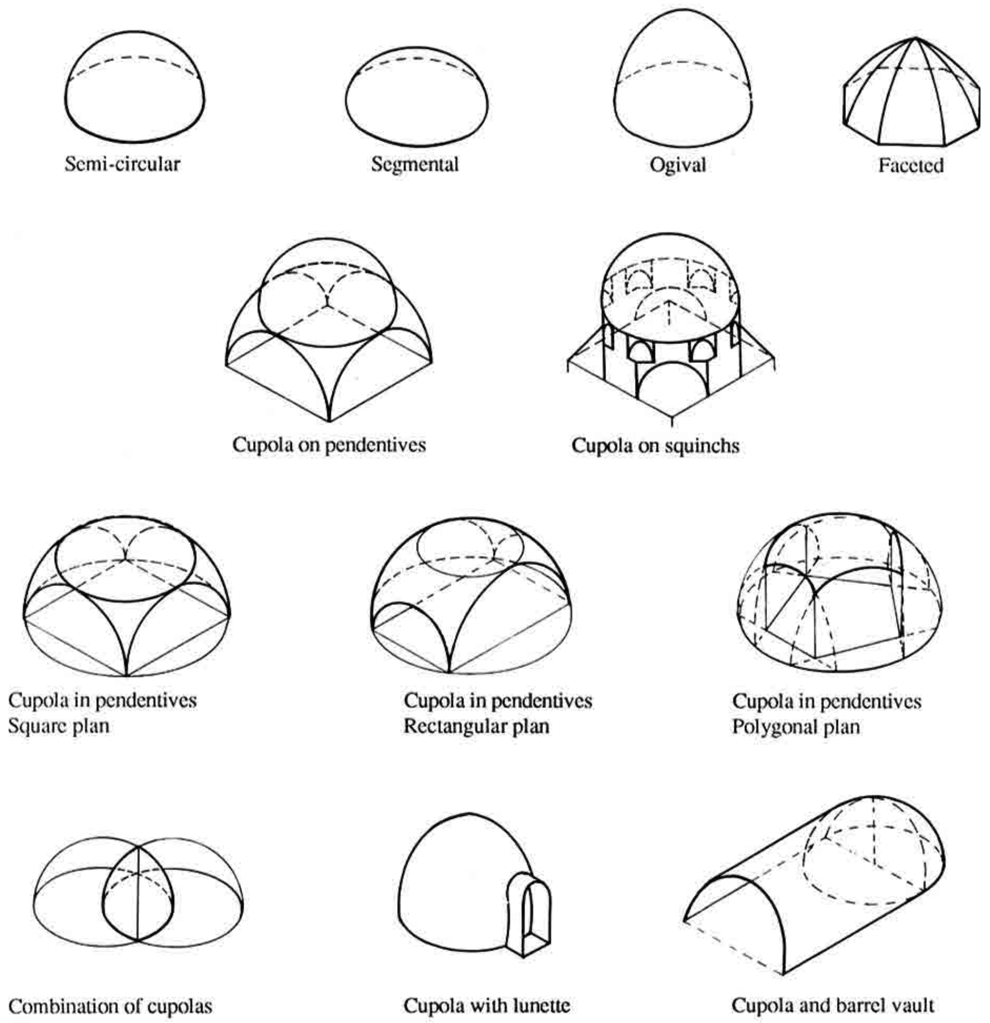


Fig. 4. From H. J. W. Thunnissen, *Bóvedas: su comportamiento y empleo en la arquitectura*, Instituto Juan de Herrera, ETSAM, Madrid 2012, p. 7, lam. 1.

GROIN AND RIB VAULTS. DETAILS OF RIBS

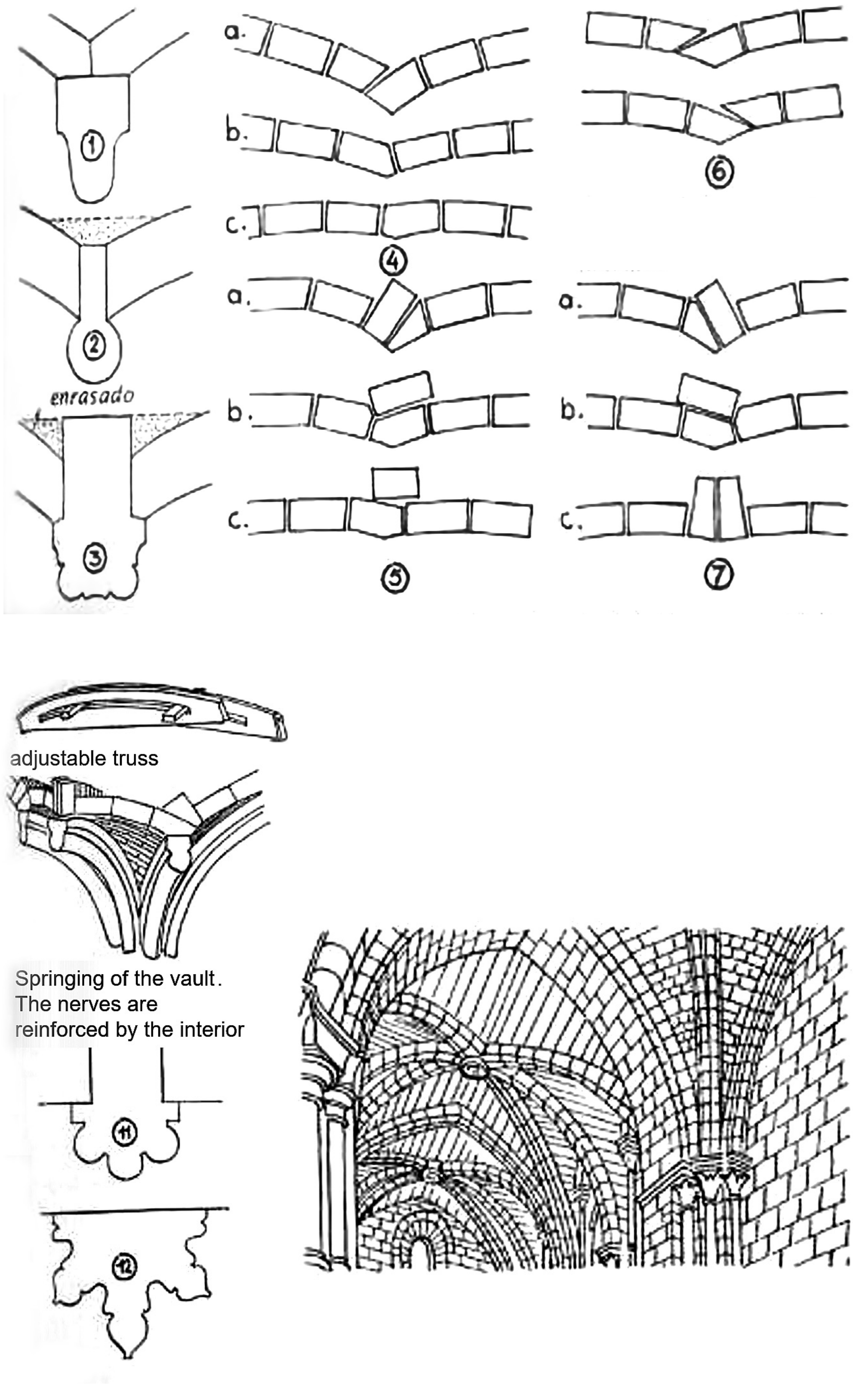


Fig. 5. From H.J.W. Thunnissen, *Bóvedas: su comportamiento y empleo en la arquitectura*, Instituto Juan de Herrera, ETSAM, Madrid 2012, p. 161, lam. 53.

CONSTRUCTIVE SYSTEMS OF ROMANESQUE AND GOTHIC VAULTS

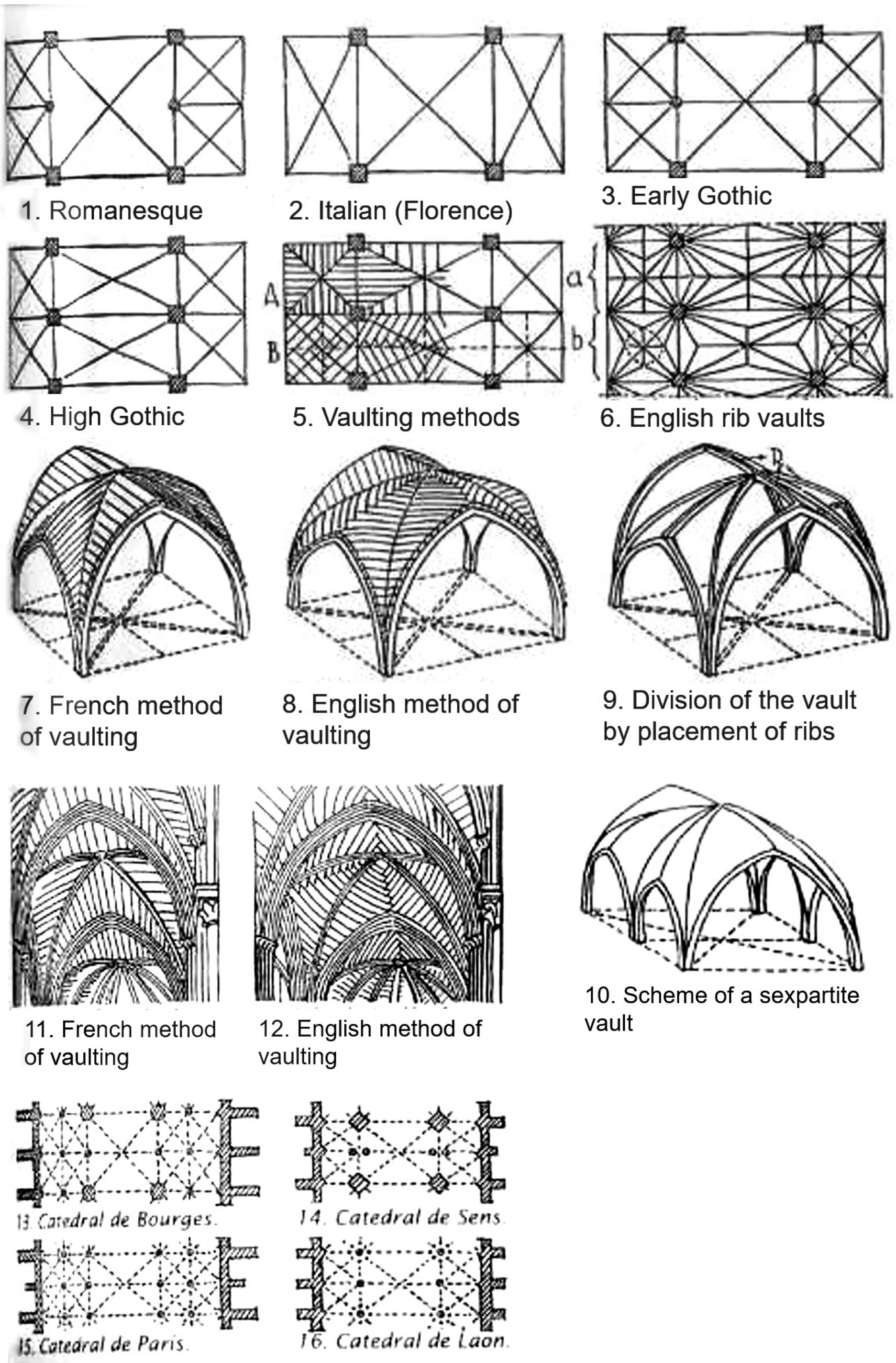
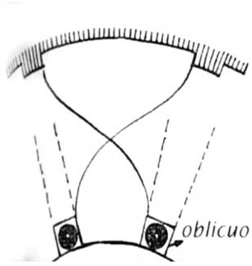
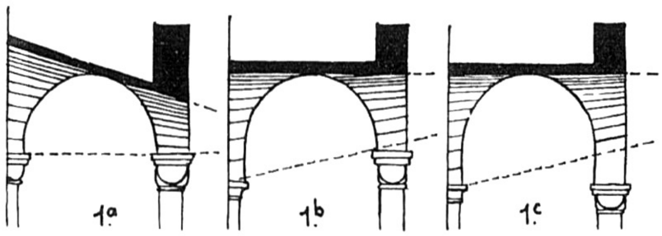


Fig. 6. From H.J.W. Thunnissen, *Bóvedas: su comportamiento y empleo en la arquitectura*, Instituto Juan de Herrera, ETSAM, Madrid 2012, p. 163, lam. 54.

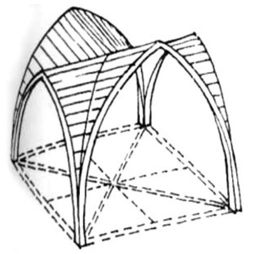
MEDIEVAL GROIN AND RIB VAULTS. LAYOUT OF THE KEYSTONE LINES



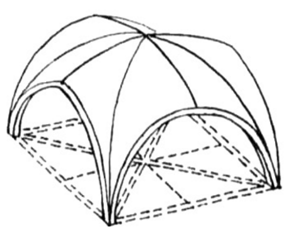
Partial plan of an apse aisle.



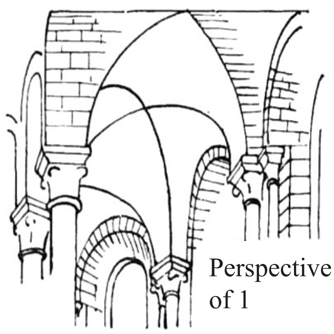
1. Different ways in which cylindrical annular corridor can intersect with a semi-conical vault (according to Ungewitter).



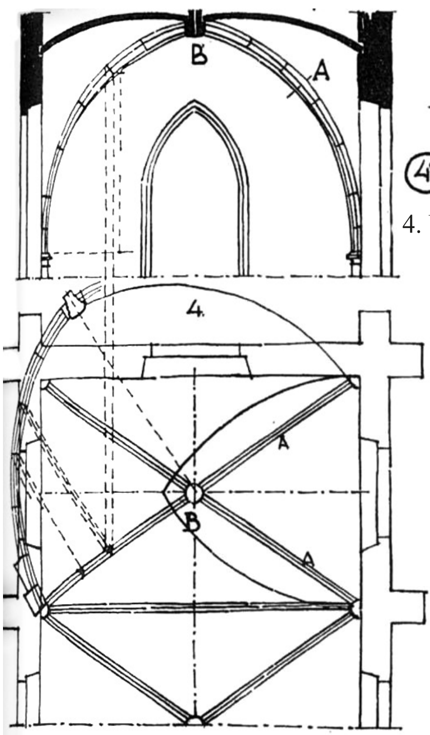
2. Groin vault with straight key lines. The front vaulting has been placed higher.

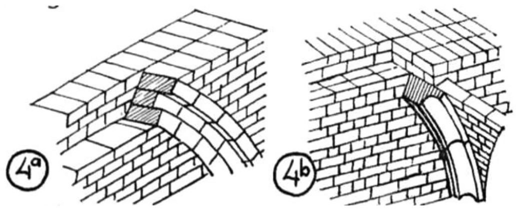


3. Ditto with curved lines and unevenly shaped edge arches.

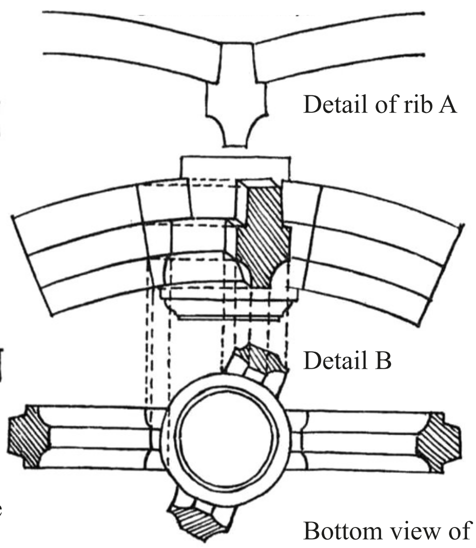


Perspective of 1





4. Union of vaults and walls (according to Wanderley)



Detail of rib A

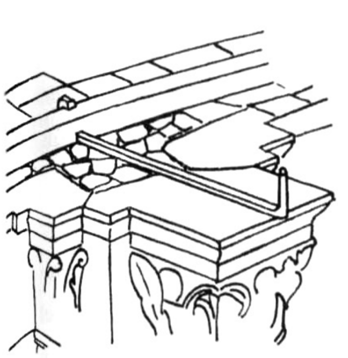
Detail B

Bottom view of key B

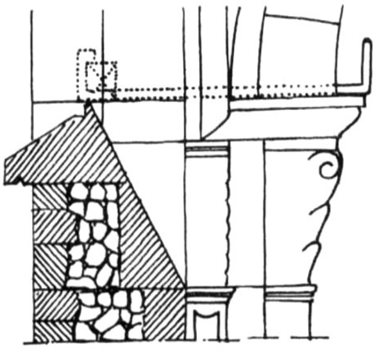
4. Groin vault with domed panels; one of the diagonal arcs has been absorbed.

Fig. 7. From H.J.W. Thunnissen, *Bóvedas: su comportamiento y empleo en la arquitectura*, Instituto Juan de Herrera, ETSAM, Madrid 2012, p. 167, lam. 55.

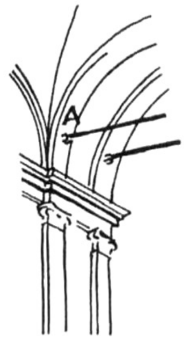
STAYED VAULTS. CONSTRUCTION OF FORMWORKS



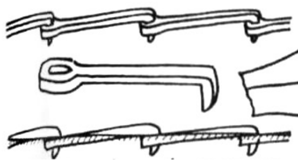
1. Wrench for temporary tie anchored to a beam within the masonry.



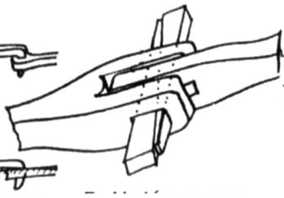
2. View of the anchor embedded in the factory.



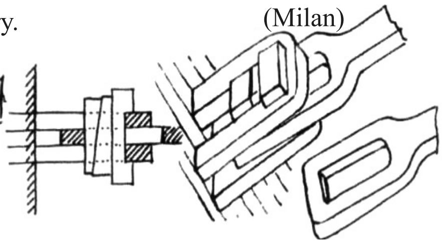
3. Seen braces (Milan)



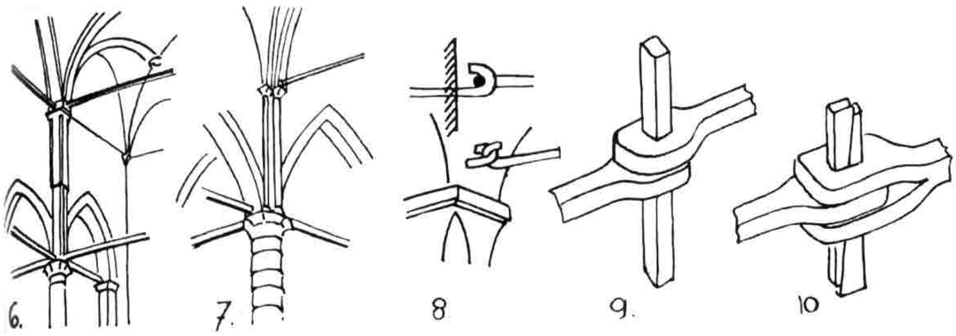
4. Chain ties used within the factory to absorbe tensile stresses.



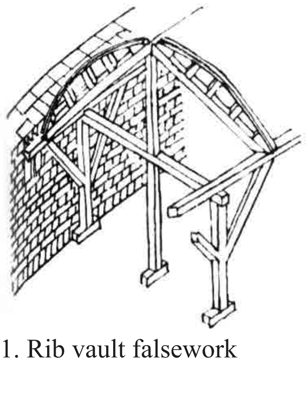
5. Braces/ties union



3ª. Anchor union detail. The iron wedges action tensions the braces.



Cable-stayed systems in various churches. 6. Venice 7. Ferrara 9. Pistoia 10. San Pietro di Roma



11. Rib vault falsework

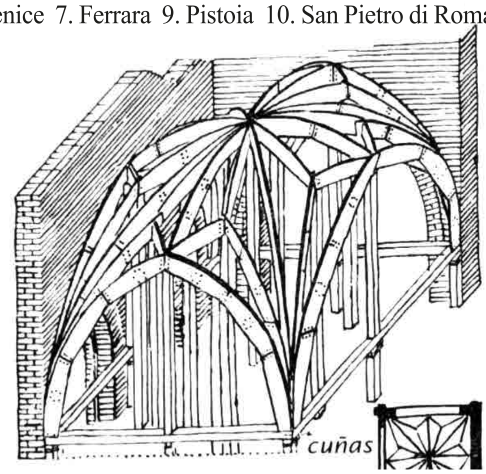


Fig. 8. From H.J.W. Thunnissen, *Bóvedas: su comportamiento y empleo en la arquitectura*, Instituto Juan de Herrera, ETSAM, Madrid 2012, p. 215.

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…

ANALYSIS OF OBSERVED PATHOLOGY

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

TYPOLOGY OF PROBLEMS

DAMAGES AND DEFORMATIONS IN A VAULT STRUCTURE

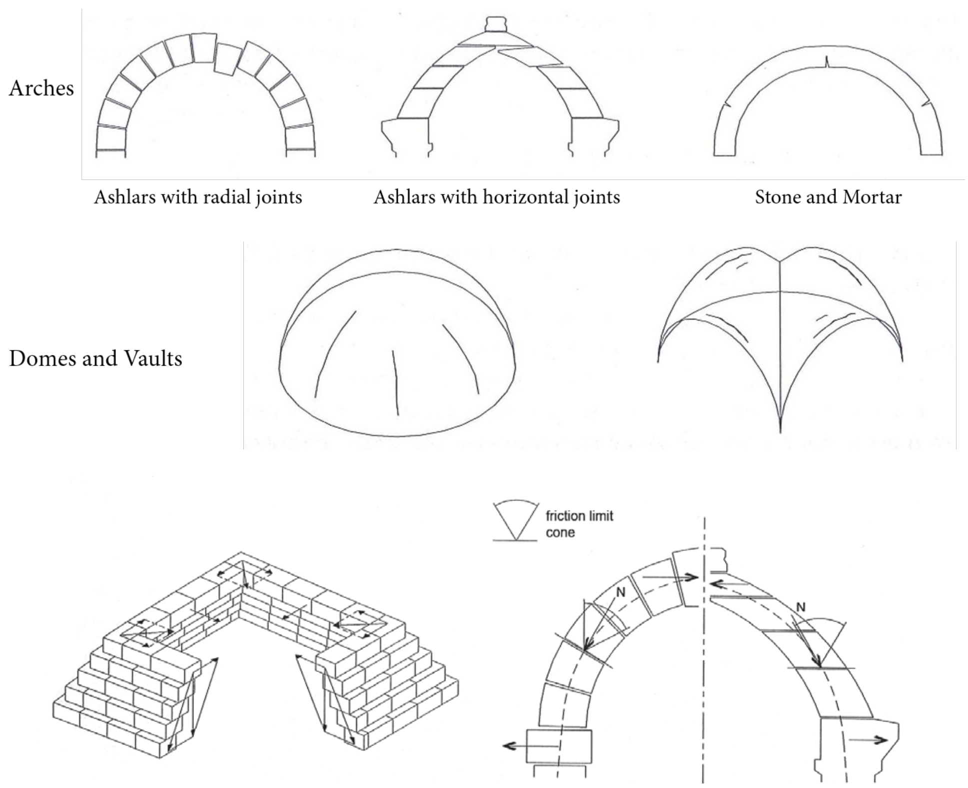


Fig. 9. From G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011, pp. 47, 121.

CAUSES

– INCOMPATIBILITY (CONSTRUCTIVE) (1)

– GROUND
  · Soil Settlement
  · Changes

– LOADS

– STRUCTURAL
  · Originally
  · Joints

– HUMAN ACTION

– MATERIALS
  · Degradation
  · Oxidation

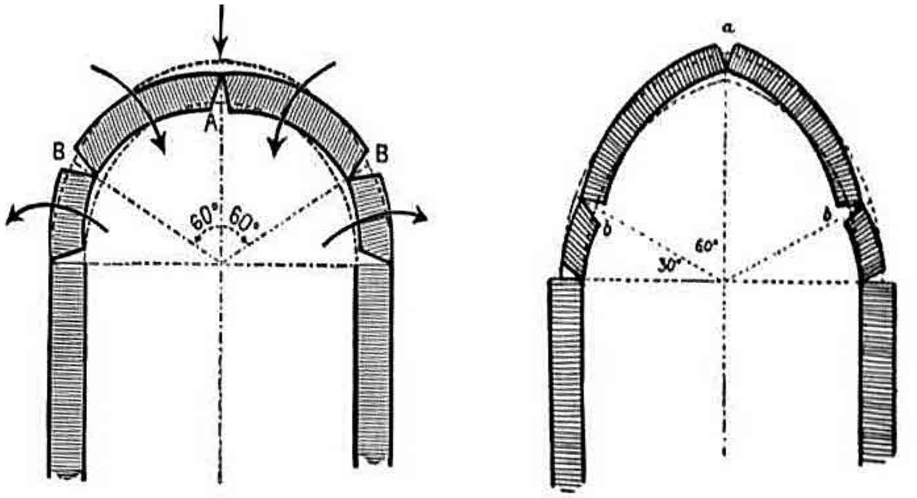


Fig. 10. From R. Di Stefano, *Il consolidamento strutturale nel restauro architettonico*, Edizioni Scientifiche Italiane, Napoli 1990, p. 96, fig. 51.

If vertical loads dominate, the arch opens at five points (on the left). If, instead, lateral loads are the dominant ones (on the right), each one of the five cracks manifests in the opposite direction.

HYPOTHESIS

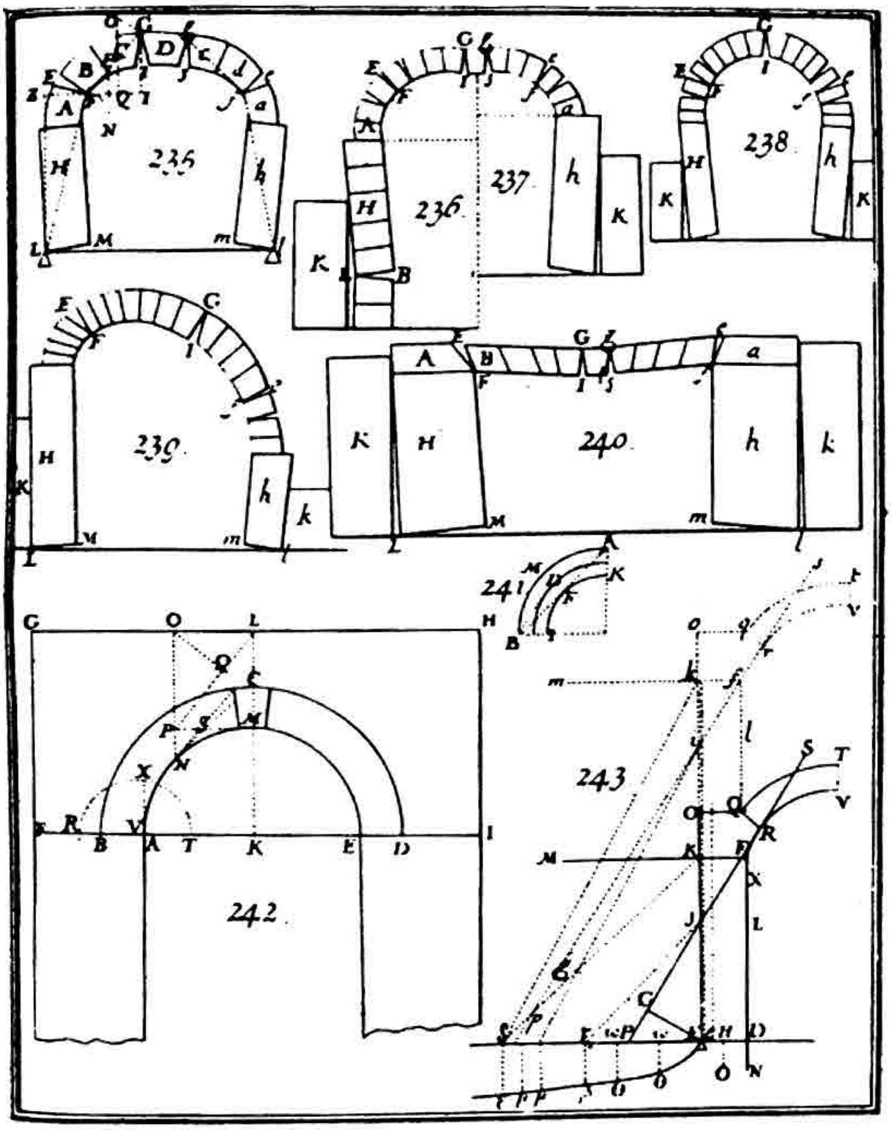
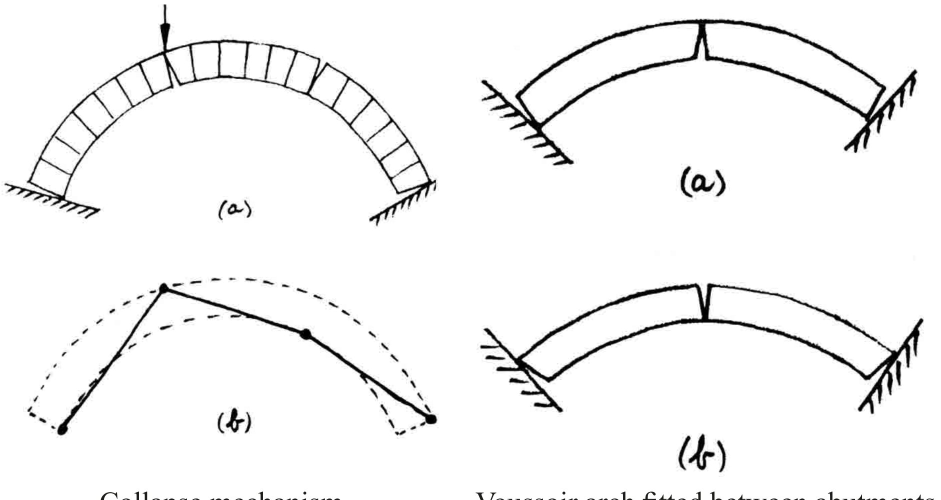


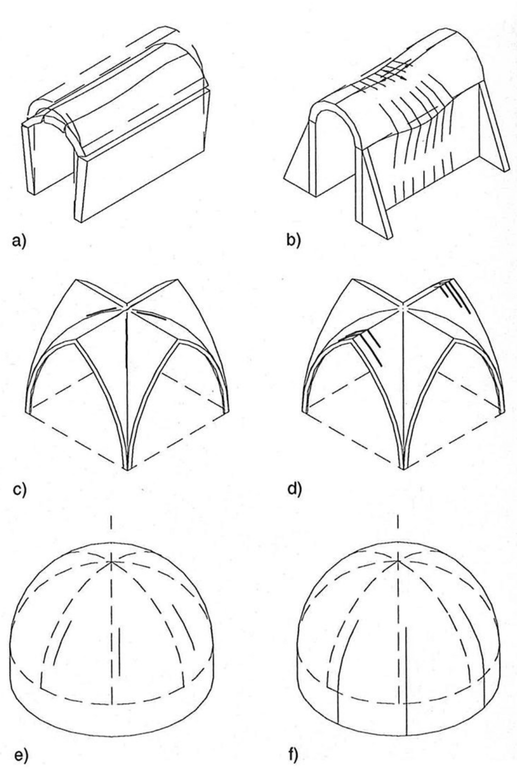
Fig. 11. From *The collapse of archs*, published by Frezier, in A. Giuffrè, *Monumenti e terrremoti, aspetti statici del restauro*, Roma 1988, p. 80.



Collapse mechanism
for a voussoir arch.
Four hinges are necessary

Voussoir arch fitted between abutments
of slightly the wrong span;
(a) too large, and (b) too small.
In either case the arch cracks
in three places

Fig. 12. Mainstone R. From L. Palaia, E. Abdilla, *Técnica de intervención en arcos*, *bóvedas y cúpulas,* "Stability concept from Renaissance to today", UPV, 1996, p. 71.



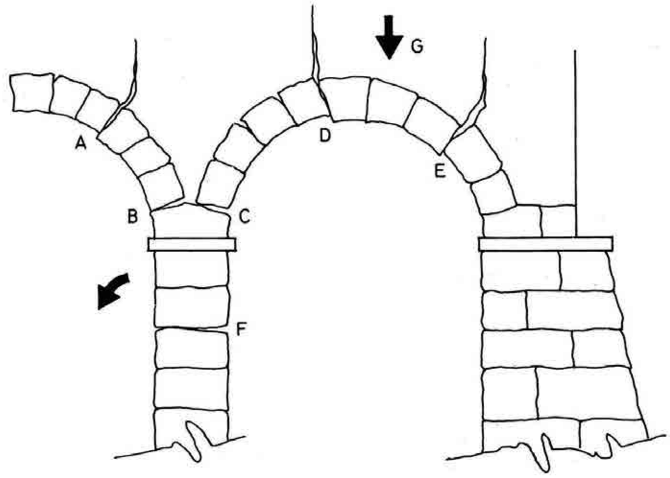


Fig. 13. On the left: from G. Croci, *Conservazione e restauro strutturale dei beni architettonici*, Utet, Torino 2011.

Fig. 14. On the right: from G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1975, p. 72.

HUMAN ACTION

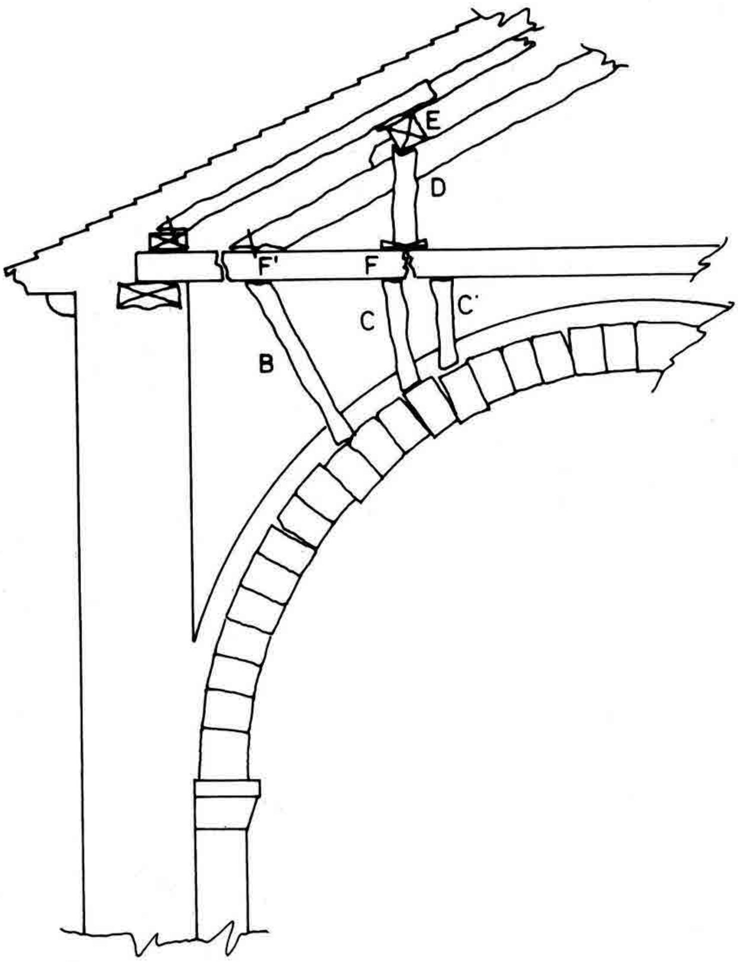


Fig. 15. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1975, p. 233.

DEFECTS IN MASONRY VAULTS: SABOURET'S CRACKS

Typical cracks in Gothic vaults. Pol Abraham distinguished between the tensile cracks near the vault crowning, 'Sabouret cracks' parallel to the wall ribs, and the separation of the vault from the walls.

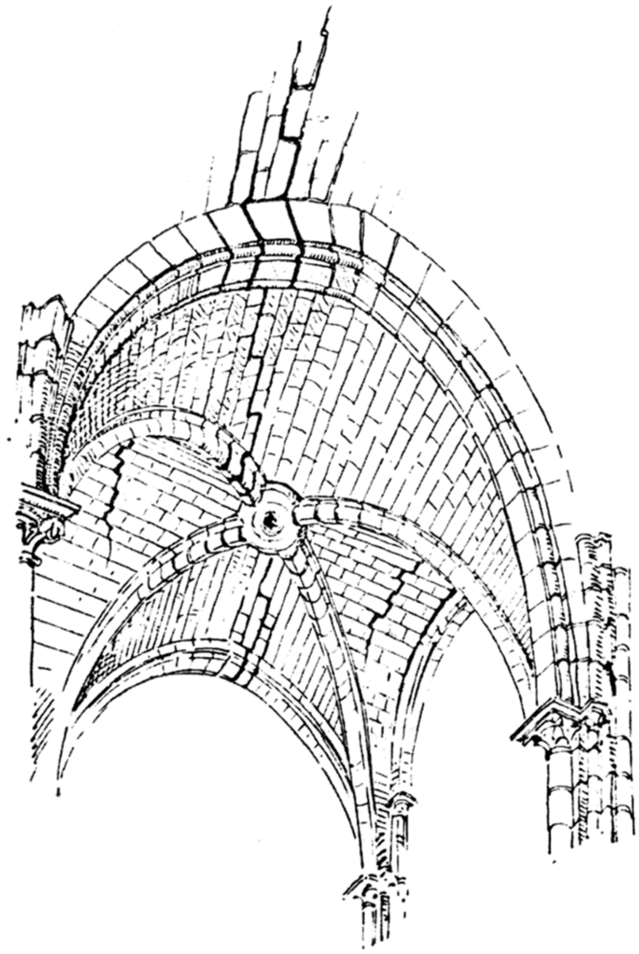
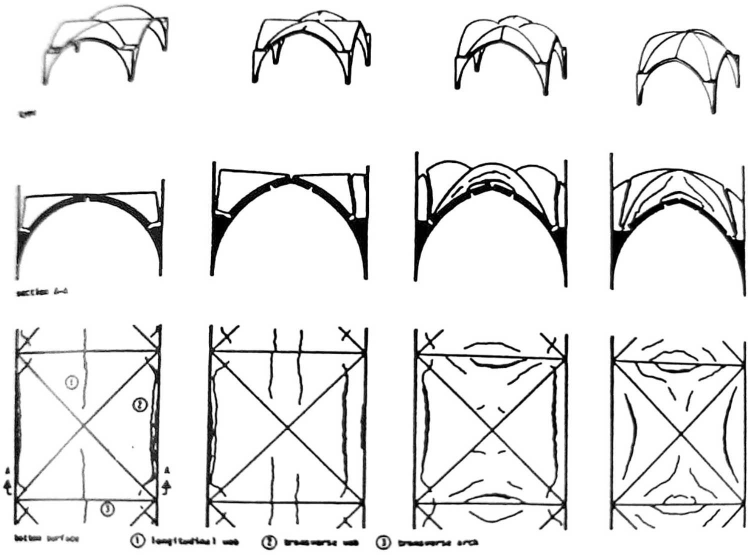


Fig.16. From J. Heyman, *The masonry arch*, Ellis Horwood serie in Engineering Science, 1982, pp. 3-19.



(a)

Fig.17. From J. Heyman, *The masonry arch*, Ellis Horwood serie in Engineering Science, 1982.

CONSOLIDATION OF VAULTS

(2)

- Reconstruction of lacunae
- Sealing of cracks
- Overlay:
  · Upper reinforcement
  · Upper structure
- Anchoring
- Restore the shape to the vault
- Shoring

RECONSTRUCTION OF LACUNA

Fig. 18. Cáceres, Spain. Photo by Susana Mora, 2014.

SEALING OF CRACKS

Fig. 19. Vault in the cloister of Carracedo Monastry, Spain. Restoration by S.P. Arroyo and S. Mora. Photo by Susana Mora.

OVERLAY

UPPER REINFORCEMENT

– Poured or Shell

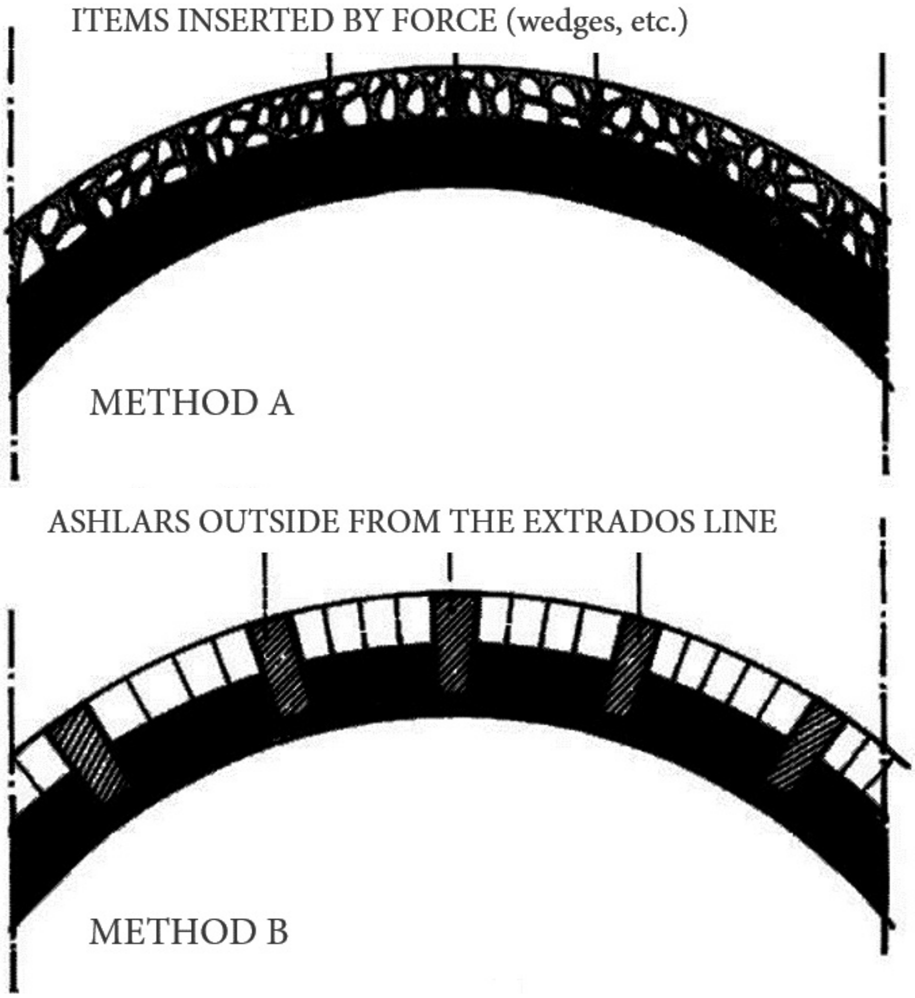


Fig. 20. From C. Piccirilli, *Consolidamento critico*, Multigrafica editrice, Roma 1989, p. 68.

– Reinforcement with metalic/glass fiber frame

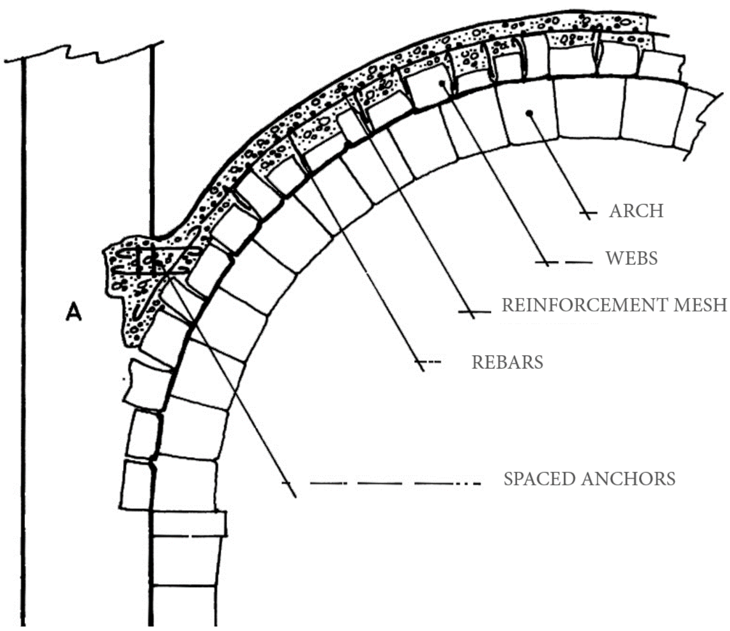


Fig. 21. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1975, p. 251.

– Reinforcement with metalic frame.

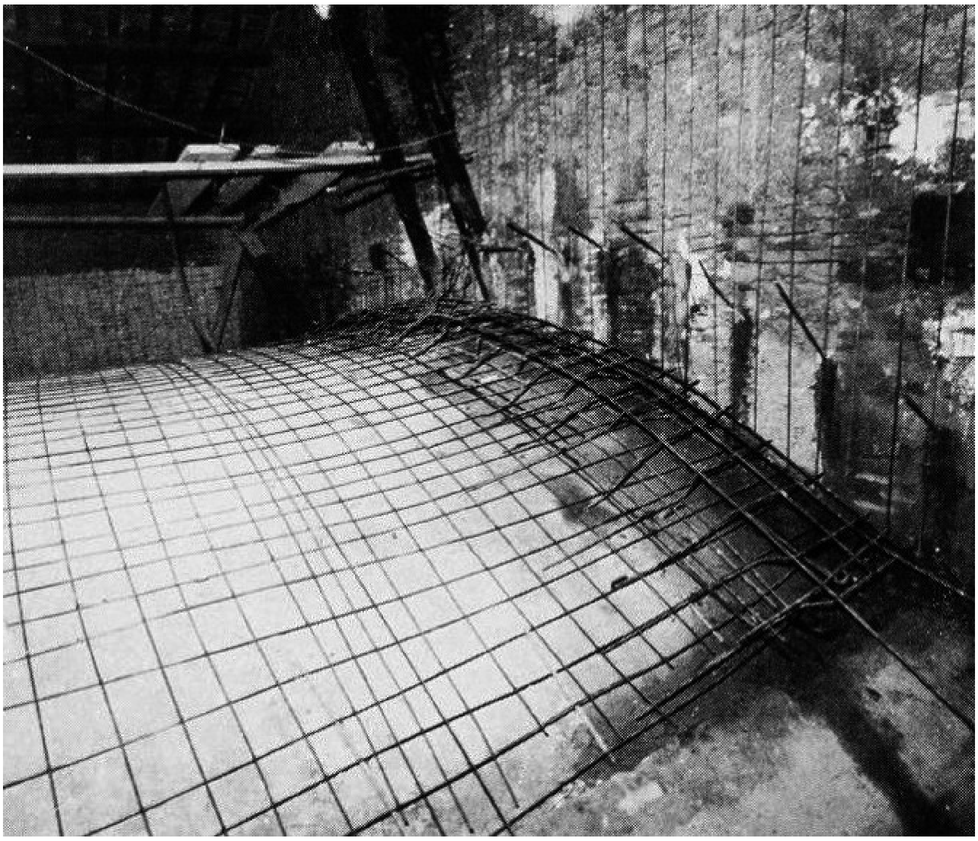


Fig. 22. San Silvestro in Capite, Roma. F. Lizzi Method. From F. Lizzi, *The static restoration of monuments*, Sagep Publisher, Genova 1982, p. 24.

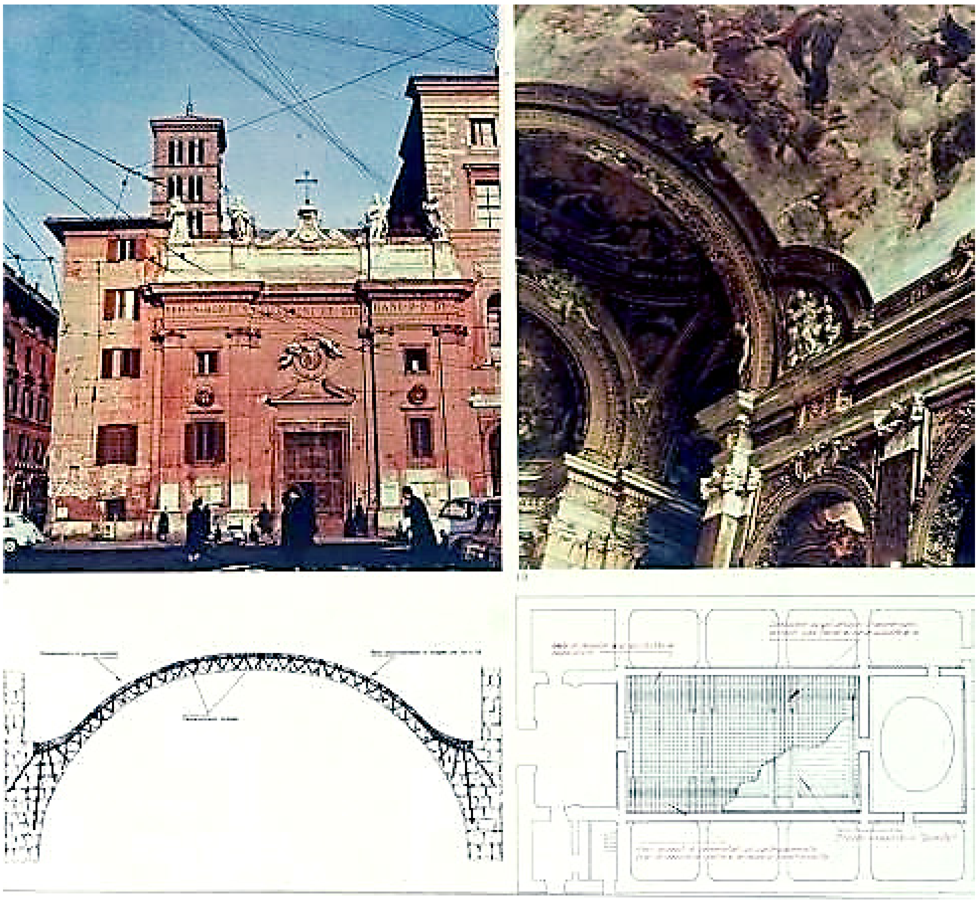
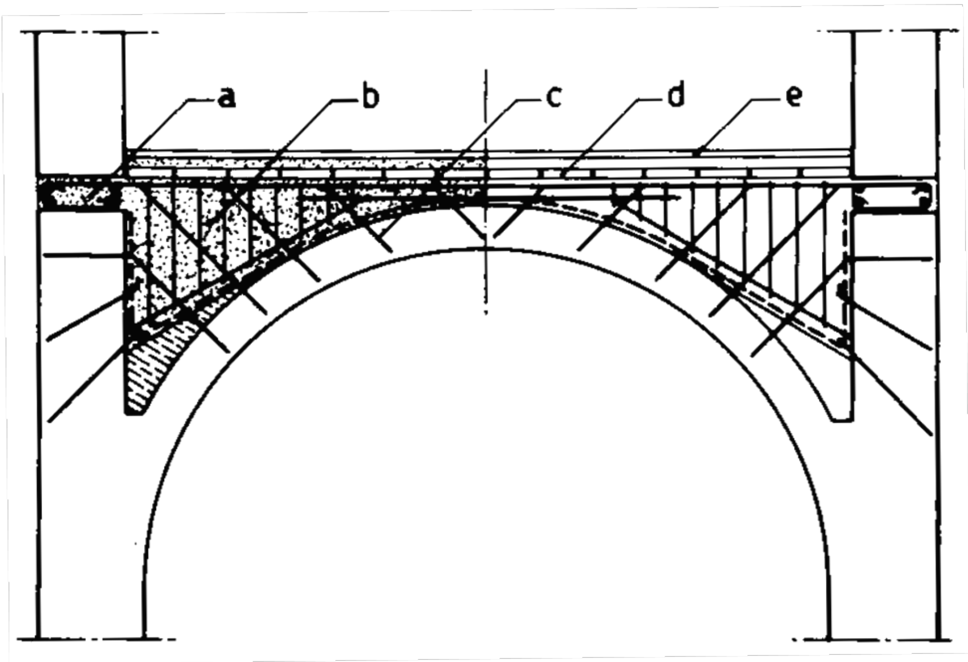


Fig. 23. San Silvestro in Capite, Roma. From F. Lizzi, *The static restoration of monuments*, Sagep Publisher, Genova 1982, p. 23.

– Reinforcement with carbon fibers.

UPPER STRUCTURE



– Hanging

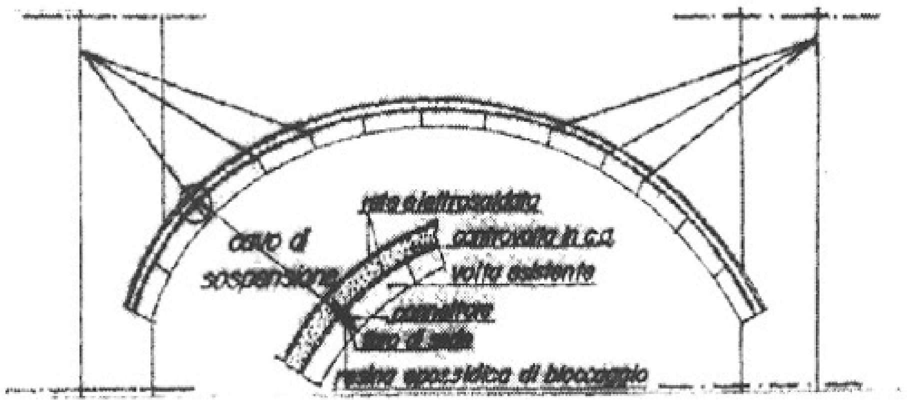


Fig. 24. From C. Piccirilli, *Consolidamento critico*, Multigrafica editrice, Roma 1989, p. 71.

ANCHORING

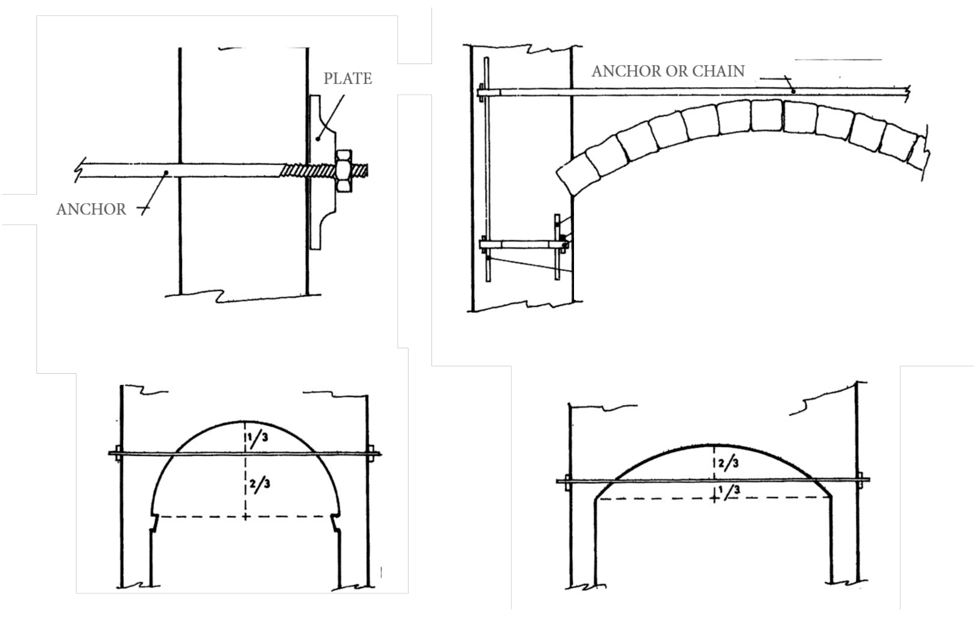


Fig. 25. From G. López Collado, *Las Ruinas en Construcciones Antiguas*, Miján, Artes, Gráficas, Ávila 1975.

RETURN THE SHAPE TO THE VAULT

REINFORCED ARCH

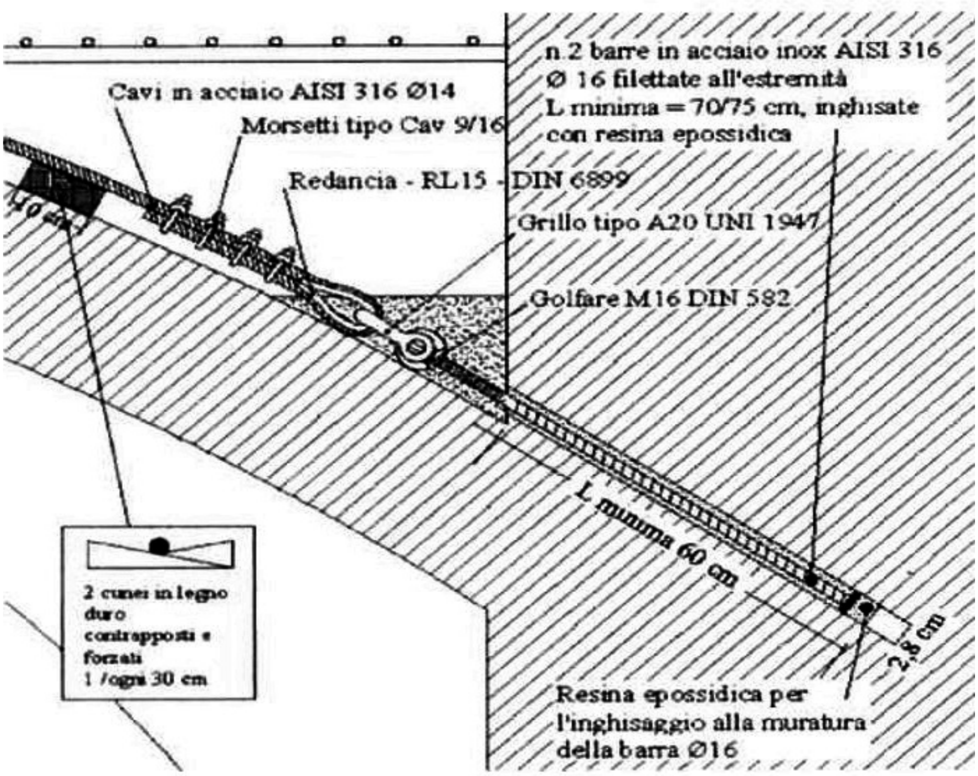


Fig. 26. Castello Mediceo. Intervention carried out by Lorenzo Jurina using the "reinforced arch" method, applied to the extrados of the vault. Details of the anchoring of the ties to the masonry, with post-tensioned by wooden wedges. From L. Jurina, *Evoluzione e declinazioni nell'uso dell'"Arco Armato"*, Politecnico di Milano 2013.

Figs. 27-29. From G. Carbonara, *Atlante del restauro architettonico,* vol. II, Utet, Torino 2004.

Fig. 30. Castello della Manta. Lorenzo Jurina used the “reinforced arch” method, applied to the extrados of the vault. Details of the anchoring of the tie-rods to the masonry and of a crossing of tie-rods, with post-tensioned by tensioners. From L. Jurina, *Evoluzione e declinazioni nell’uso dell’“Arco Armato”*, Politecnico di Milano 2013.

Fig. 31. Villa S. Carlo Borromeo. Lorenzo Jurina used the “reinforced arch” method, applied to the intrados of the vault. View of the intrados. Details of the anchoring of the tie-rods to the masonry, with post-tensioned by tensioners. From L. Jurina, *Evoluzione e declinazioni nell’uso dell’“Arco Armato”*, Politecnico di Milano 2013.

SHORING

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

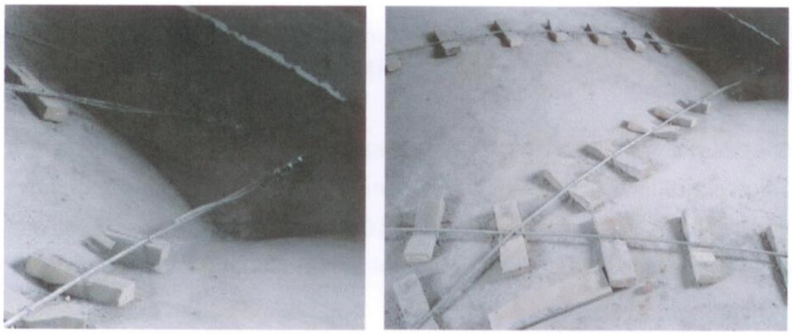


Fig. 32. Monastero Olivetano. Lorenzo Jurina used the “reinforced arch” method, applied to the extrados of the vault. Details of the anchoring of the tie-rods to the masonry and of a crossing of tie-rods, with post-tensioned by wooden wedges. From L. Jurina, *Evoluzione e declinazioni nell’uso dell’“Arco Armato”*, Politecnico di Milano 2013.

Fig. 33. Santa Maria di Collemaggio, L’Aquila. Photo by Susana Mora, 2012.

NOTES

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CHAPTER 10. FLOORS: CONSTRUCTIVE SYSTEMS, PROBLEMS, CAUSES AND SOLUTIONS

Floors wear down to receive the loads of the building and transfer them to the vertical structural elements.

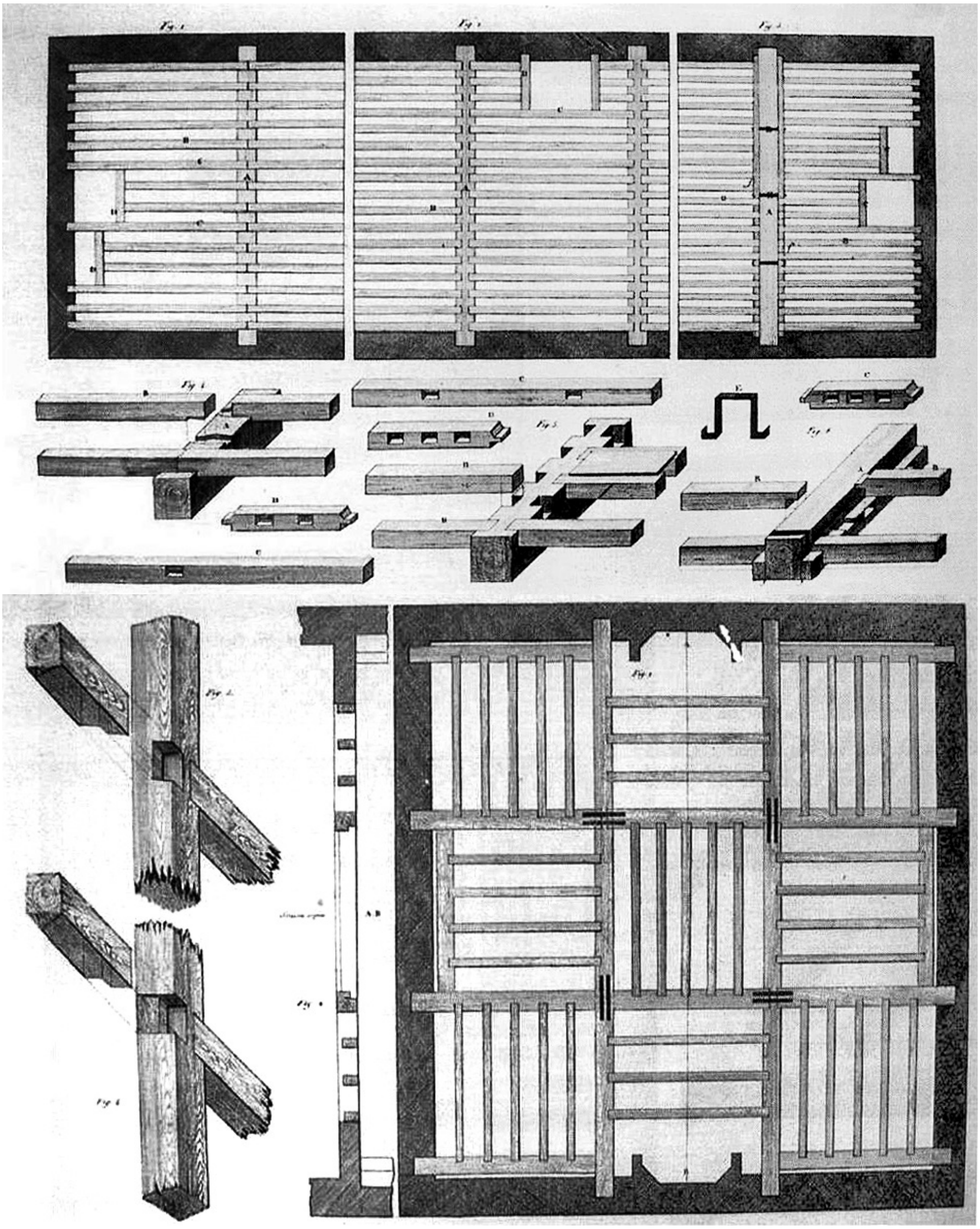


Fig. 1. Beam filling with layers of differentiated function. From G. Rondelet, *Trattato teorico e pratico dell'arte di edificare*, Mantova 1832, Vol. I, Tab. LXXXVIII.

HISTORIC EVOLUTION

Historic floors were made in wood but they changed:

BEAM FILLING

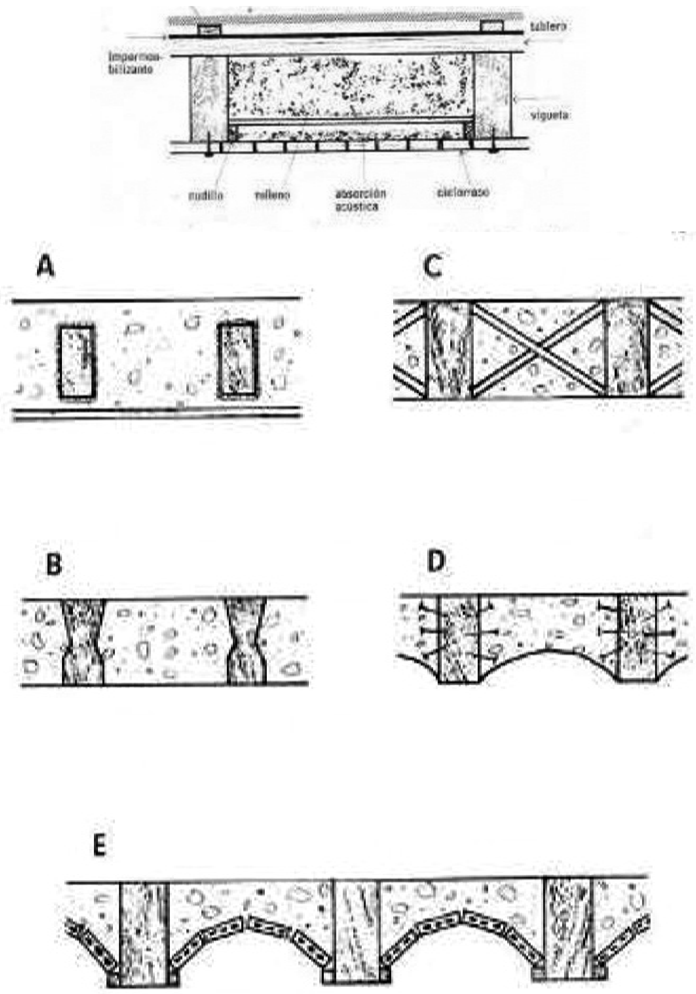


Fig. 2. Redesigned by Susana Mora.

CEILING

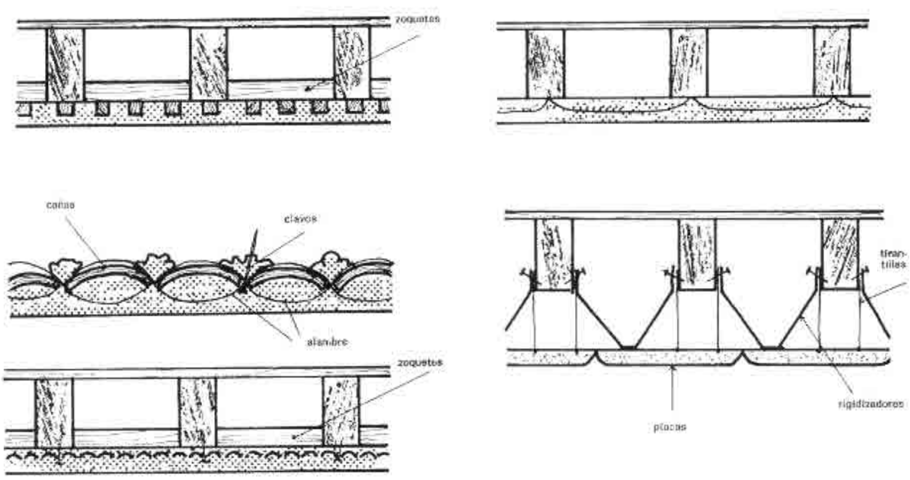
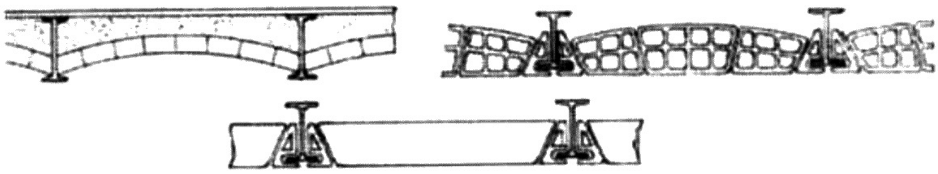


Fig. 3. Redesigned by Susana Mora.

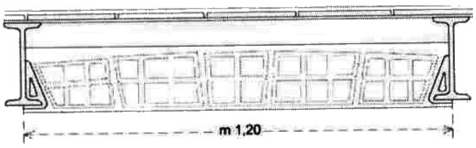
STEEL BEAMS



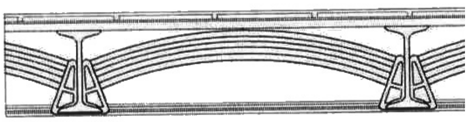
(1)

Fig. 4. From A. Ciappi, *Manuale dell'architetto*, Torino 1946.

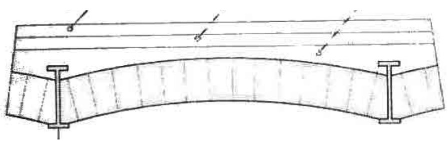
Fig. 5. From A. Ciappi, *Manuale dell'architetto*, Torino 1946.



Flooring with ceramic vaults.



Flooring with arched planks.



Example of steel flooring.

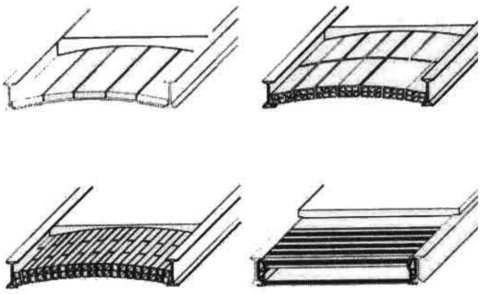


Fig. 6. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001, "Anatomia degli organismi edilizi moderni", Section B1.2., B36.

REINFORCED CONCRETE FLOORS

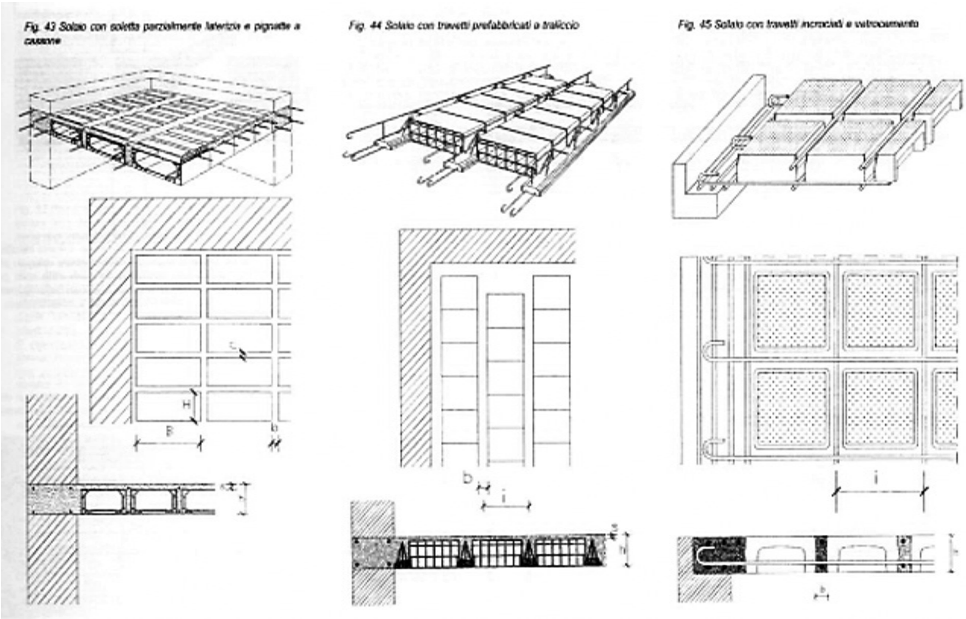
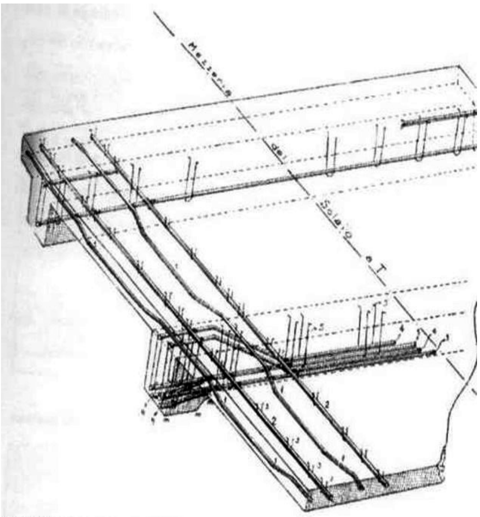
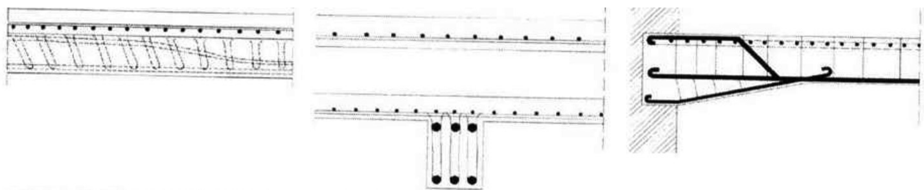


Fig. 7. Hennebique System. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001, "Anatomia degli organismi edilizi moderni", cemento armato, B1.1., B4.

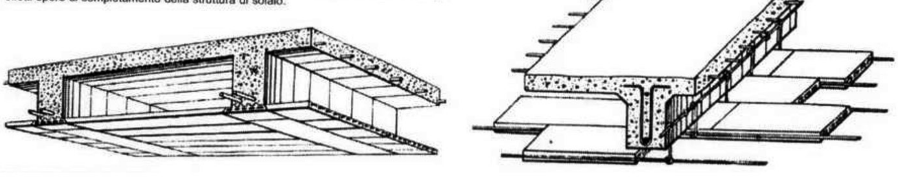
T Floor System



Ceiling



Per evitare la vista delle nervature e migliorare l'isolamento acustico venenro sovente realizzate soffittature che coprivano l'intradosso al fine di renderlo completamente piano e relativamente insonorizzato. Un esempio sono i controsoffitti tipo "Frazzi", con tavelloni di laterizio ad incastro, e tipo "Perret", con tavelle armate: erano a tutti gli effetti opere di completamento della struttura di solaio.



"Frazzi" ceiling — Breymann

"Perret" ceiling — Breymann

Fig. 8. Hennebique System. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001, "Anatomia degli organismi edilizi moderni", cemento armato, B10, B1.1.

Structural Hollow Clay Block

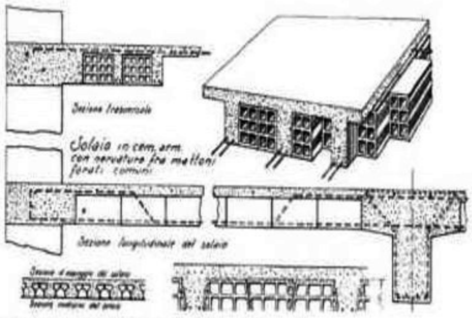
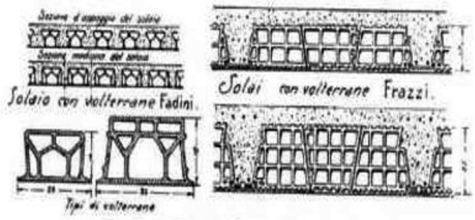
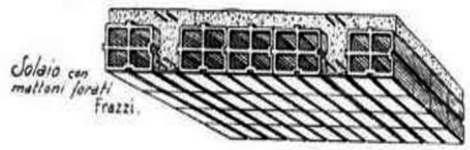


Fig. 28 Solaio integrato con laterizi per murature (da Breymann)

I solai a nervatura incrociata si diffusero solo negli anni trenta. È il caso dei solai a nervature limitate da isole laterizie semplici o composte, come il solaio "Castori", il solaio "Villa", il solaio "Duplex". Questi venivano adottati su piante quadrate o prossime al quadrato ed agivano chiamando all'azione resistente tutti i muri perimetrali. Non ponevano limiti, inoltre, alla posizione dei divisori, per i quali erano necessarie armature di rinforzo nel caso di altri tipi di solaio. Nei casi di perimetri d'appoggio rettangolari allungati le nervature potevano assumere andamento diagonale a 45°, come nel solaio "Diagonal Cavallazzi", o sfalsate, come nel solaio "Semi-diagonal Cavallazzi".



Frazzi floor



Frazzi floor

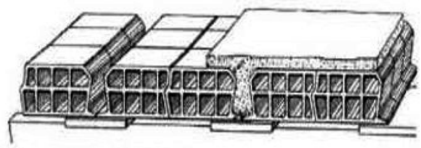


Fig. 29 Diversi tipi di volterrane laterizie (da Breymann)

Different types of floors (Breymann)

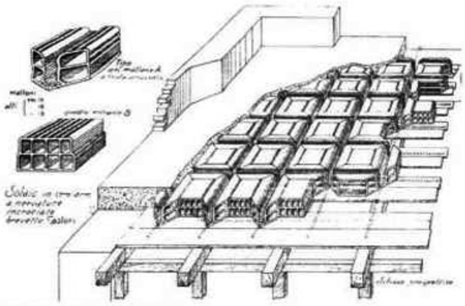


Fig. 30 Solaio tipo "Castori" (da Breymann)

Castori floor (Breymann)

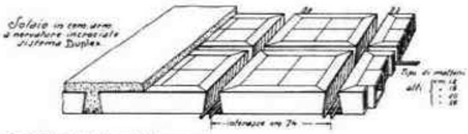


Fig. 32 Solaio tipo "Duplex" (da Breymann)

Duplex floor (Breymann)

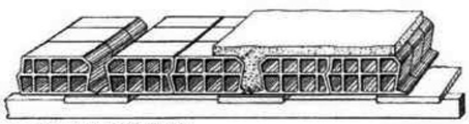


Fig. 31 Solaio tipo "Villa" (da Breymann)

Villa floor (Breymann)

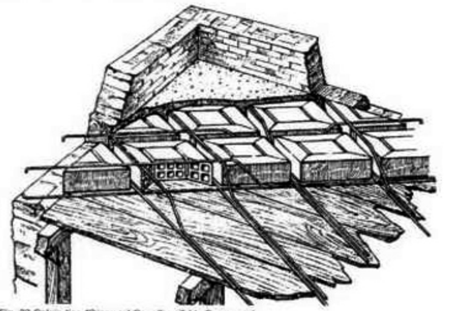


Fig. 33 Solaio tipo "Diagonal-Cavallazzi" (da Breymann)

Diagonal, cavalazzi (Breymann)

Fig. 9. Hennebique System. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001, "Anatomia degli organismi edilizi moderni", cemento armato, B11.

Other Types of Floors

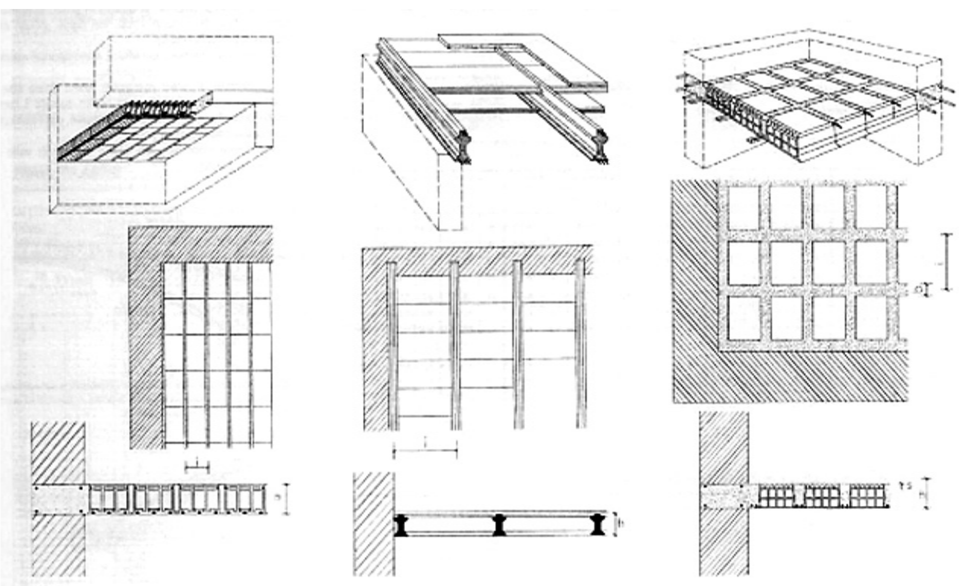


Fig. 10. Hennebique System. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001, "Anatomia degli organismi edilizi moderni", cemento armato, B14.

CAUSES

FOUNDATION AND GROUND DAMAGES
Internal Damages

Wall is uniformly pushed and displaced with vertical shear cracks.

SOLUTIONS

CONSOLIDATION OF FLOORS

- Shorten distance from a beam
- Shear connectors
- Overlay:
  - · Reinforcement
  - · Suspended structure
- Anchoring

SHORTEN DISTANCE FROM A BEAM

Fig. 12. Almudín, Valencia. Photo by Susana Mora, 2010.

SHEAR CONNECTORS

The use of connectors can allow for a significant reduction of the beam whilst ensuring the same load-bearing capacity.

- Wooden Beams.

(2)

Fig. 13. Tecnaria, Bassano del Grappa, Italy.

- Steel Beams.

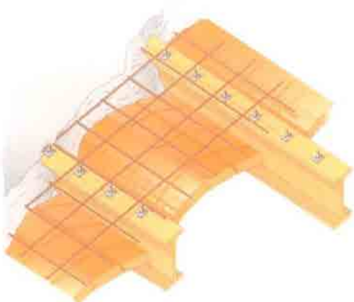


Fig. 14. Tecnaria, Bassano del Grappa, Italy.

Fig. 15. Tecnaria, Bassano del Grappa, Italy.

OVERLAY

- Reinforcement with concrete.

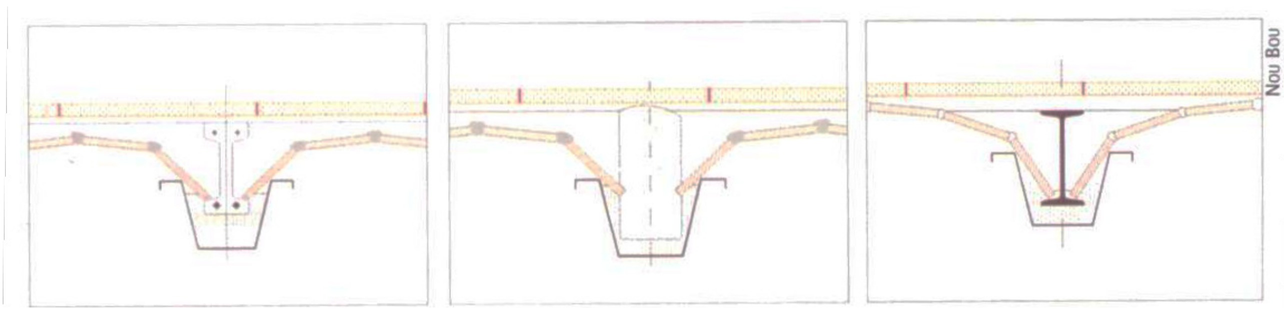


Fig. 16. Avis Technique CSTB.

- Reinforcement. Steel Auxiliary Structure. Axial effort increased.

Fig. 17. Palazzo Altemps, Roma. Photo by Calogero Bellanca, 2020.

- Reinforcement. Fibers:

Many new products composed of FRP (fiber reinforced polymers) are now used to consolidate traditional structures for the reinforcement of concrete and sustitution of iron elements: glass, carbon, aramide, basalt, PBO, metallic and natural fibers.

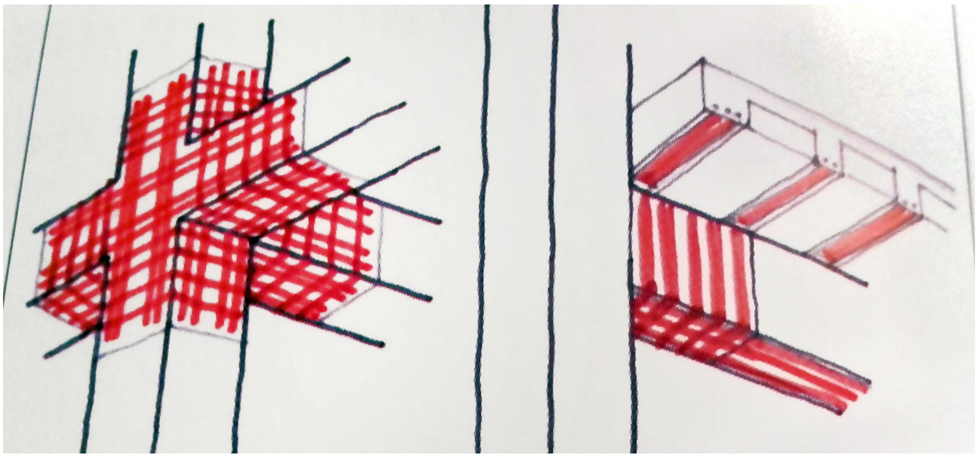


Fig. 18. From F. De Cesaris, "Materiali e strutture", n. 12, 2017, p. 78.

ANCHORING

Anchoring of the floor to the masonry consolidation.

Fig. 19. Refectory and new roof of San Pedro de Arlanza, Hortigüela, Burgos. Salvador Pérez Arroyo and Susana Mora. Photo by Susana Mora, 2012.

Fig. 20. New beams anchors in the vaults of the Refectory, San Pedro de Arlanza, Salvador Pérez Arroyo and Susana Mora. Photo by Susana Mora, Burgos, 2012.

NOTES

RONDELET G., *Traité Theorique et pratique de l'art de Batir*, Paris 1804, prima edizione italiana a cura di Basilio Soresina, Mantova 1832;

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1) Don't forget: DE CESARIS F., *Solai*, sezione C.4, *Atlante del Restauro*, tomo 1, diretto da Carbonara G., Torino 2004., pp. 236-257;

2) DI STEFANO R., *Il Consolidamento,* …, Napoli 1990, pp. 230-243; DE CESARIS F., *Interventi su solai e coperture*, sezione G 5, in *Atlante del Restauro*, tomo 2, a cura di Carbonara G., Torino 2004, pp. 583-601; GALLO CURCIO A., *Sul consolidamento degli edifici Storici*, Roma 2007, pp. 253-278.

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CHAPTER 11. ROOFS: CONSTRUCTIVE SYSTEMS, PROBLEMS, CAUSES AND SOLUTIONS

> “What is reputed to be the oldest surviving timber roof truss, found in the church of St Catherine on Mount Sinai, dates from the sixth century. It is probable that the early Roman basilicas, such as St Peter’s and St Paul’s outside the walls, had trussed roofs of timber. The Pantheon anticipated stuctural development by some seventeen centuries by having a metal truss of bronze; unfortunately, it was melted down… Early mediaeval roofs consisted couples of rafters pinned together at the apex and having a short collar about one-third of the way down. These rafters were covered with longitudinal battens to which the roof covering was fixed”.
>
> From FEILDEN, B. M., *Conservation of Historic Buildings*, Butterworths, London, 1982, p. 51.

CONSTRUCTIVE SYSTEM

TRADITIONAL STRUCTURAL SOLUTIONS

– BUNDLE OF RAFTERS (+ joists):
  · Directly supported on the masonry.
  · Supported on sleepers: “A par y picadero”.

– BUNDLE OF JOISTS (+ small rafters):
  · Supported on the masonry: “A la molinera”.

– BUNDLE OF RAFTERS ON GABLE ROOF:
  · Counteracting on the head:
    - Against a ridge bar: “A par e hilera” or close couple roof.
  · Counteracting on the foot:
    - Fixed masonry embebed.
    - With a tensined bar: “Rafter and tie beam”.

Fig. 1. Carracedo Monastry, “Cocina de la Reina”, wood roof structure during restoration. Photo by Susana Mora, 1990.

ISOLATED BARS

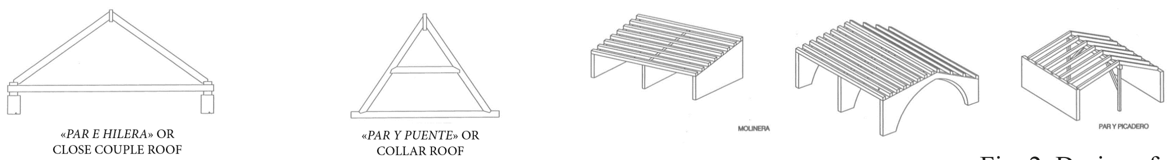


Fig. 2. Designs for ETSAM by Susana Mora.

ISOLATED BARS: "A LA MOLINERA"

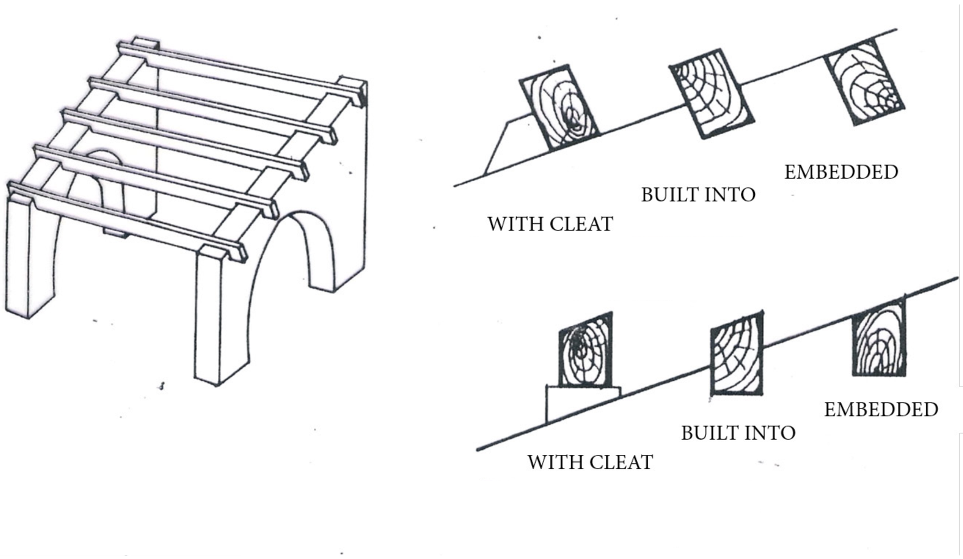


Fig. 3. On the left: design for ETSAM by Susana Mora, 2003. On the right: designs by A. Cámara "Apuntes de Madera", ETSAM, 1960.

ISOLATED BARS: "PAR Y PICADERO"

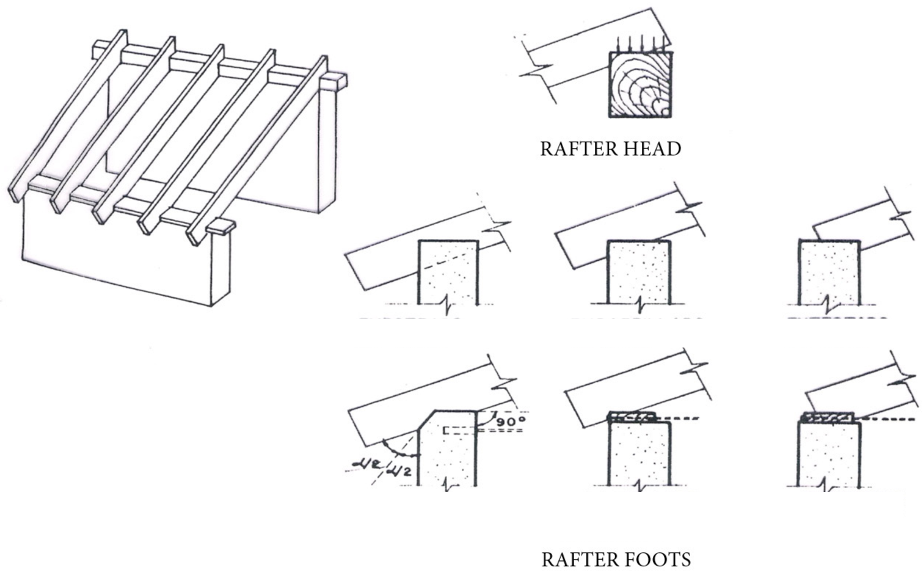


Fig. 4. On the left: design for ETSAM by Susana Mora, 2003. On the right: designs by A. Cámara "Apuntes de Madera", ETSAM, 1960.

ISOLATED BARS: "PAR E HILERA" OR CLOSE COUPLE ROOF

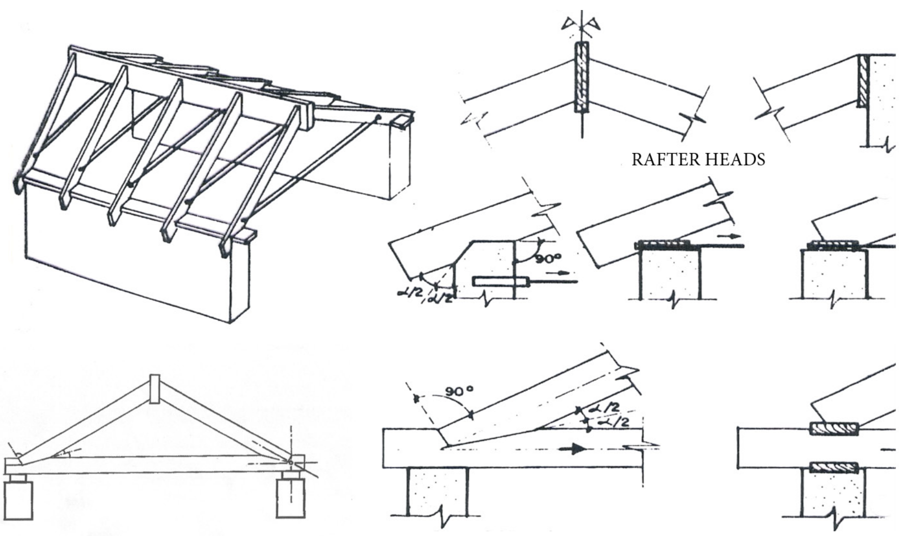


Fig. 5. On the left: design for ETSAM by Susana Mora, 2003. On the right: designs by A. Cámara "Apuntes de Madera", ETSAM, 1960.

CONSTRUCTIVE DETAILS (1)

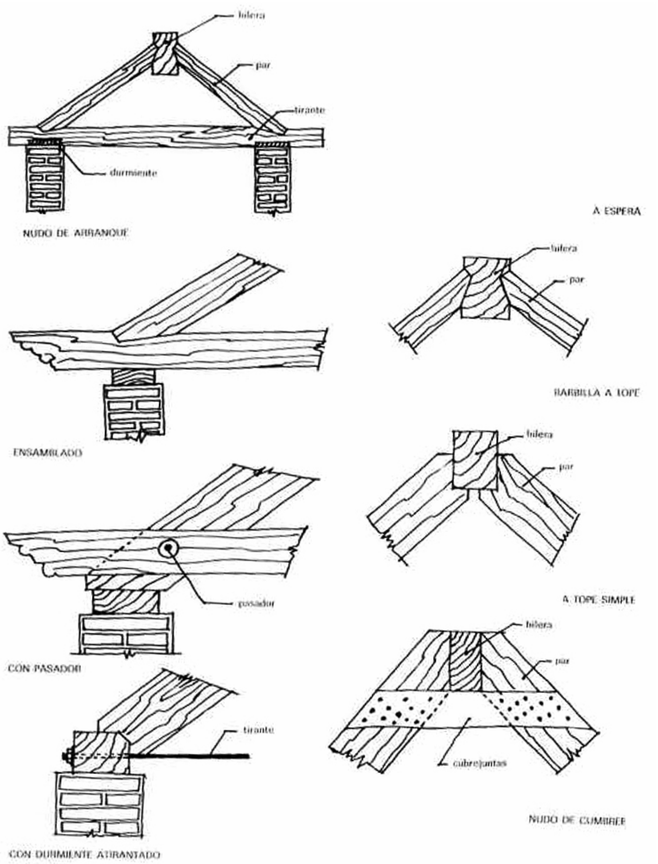


Fig. 10.6. Cubierta de par e hilera.

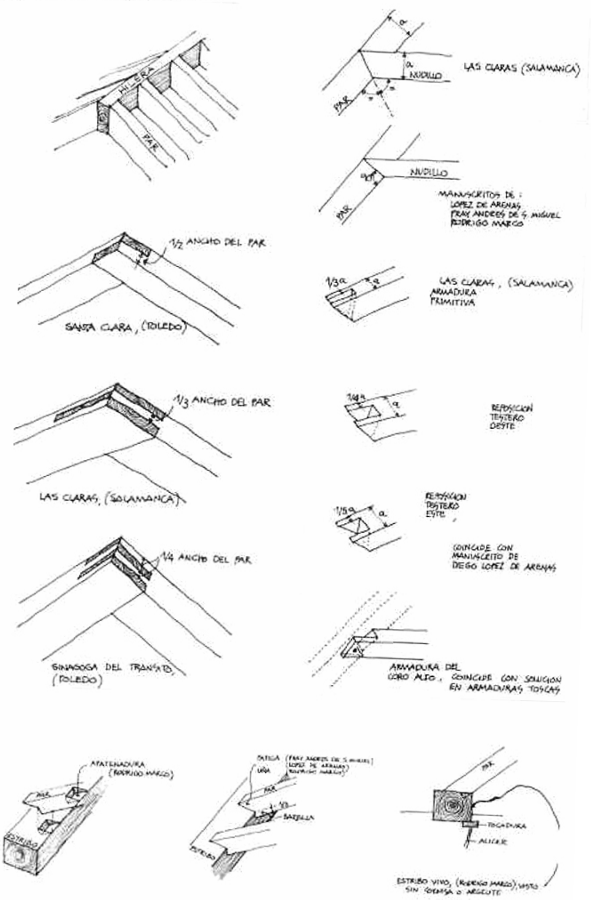


Fig. 6. Designs by A. Cámara “Apuntes de Madera”, ETSAM, 1960.

TRIANGULAR LAYOUT BARS

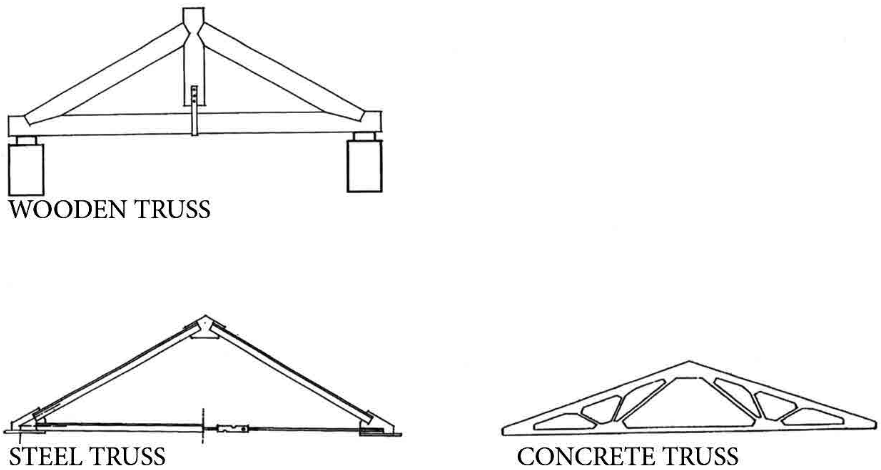


Fig. 7. Designs by Susana Mora for ETSAM, 2007.

TRIANGULAR LAYOUT BARS: TRUSSES

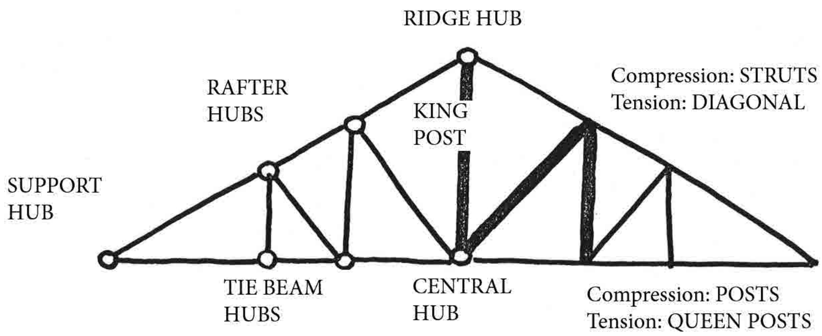


Fig. 8. Designs by Susana Mora for ETSAM, 2007.

BASIS STRUCTURE

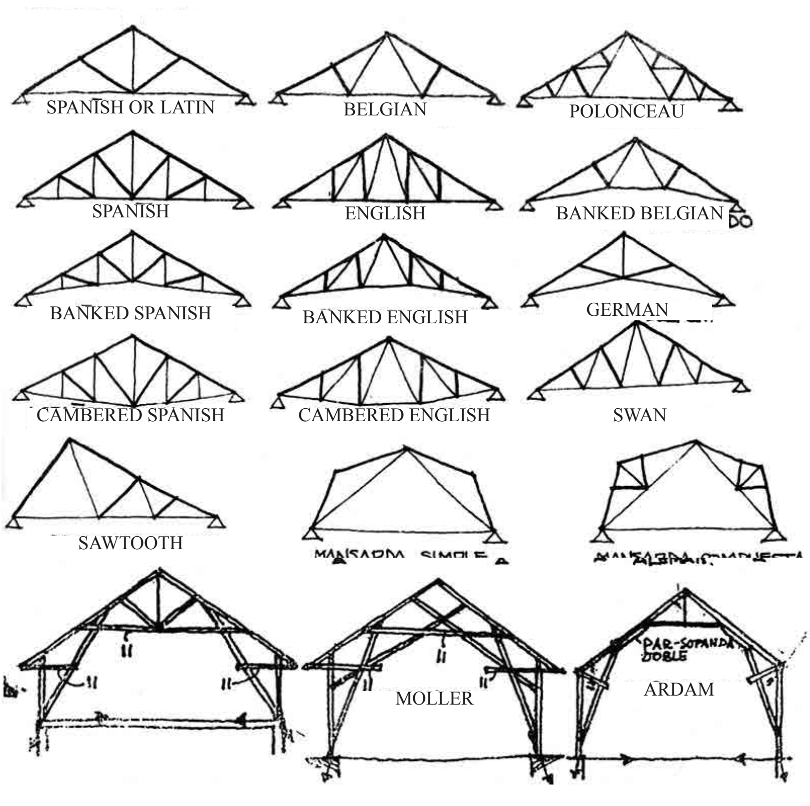


Fig. 9. Types of trusses. Designs by Susana Mora for ETSAM, 2007.

NOMENCLATURE

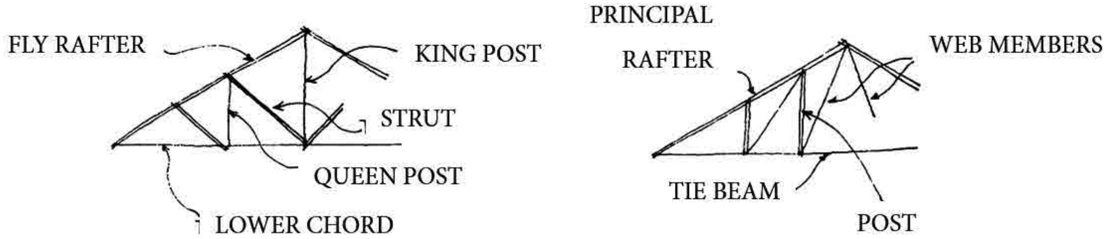


Fig. 10. Designs by Fernando Ripollés, “Construcción obra gruesa”, ETSAM, 1998.

ORGANIZATION: SUPPORT TRUSSES

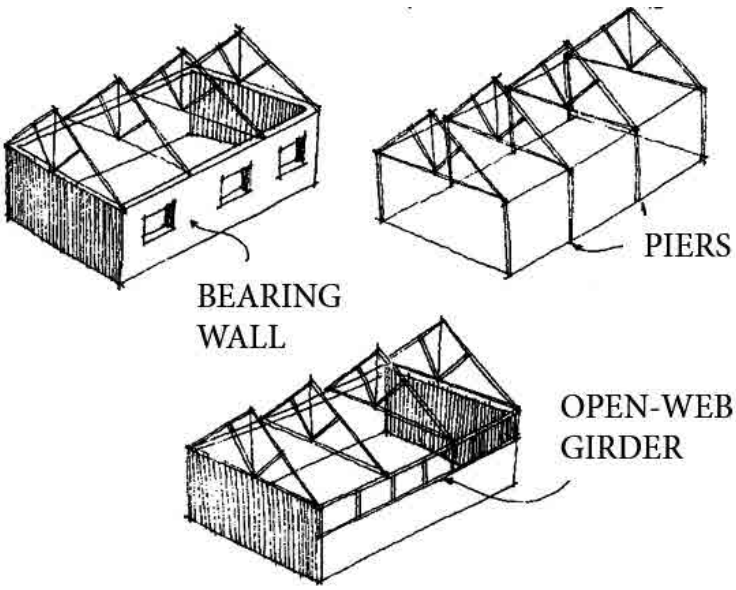


Fig. 11. Designs by Fernando Ripollés, “Construcción obra gruesa”, ETSAM, 1998.

TRUSSES BRACING

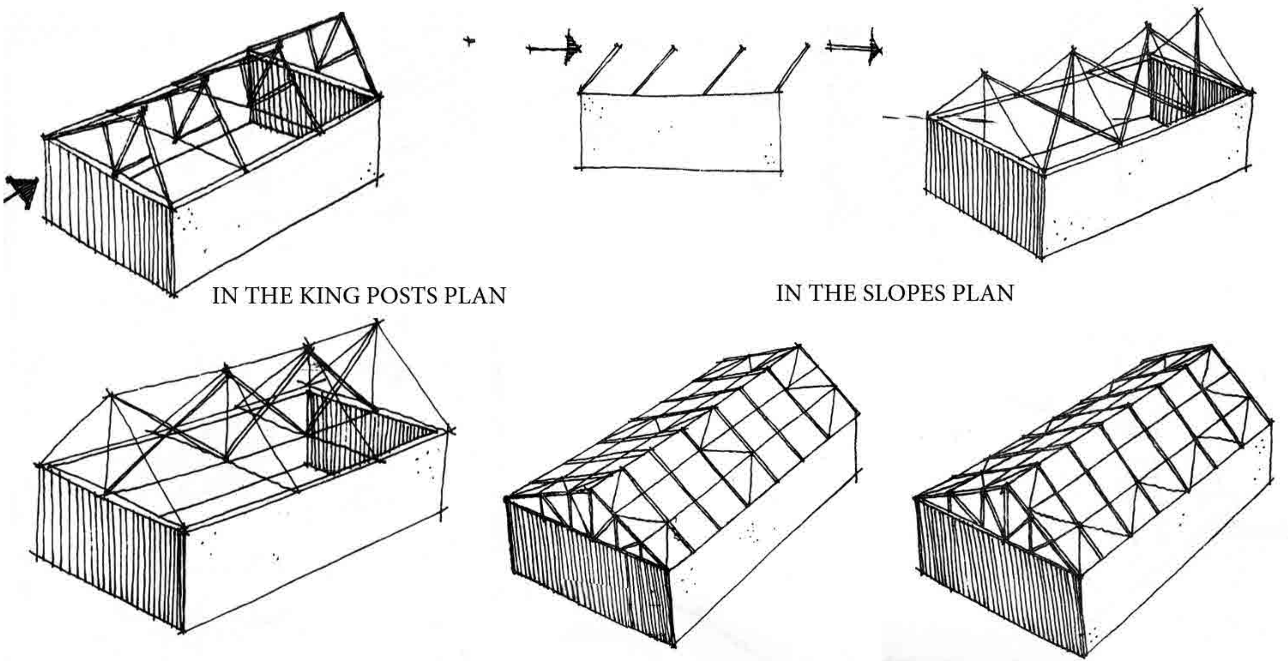


Fig. 12. Designs by F. Ripollés, “Construcción obra gruesa”, ETSAM, 1998.

TRADITIONAL SOLUTIONS: ASSEMBLED WOOD

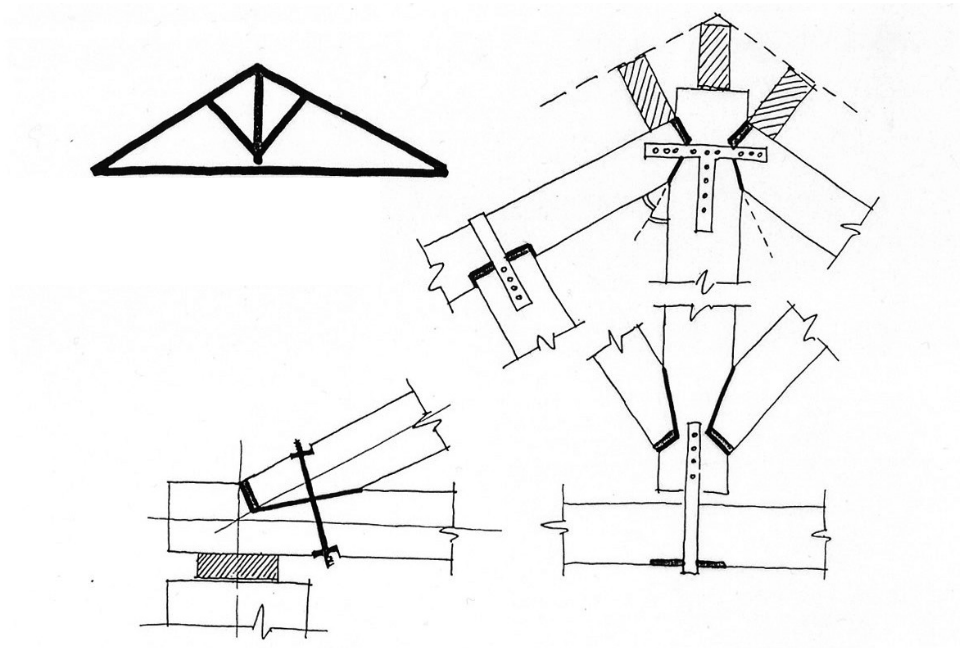


Fig. 13. Designs by Susana Mora for ETSAM, 2007.

TRADITIONAL SOLUTIONS: BOLTED WOOD

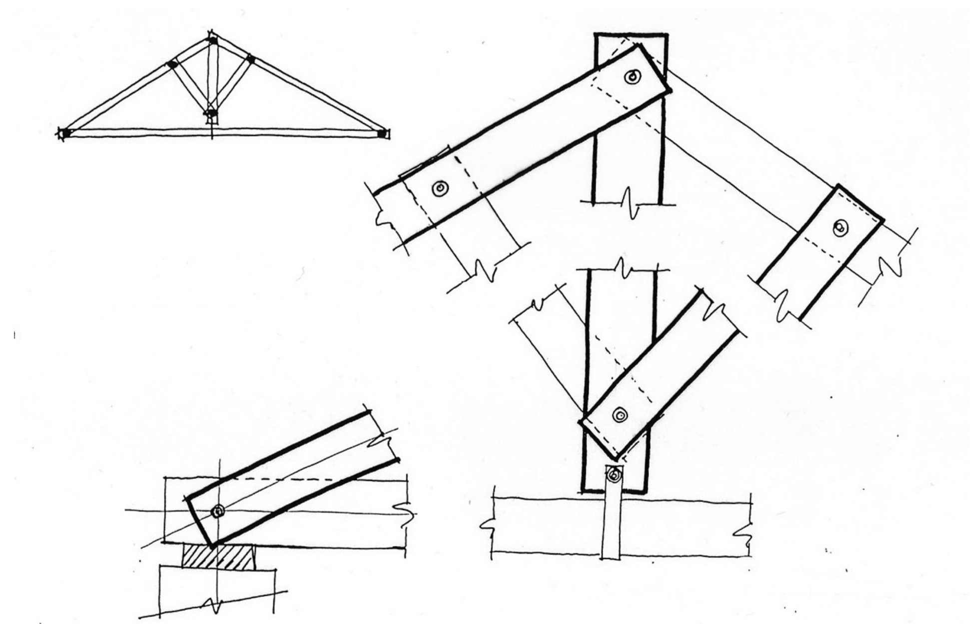


Fig. 14. Designs by Susana Mora for ETSAM, 2007.

CONSOLIDATION OF WOODEN STRUCTURES

– BETA SYSTEM
– EXTERNAL REINFORCEMENTS

BETA SYSTEM

A technique for consolidating structural wood elements that permits the (2)
recuperation not only of their mechanical capacity but also their original appearance. This technique doesn't require disassembling of the elements because the treatment is done on-site,

STEPS OF THE BETA SYSTEM

Elimination of damaged wood from the support of a scissor truss.
Perforation and placement of the pretensioned rods.
Forming and filling with epoxy resin grout.
Final appearance of the repaired zone.

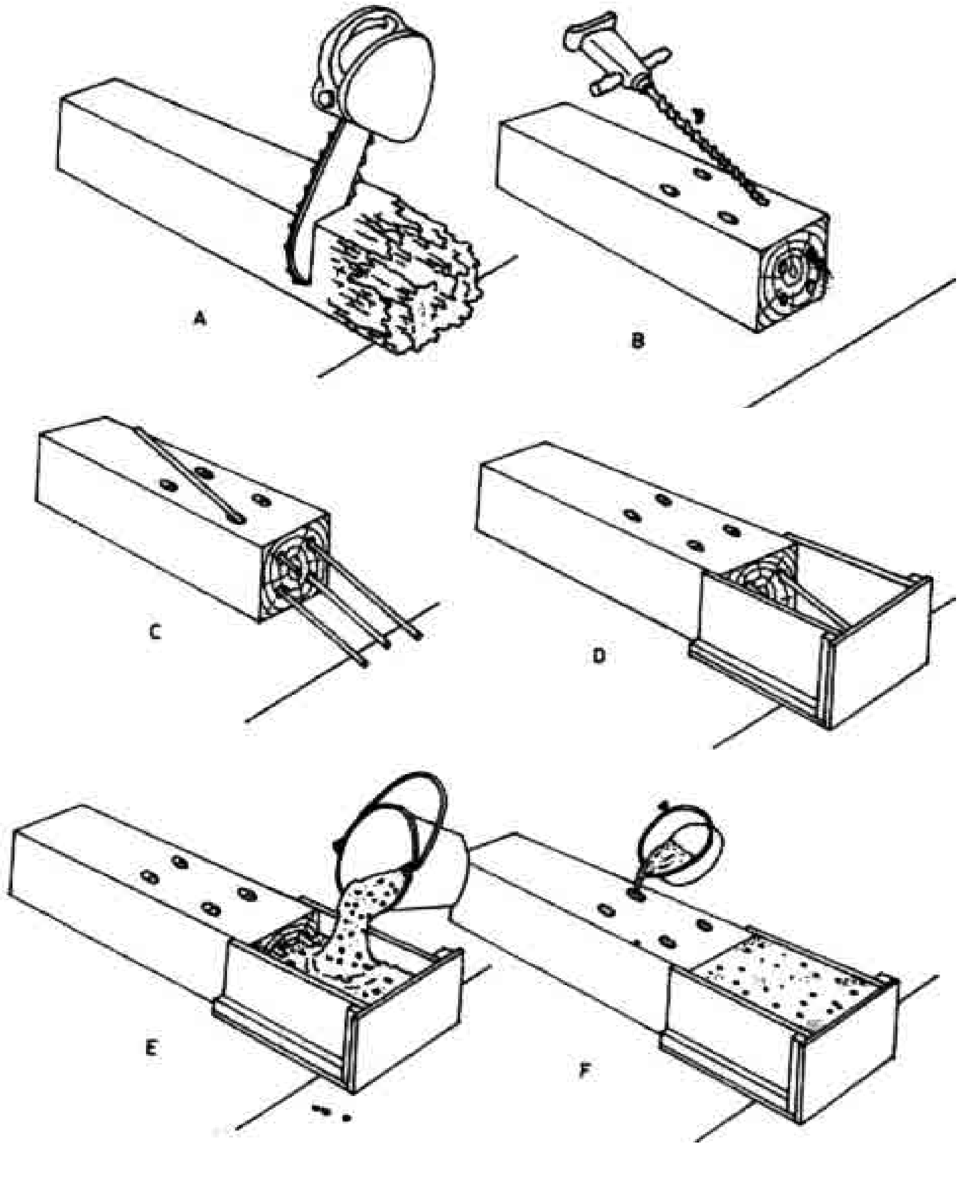


Fig. 15. From J. A. Rodríguez Barreal, *Patología y técnicas de intervención. Elementos estructurales*, Tomo 3: "Tratamientos preventivos y curativos de la madera", Munilla-Lería, Madrid 1999, p. 277.

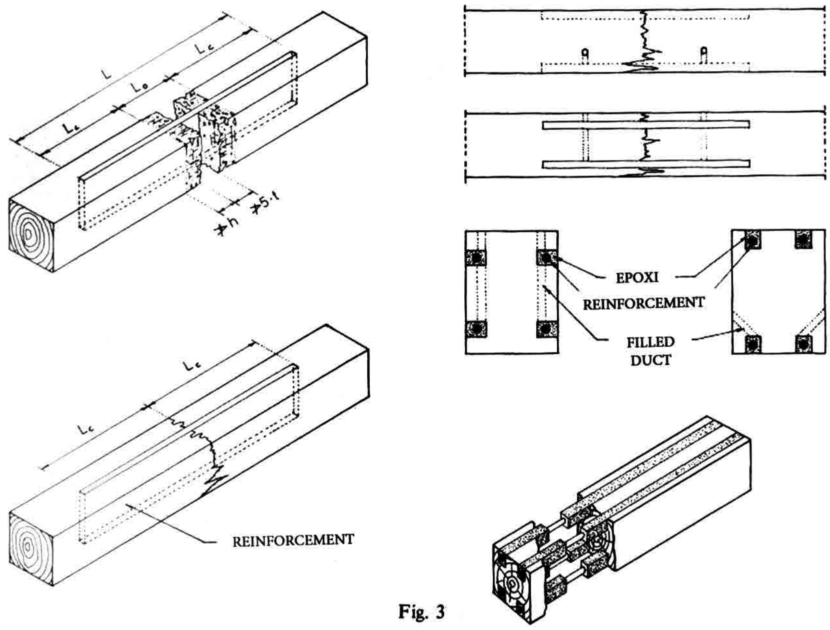


Fig. 16. From J. A. Rodríguez Barreal, *Patología y técnicas de intervención. Elementos estructurales*, Tomo 3: "Tratamientos preventivos y curativos de la madera", Munilla-Lería, Madrid 1999.

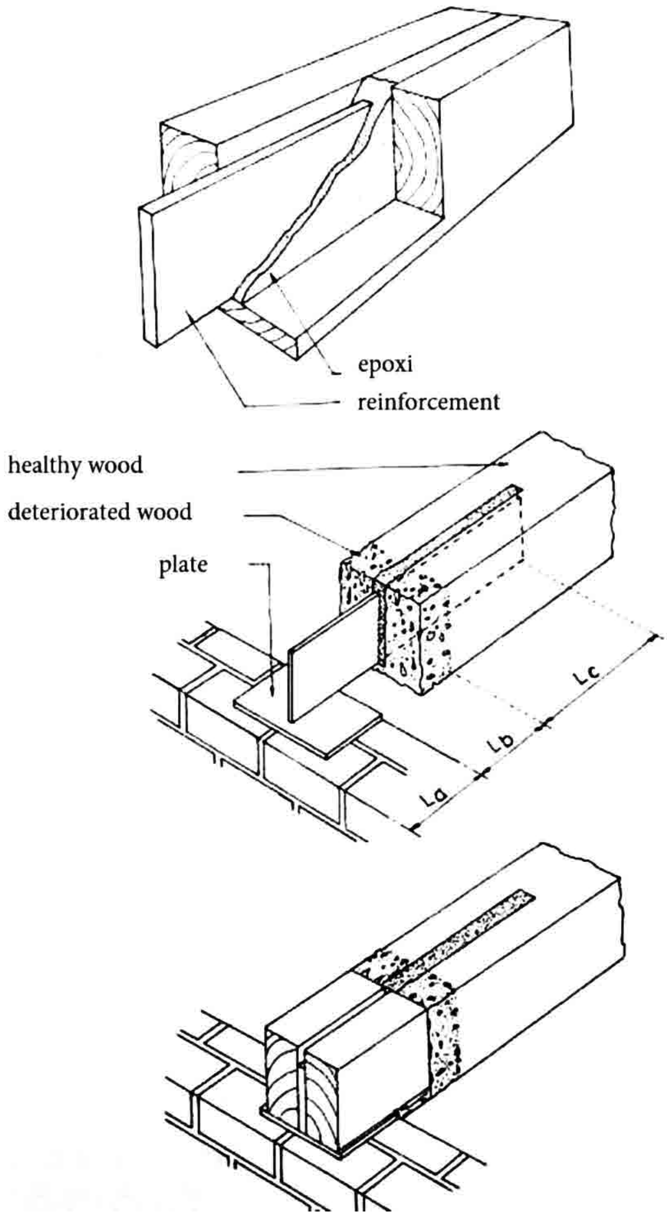


Fig. 17. From J. A. Rodríguez Barreal, *Patología y técnicas de intervención. Elementos estructurales*, Tomo 3: "Tratamientos preventivos y curativos de la madera", Munilla-Lería, Madrid 1999.

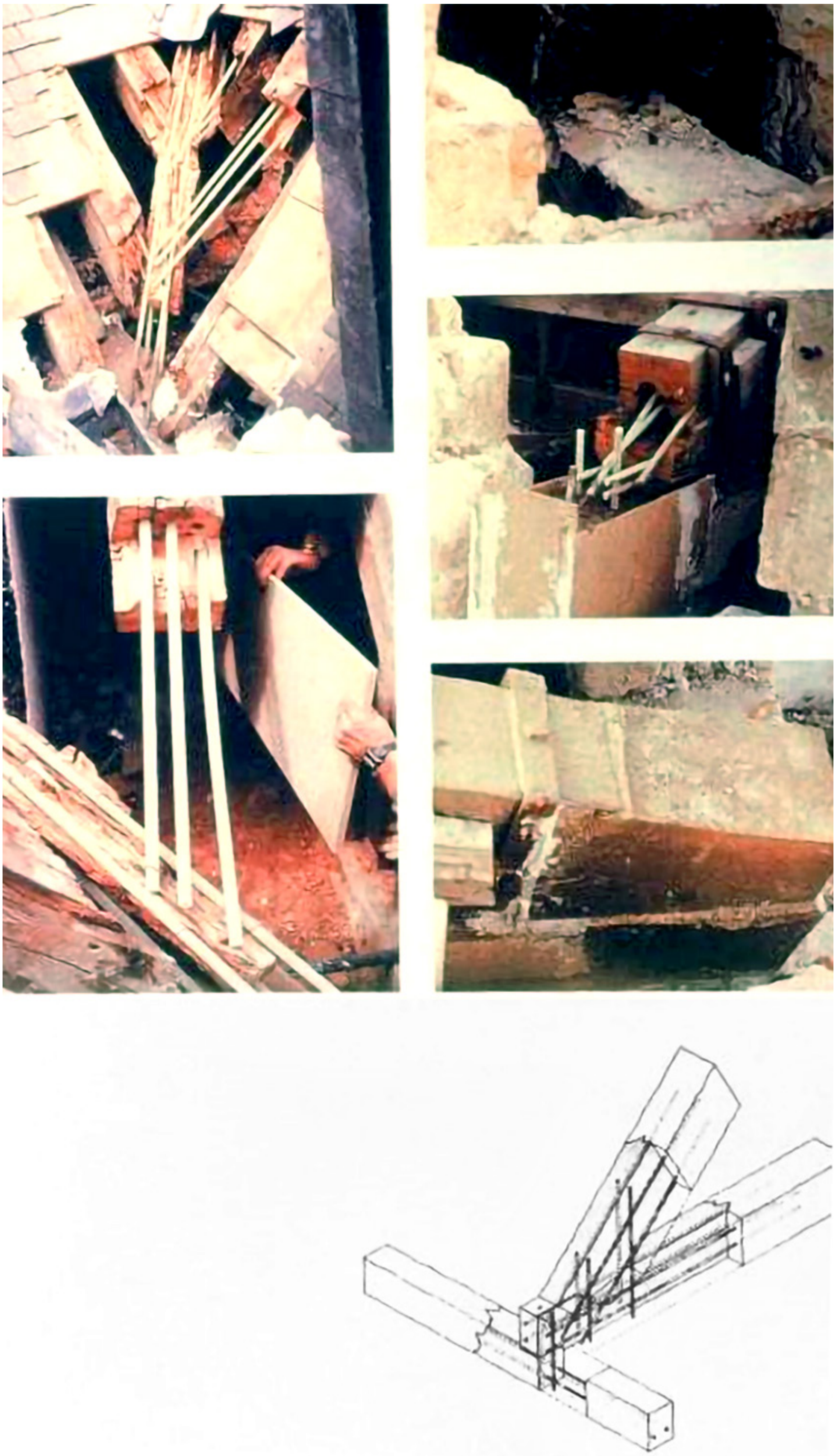


Fig. 18. From J. A. Rodríguez Barreal, *Patología y técnicas de intervención. Elementos estructurales*, Tomo 3: “Tratamientos preventivos y curativos de la madera”, Munilla-Lería, Madrid 1999.

EXTERNAL REINFORCEMENTS

(3)

Fig. 19. Palazzo Bizzarrini e Casa Seri, Siena. From F. Doglioni, *Nel restauro. Progetti per le architetture del passato*, (IUAV Documenti), Marsilio 2008.

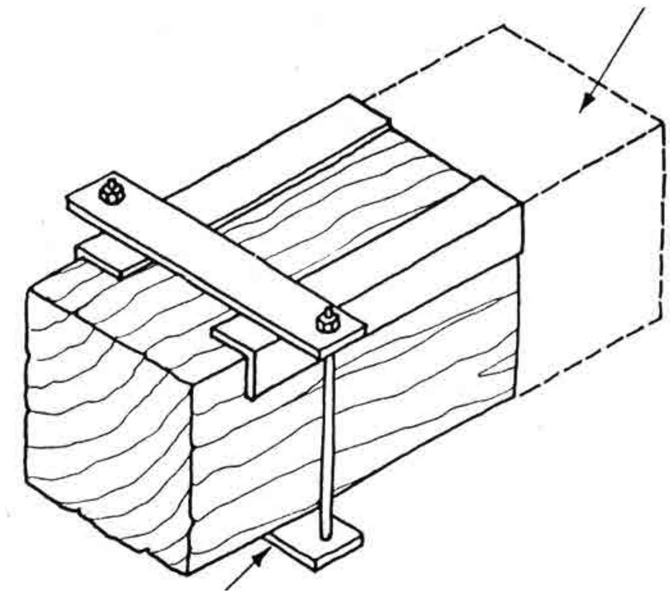


Fig. 20. From A. Bellini, *Tecniche della conservazione*, Ex fabrica, FrancoAngeli, Milano 1990, p. 277.

Fig. 21. Beam of the church of Santa María de Carracedo Monastry. Photo by Susana Mora, 1989.

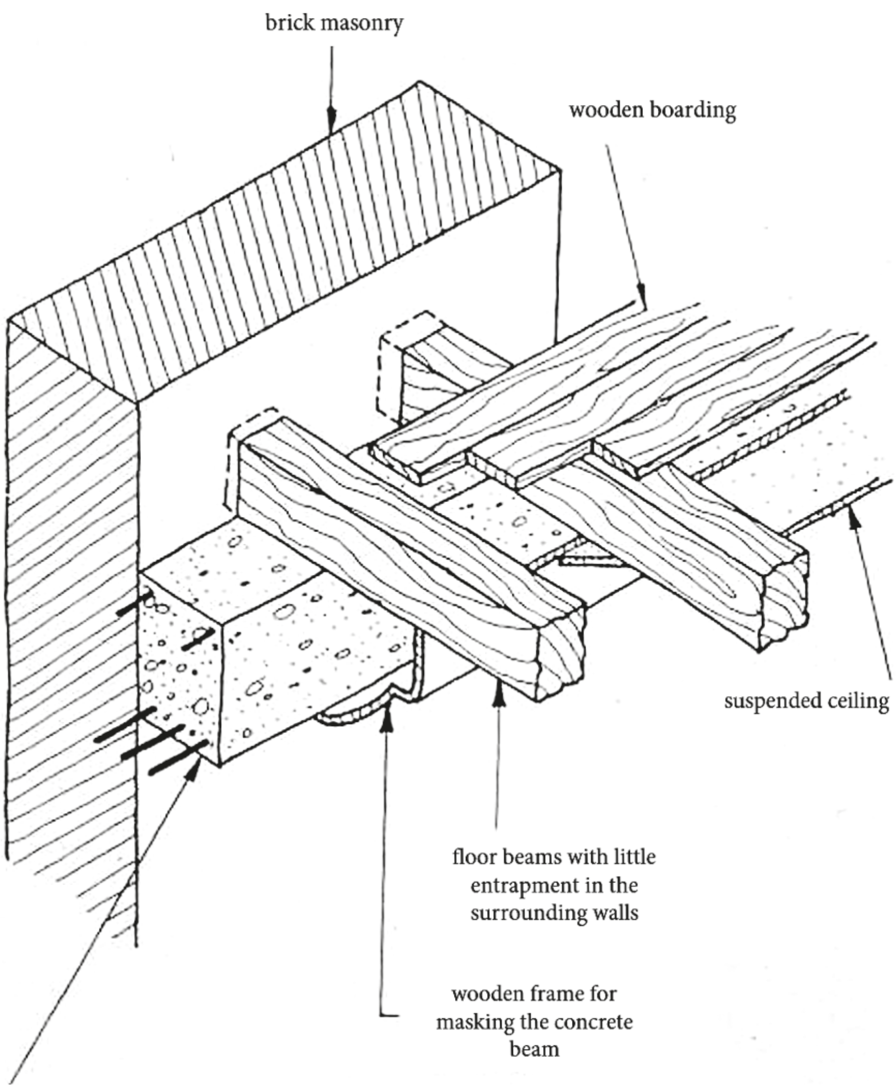


Fig. 22. Reinforced concrete beam for the support of wooden floor beams. From A. Bellini, *Tecniche della conservazione*, Ex fabrica, FrancoAngeli, Milano 1990, p. 280.

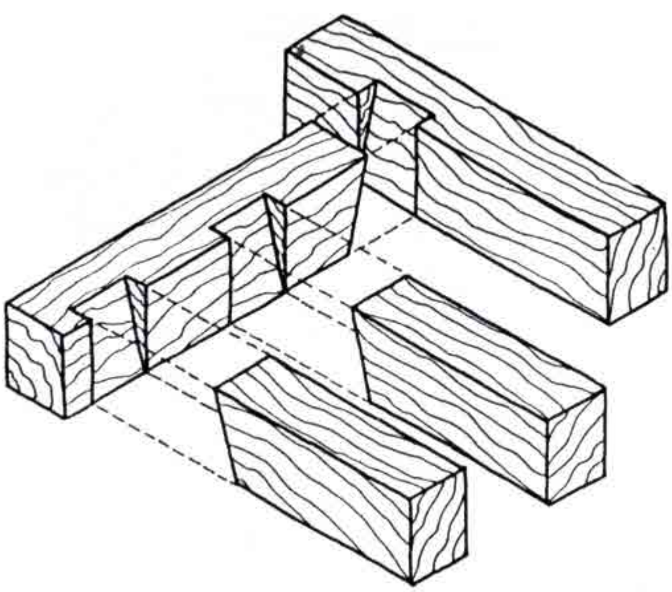


Fig. 23. From A. Bellini, *Tecniche della conservazione*, Ex fabrica, FrancoAngeli, Milano 1990, p. 277.

(4)

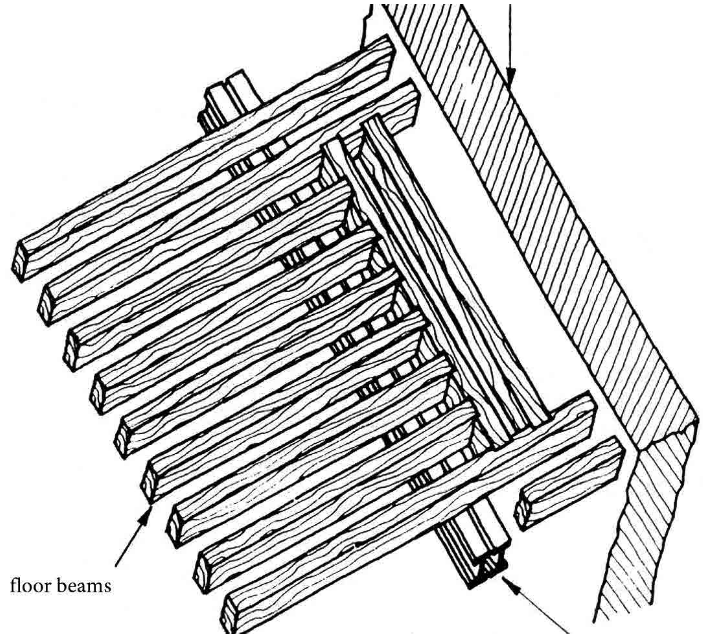


Fig. 24. From A. Bellini, *Tecniche della conservazione*, Ex fabrica, FrancoAngeli, Milano 1990.

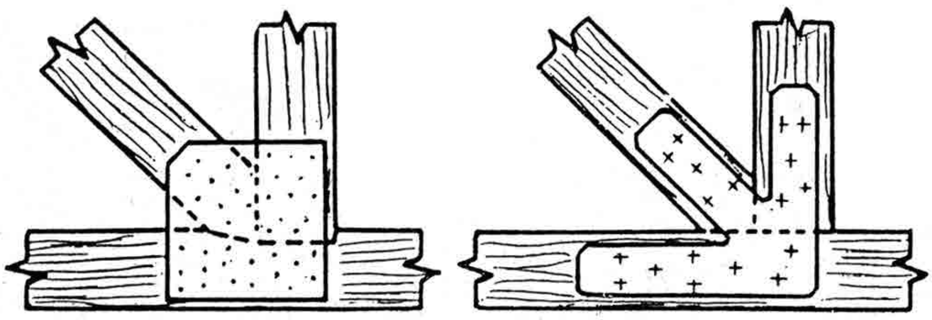


Fig. 25. From A. Bellini, *Tecniche della conservazione*, Ex fabrica, FrancoAngeli, Milano 1990.

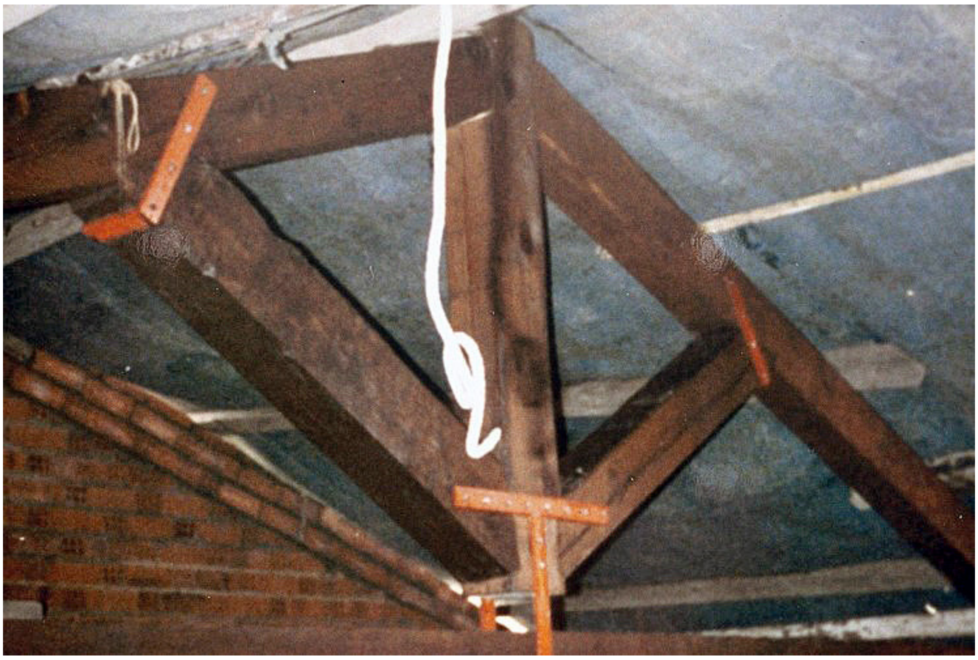


Fig. 26. Capitulo roof structure of Gradefes Monastry. Restoration and photo by Susana Mora, 1989.

(5)

Fig. 27. Library floor reinforcement of Santa María de Carracedo Monastry. Restoration by S. Perez Arroyo and S. Mora. Photos by Susana Mora, 1990.

Fig. 28. Library floor reinforcement of Santa María de Carracedo Monastry. Restoration by S. Perez Arroyo and S. Mora. Photo by Susana Mora, 1990.

CONSTRUCTIVE SYSTEM

REINFORCED CONCRETE

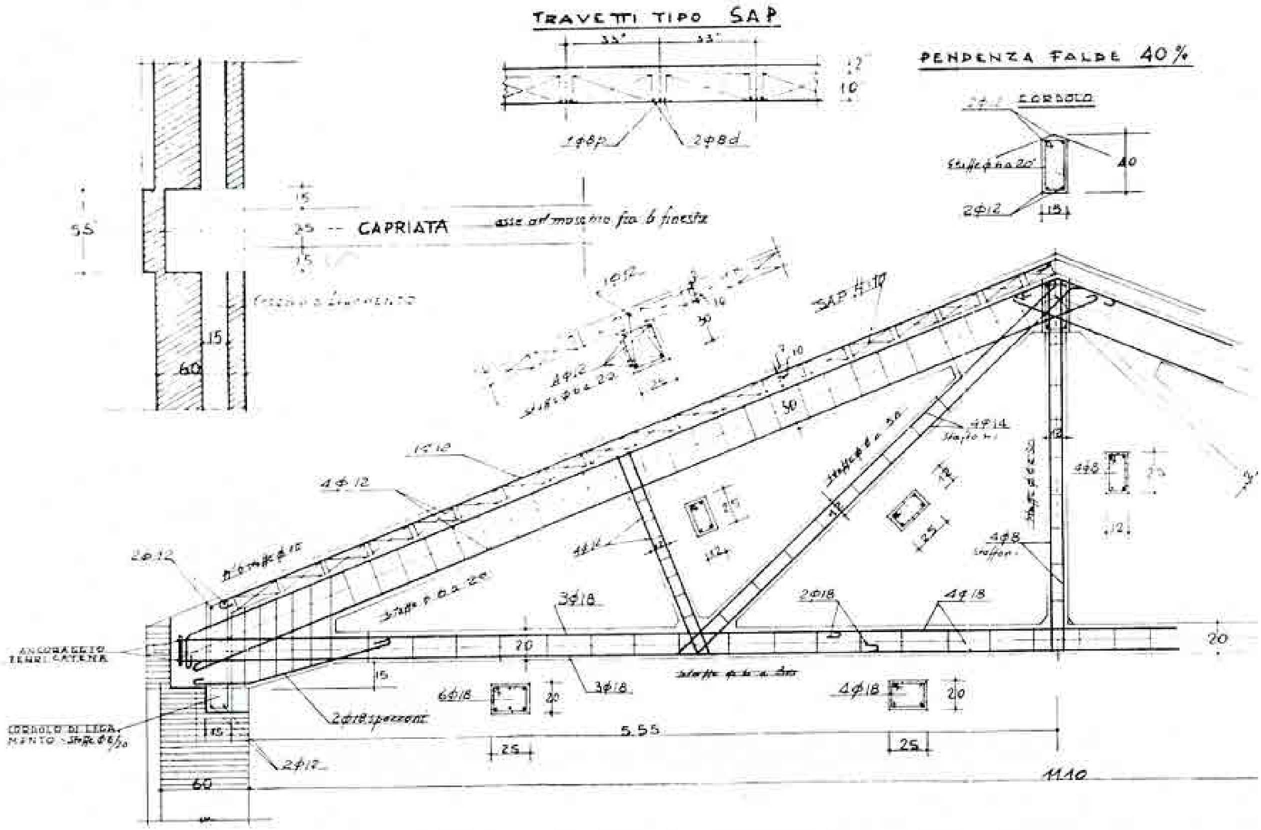


Fig. 29. Basilica of Sant'Apollinare Nuovo, Ravenna. From G. Carbonara (a cura di), *Restauro e cemento in Architettura*, Aitec, Roma 1981, p. 146.

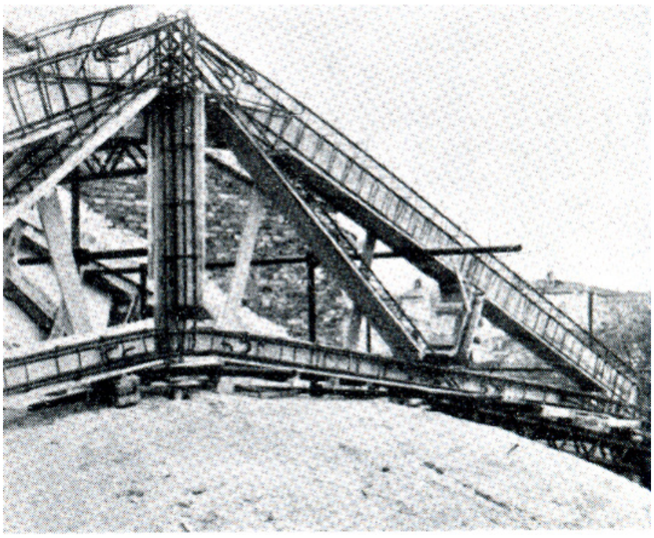


Fig. 30. Basilica of Sant'Apollinare Nuovo, Ravenna. From G. Carbonara (a cura di), *Restauro e cemento in Architettura*, Aitec, Roma 1981, p. 146.

Fig. 31. Basilica of Sant'Apollinare Nuovo, Ravenna. From G. Carbonara (a cura di), *Restauro e cemento in Architettura*, Aitec, Roma 1981, p. 146.

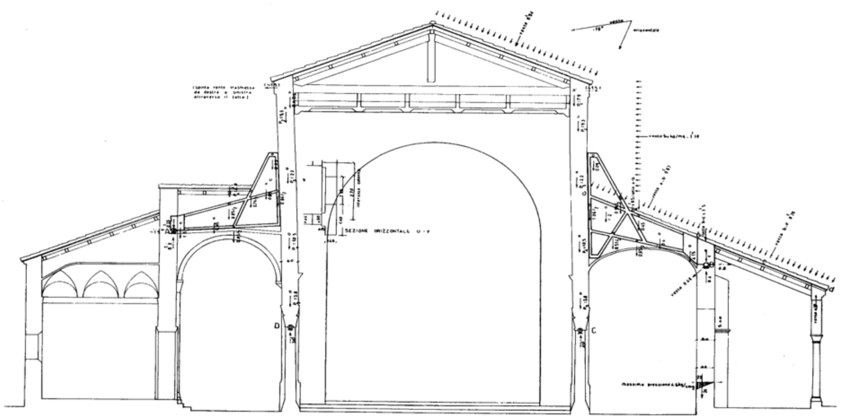


Fig. 32. From G. Carbonara (a cura di), *Restauro e cemento in Architettura*, Aitec, Roma 1981, p.147.

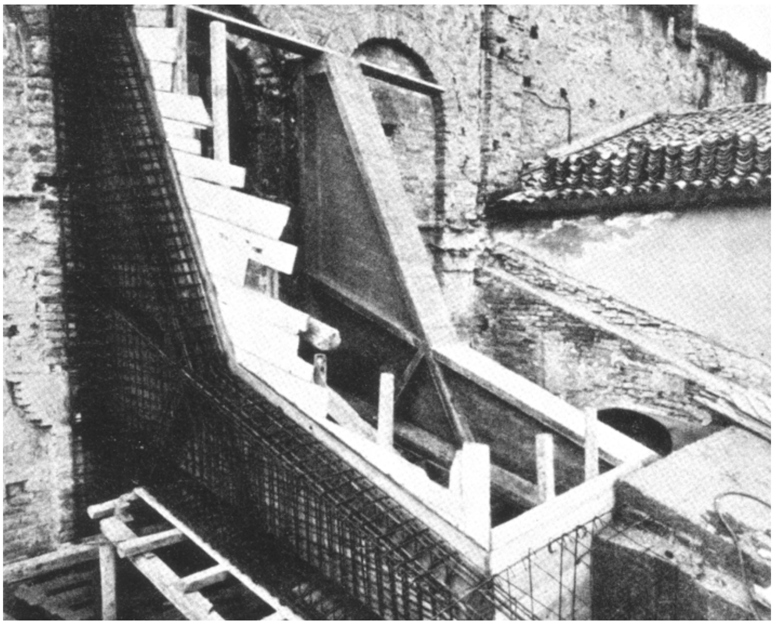
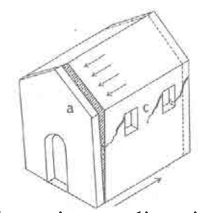


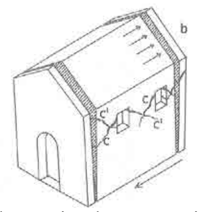
Fig. 33. From G. Carbonara (a cura di), *Restauro e cemento in Architettura*, Aitec, Roma 1981, p. 147.

PROBLEMS

Problems in roof structures may cause damages in the walls, as we have seen before.

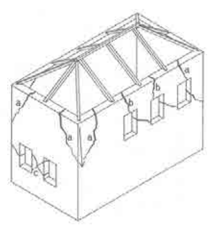


Thrust in one direction: detachment of the facade a and formation of fractures c.



Thrust in the opposite direction: detachment of the wall b and shear cracks c'.

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.

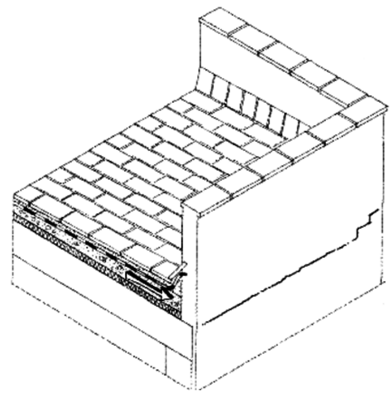
Fig. 34. From G. Cigni, *Il consolidamento murario. Tecniche d'intervento*, Edizioni Kappa, Roma 1978, pp. 306-309.

CAUSES

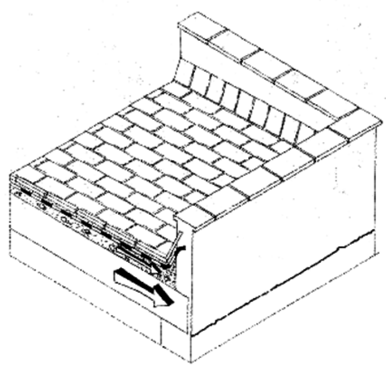
– INCOMPATIBILITY (constructive)
– STRUCTURAL
  · Originally
  · Joints
– WATER
  · Rain
  · Condensation
– BIOLOGICAL AGENTS
– CONTAMINATION
– HUMAN ACTION
– THERMAL
– MATERIALS
  · Degradation
  · Oxidation

TERRACES

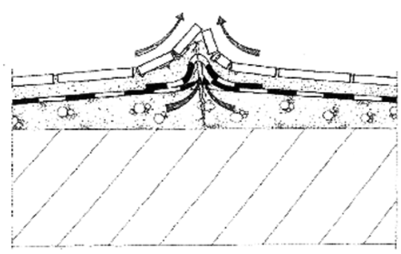
Some examples of problems:



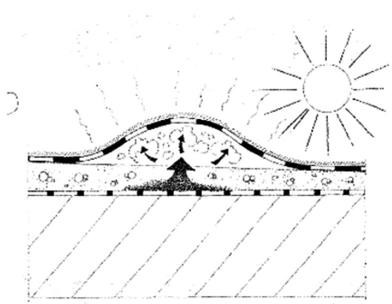
Cracks by thrust of the slope layer locked to the perimeter



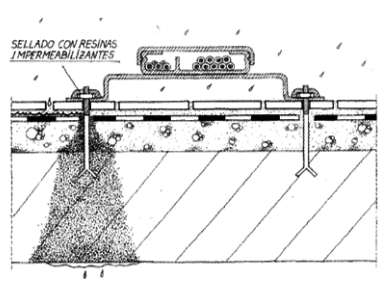
Cracks due to non-insulated floor



Crack in meeting of slopes for lack of roof joint



Bulging produced by evaporating the water contained in the materials



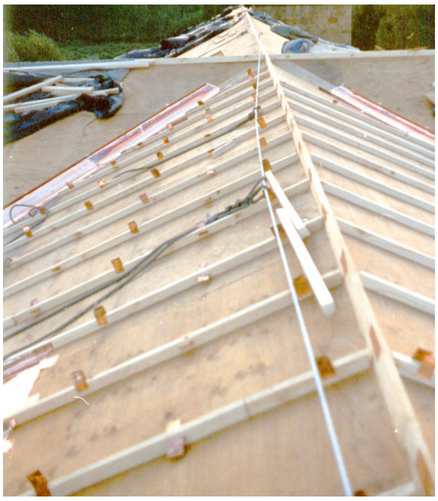
Punching in the membrane

Fig. 35. Designs by Susana Mora, 2007.

BOARDS

Copper covers, with joints on battens. Hidden gutters. (6)
Existing reinforcements in the wooden structure.

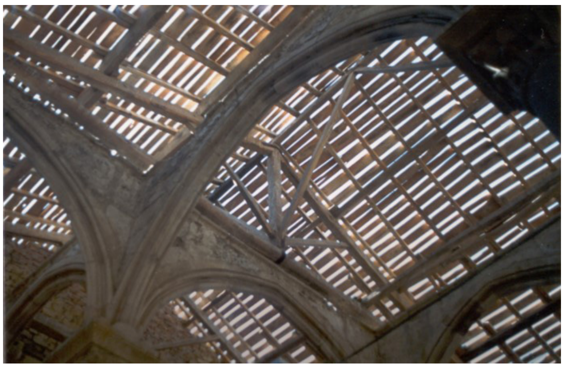




Figs. 36-38. Restoration by S. Perez Arroyo and S. Mora. Photos by Susana Mora.

Copper roof over wooden board. Consolidation of existing wood structures.





Figs. 39-41. Restoration by S. Perez Arroyo and S. Mora. Photos by Susana Mora.

WATERPROOFING

FLAT: TERRACES

Fig. 42. Villa Tugendhat. From A. Van Grieken, *Condition Assessment of aged Structures*, Delft University of Technology, 2008.

FORMS OF CONSTRUCTION IN THE EARLY MODERN MOVEMENT

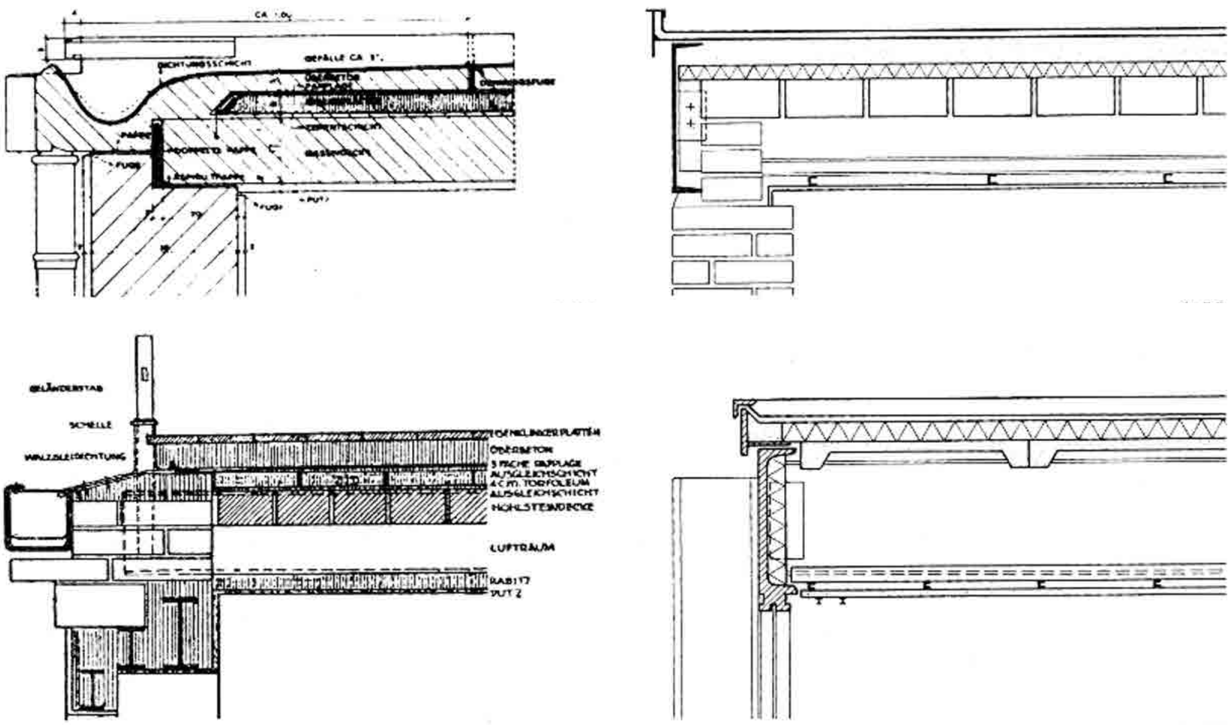


Fig. 43. Roof edge detail: a) Frankfurt standard for small dwellings, 1927; b) Erich Mendelsohn; c) Crown Hall, Chicago, 1953, Mies van der Rohe; d) Farnsworth House, Illinois 1950, Mies van der Rohe.

REPAIR SOLUTIONS

(7)

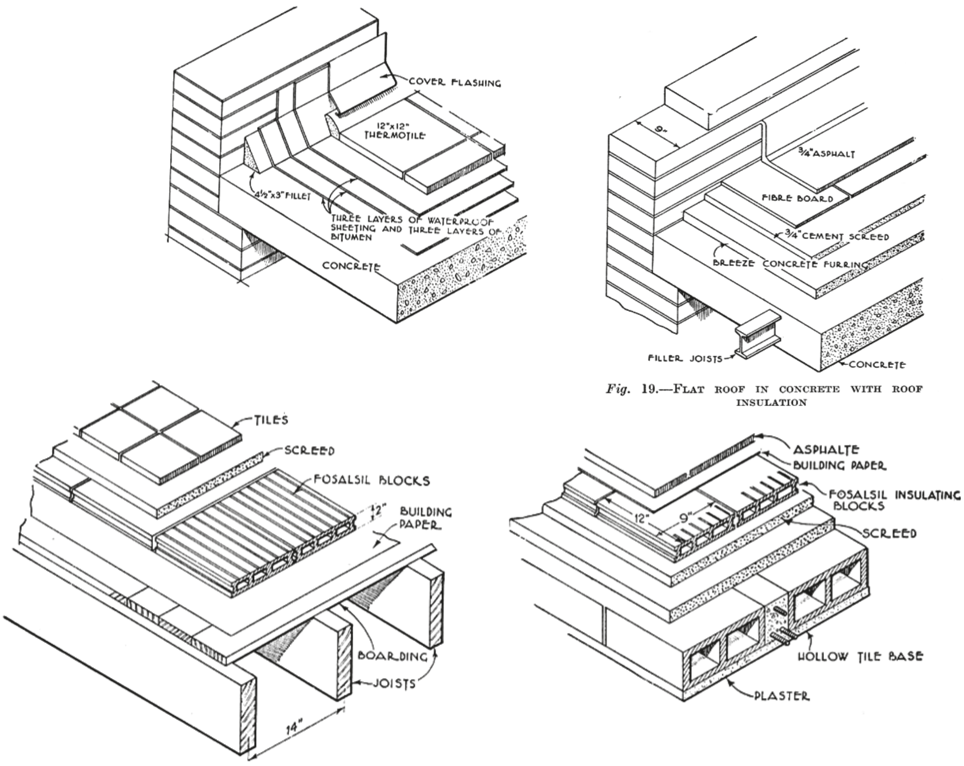
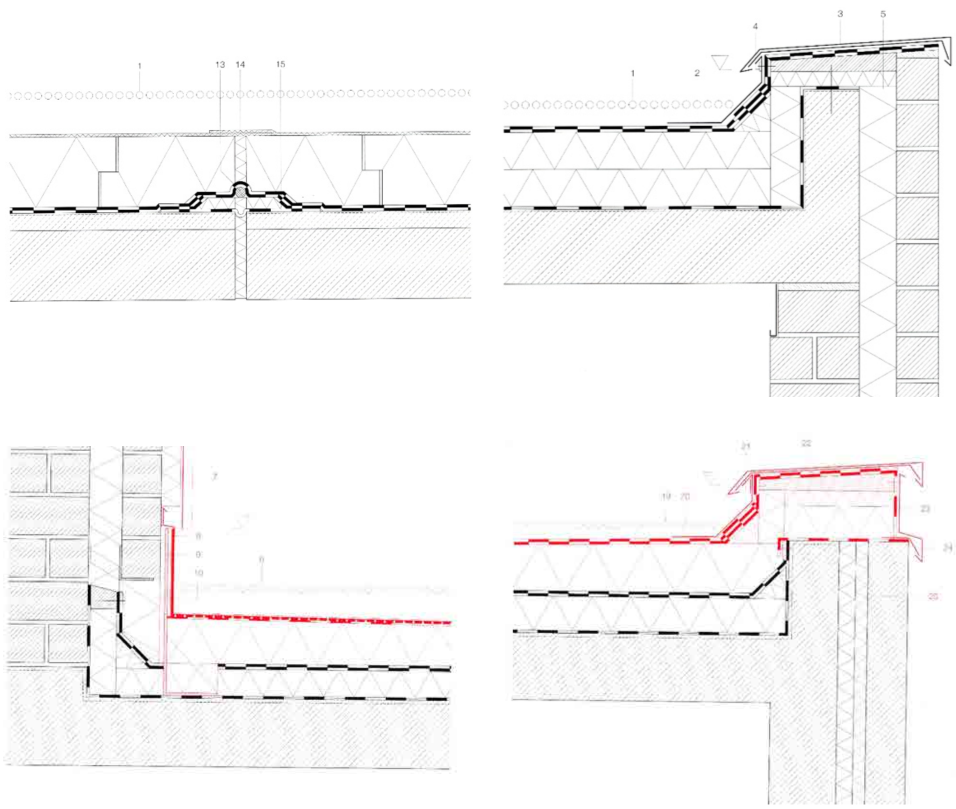


Fig. 44. Redesigned by Susana Mora.

DETAIL SOLUTIONS



Figs. 45-48.
Above left: joint. Above right: roof edge. Below left: junction with wall. Below right: roof edge. Designs by Susana Mora for ETSAM (UPM), 2015.

NOTES

1) GALLO CURCIO A., *Sul consolidamento degli edifici storici*, Roma 2007, si veda *coperture in legno*, pp. 279-291; DE CESARIS F., *Coperture*, C.5, in *Atlante del Restauro Architettonico*, diretto da Carbonara G., Torino 2004, vol. 1, pp. 258-283, DAL MAS R., *Legno*, B.6, in Ibidem, pp. 130-156;

2) See to: LA REGINA F., *Sicurezza e Conservazione del Patrimonio Architettonico*, Napoli 1995, pp. 247-253; DE CESARIS F., *Interventi su Solai e coperture*, in *Atlante del Restauro architettonico*, vol. 2, diretto da Carbonara G., Torino 2004, pp. 583-601; TAMPONE G., edited by, *Conservation of Historic Wooden Structures*, Firenze 2005;

3) During the restoration works in Santa Maria de Carracedo Monastry, Leon, it appeared in the church an interesting old work of consolidation of a beam in the wooden structure of the roof of the church (project and direction of works S. Perez Arroyo and Susana Mora, 1985-2000);

4) Reinforcement of a truss in the roof of the “Capitulo” of Gradefes cistercian monastry, Leon. (Project and direction of works Susana Mora, 1990-2000);

5) Reinforcement of the wooden structure of the library floor in Santa María de Carracedo Monastry, Leon. It was difficult to reinforce the wooden beams without touching the Refectory vaults below them;

6) Copper roof in Santa María de Carracedo Monastry, Leon. (Project and direction of works S. Perez Arroyo and S. Mora, 1985-2000);

7) It is necessary to read: DE CESARIS F. *Coperture*, C5, in *Atlante del Restauro Architettonico*, volume 1, diretto da Carbonara G., Torino 2004, pp. 258-269.

HAMMER D., HAMMER I., TEGETHOFF W., *Tugendhat House, Ludwig Mies van der Rohe*, Birkhauser 2014.

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CHAPTER 12. STRUCTURES: CONCRETE AND METALS

OTHER TRADITIONAL STRUCTURES

– METALLIC STRUCTURES

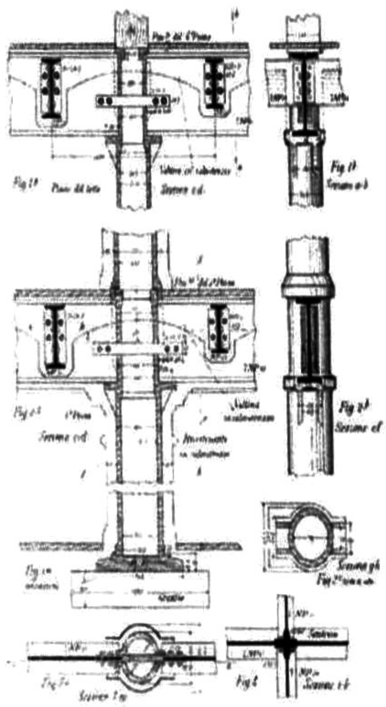
– REINFORCED CONCRETE STRUCTURES

Fig. 1. Atocha Station, Madrid. Photo courtesy of Pepa Cassinello.

Fig. 2. Hipódromo de la Zarzuela, Madrid. Photo courtesy of Pepa Cassinello, Headmaster of Museo Torroja, Madrid.

METALLIC STRUCTURES

(1)



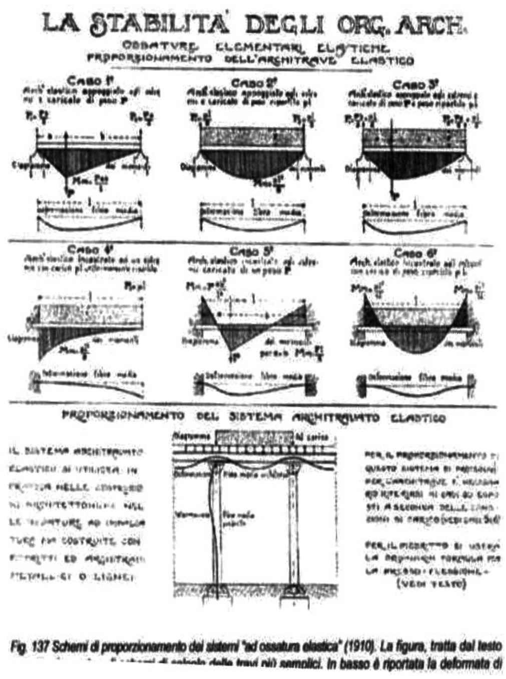


Fig. 3. Breymann. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001. "Anatomia degli organismi edilizi moderni", 2.1.B., B.39. Also in M. Bussell, *Use of iron and steel in buildings*, pp. 173-175.

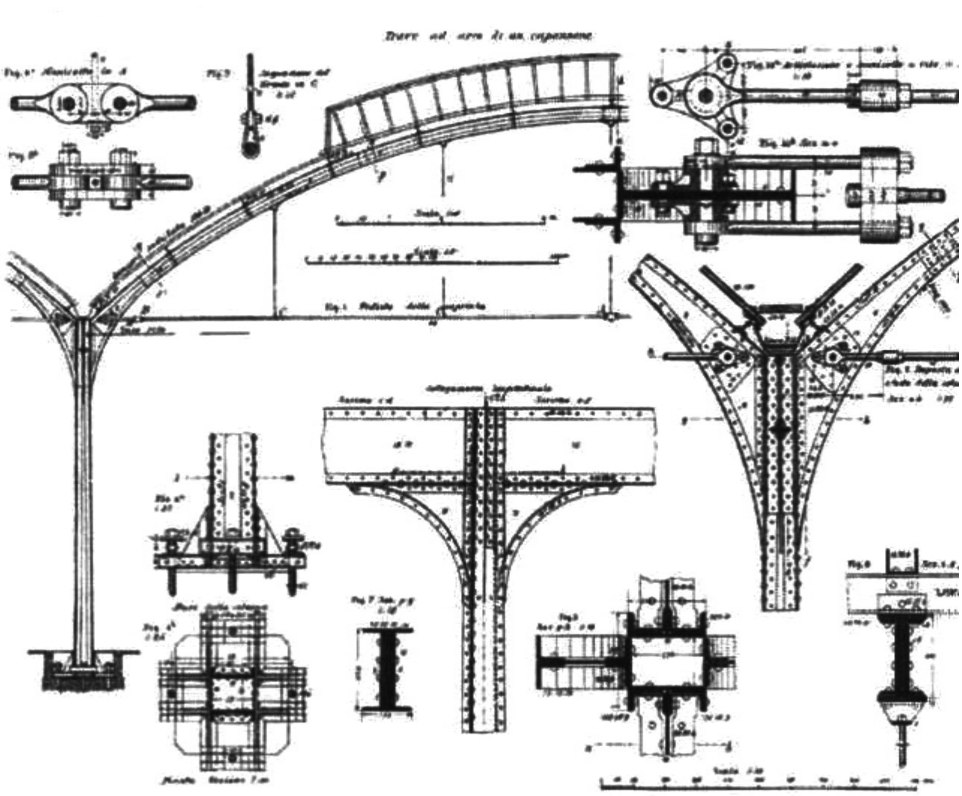


Fig. 4. Breymann. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001. "Anatomia degli organismi edilizi moderni", 2.1.B., B.39. Also in M. Bussell, *Use of iron and steel in buildings*, pp. 173-175.

Joints

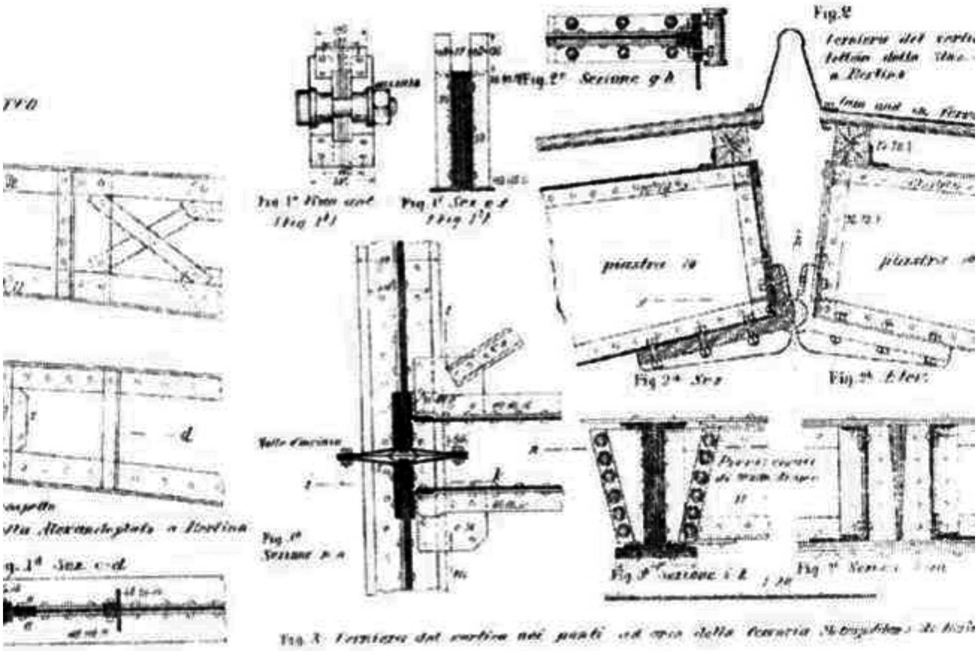


Fig. 5. Breymann. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001. “Anatomia degli organismi edilizi moderni”, 2.1.B., B.39. Also in M. Bussell, *Use of iron and steel in buildings*, pp. 173-175.

Cast-iron structures

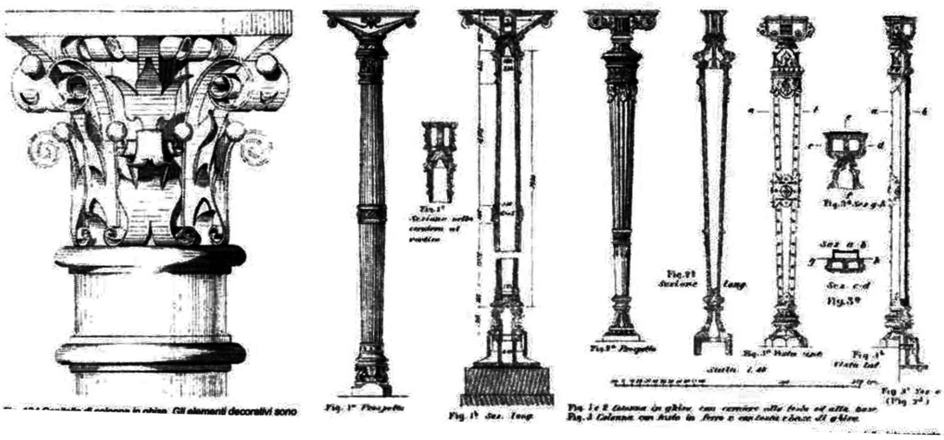


Fig. 6. Breymann. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001. “Anatomia degli organismi edilizi moderni”, 2.1.B., B.39. Also in M. Bussell, *Use of iron and steel in buildings*, pp. 173-175.

REINFORCED CONCRETE STRUCTURES

(2)

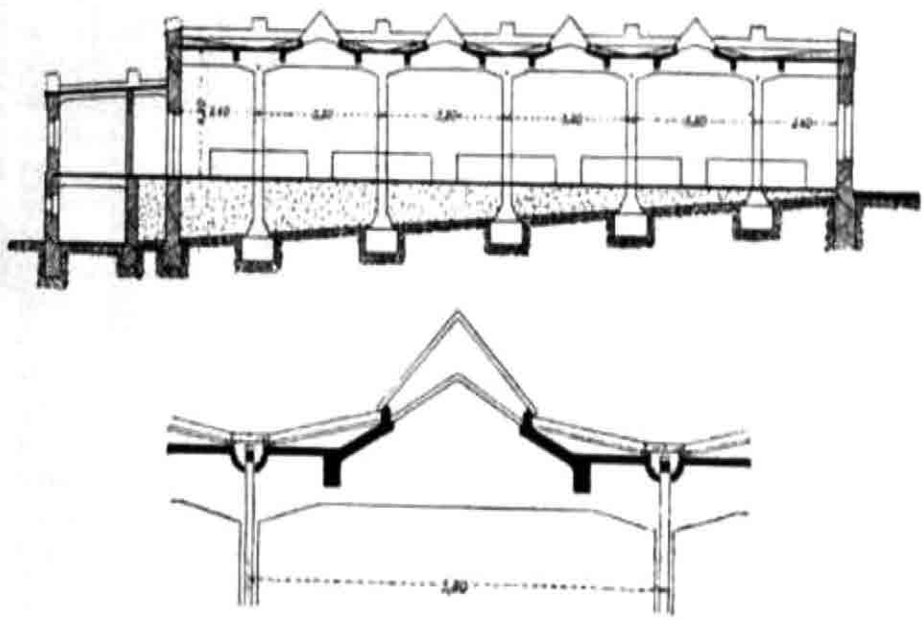


Fig. 7. Scheme of one of the first industrial buildings in reinforced concrete. The lighting was through roof opening. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001. "Anatomia degli organismi edilizi moderni", B.1.1. in Proceedings of the 4th International Conference on Concrete Repair, Rehabilitation and Retrofitting (ICCRRR-4), Leipzig 2015, Germany.

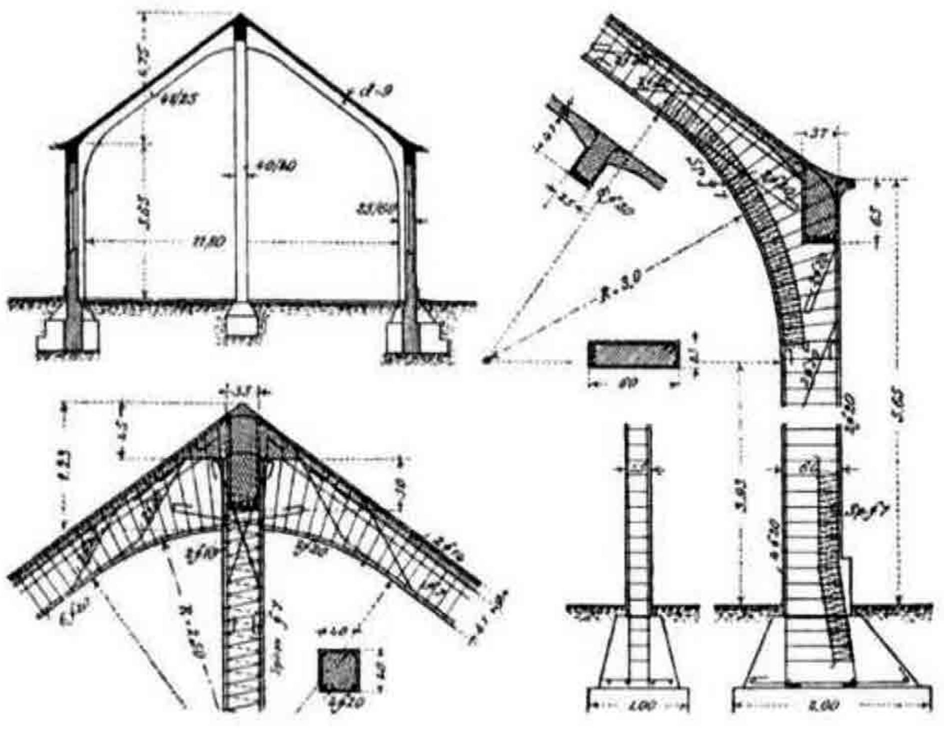


Fig. 8. Depot for locomotives in Balingen (1919). Note the arrangement and folding of the irons in the various sections. The central pillar is staffed with a spiral that reaches up to the superior node, while there is no adequate anchorage to the vertical bars of the pillars in correspondence with the foundation plinth. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001. "Anatomia degli organismi edilizi moderni", B.22. in Proceedings of the 4th International Conference on Concrete Repair, Rehabilitation and Retrofitting (ICCRRR-4), Leipzig 2015, Germany.

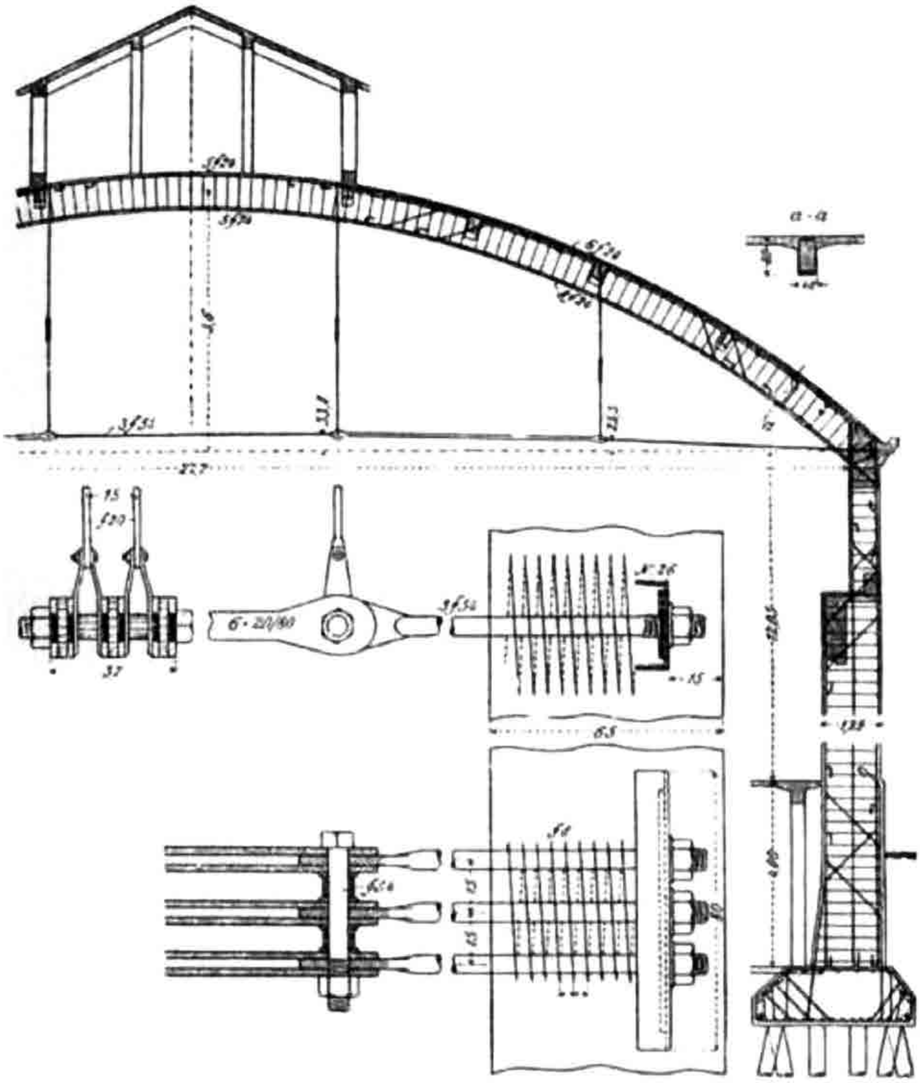


Fig. 9. From C. Blasi, *Manuale del restauro architettonico*, Mancosu, Roma 2001. "Anatomia degli organismi edilizi moderni", B.1.1, B.22, in Proceedings of the 4th International Conference on Concrete Repair, Rehabilitation and Retrofitting (ICCRRR-4), Leipzig 2015, Germany.

METALLIC STRUCTURES

DAMAGE AND DETERIORATION

(3) – According to the enviroment: industrial or rural, marine, wet or dry, etc.

– According to the exposure of the structure: with / without roof, totally or partially out in the open, etc.

– According to design of the structure

Fig. 10. Photos courtesy of Celia Barahona.

PROTECTION

– Paints for metal surfaces

– Galvanizing of metallic structures

– Protection against fire in metallic structures

Fig. 11. Photos courtesy of Alfonso García Santos.

CONCRETE

DAMAGE AND DETERIORATION

– Concrete defects and damage
  · Mechanical attack
  · Chemical attack
  · Physical attack

– Concrete damage due to steel reinforcement corrosion
  · Chemical attack
  · Corrosive contaminants (e.g. chlorides)
  · Stray electrical current

CONCRETE REPAIR. SYSTEMS AND SOLUTIONS

– Replacement mortars / Repair mortars
– Concrete protection
– Structural strengthening
– Grouting

Figs. 12-14. From *Patología y técnicas de intervención*, T. III, Munilla-Lería, Madrid 1993.

NOTES

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1) We must see DAL MAS R. M., *Metalli*, B. 5, in *Atlante del Restauro Architettonico*, volume 1, diretto da Carbonara G., Torino 2004, pp. 107-129;

2) LI Y., VROUWENVELDER T., *Spatial variability of concrete deterioration and repair strategies*, in *Structural Concrete*, vol.2, Issue 3, Delft University of Technology, 2004, pp. 121-129;

3) See: VAN GRIEKEN A., *Condition Assessment of aged Structures*, Delft University of Technology 2008; don't forget MASSAZZA F., *Interazione fra i materiali antichi ed i moderni materiali di restauro: il comportamento fisico. chimico; in Restauro e cemento in Architettura*, a cura di Carbonara G., AITEC, Roma 1984, pp. 162-173.

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CHAPTER 13. SURFACE FINISHES, INTERIOR WOODWORK

"It is first and foremost, the recognition of this architectural value of the external surfaces of artefacts composed of multiple parts, each in strict rapport with the others and inseparable from them, which leads to the direct consequence of the necessity of intervention and, therefore, of studying and considering the surfaces of the architecture, as a question of real and proper restoration. Thus it would not be appropriate to tackle the issue of the treatment of surfaces of edifices as a separate problem".

From MURATORE O., The colour of the historical town, in *Methodical approach to the restoration of Historic Architecture*, edited by Bellanca C., Firenze 2011, p. 41.

SURFACE FINISHES

– SURFACE CONSOLIDATION

– PLASTER

– PAVEMENTS

– INTERIOR WOODWORK

SURFACE CONSOLIDATION

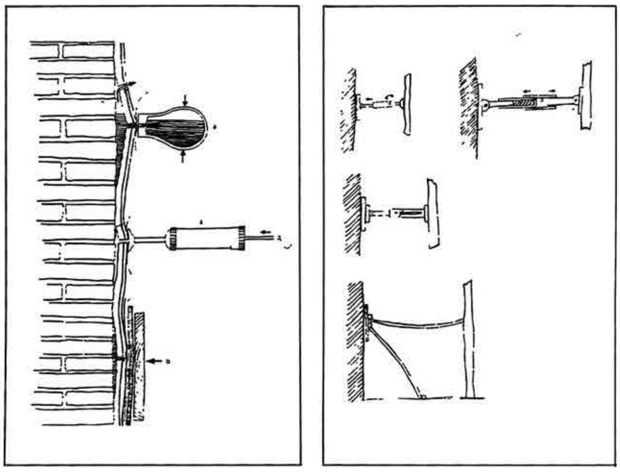


Fig. 1. Escuela-Taller San Isidoro, León, Acabados, Diputación de León, 1999.

CEERAMIC ELEMENTS TO FIX SURFACES

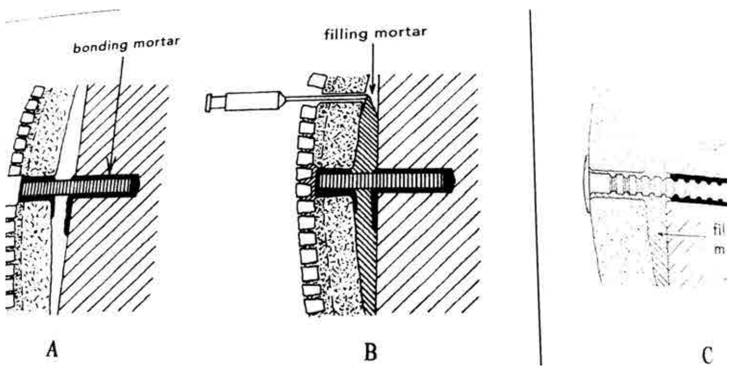


Fig. 2. From A. Ugolini, "Ceramica per l'architettura, L'uso sperimentale dei prodotti ceramici 'avanzati' nel restauro delle opere d'arte (1988-1995)", in *Materiali e strutture*, n. 12, anno 2017, p. 68.

PLASTER

(1) The most common work is the "*intonaco*" with three layers called "rinzaffo", "arriccio" and "*intonachino*". There are many ways to finish it. A particular way to finish is "*affresco*", with the last layer with paint.

STUCCO:

- WORK PROCESS:

1. Creation of a floating render with lime mortar in mixed paste or mortar.
2. Application of the first layer of lime and marble sand with granulometry of 1.2 mm.
3. Floating.

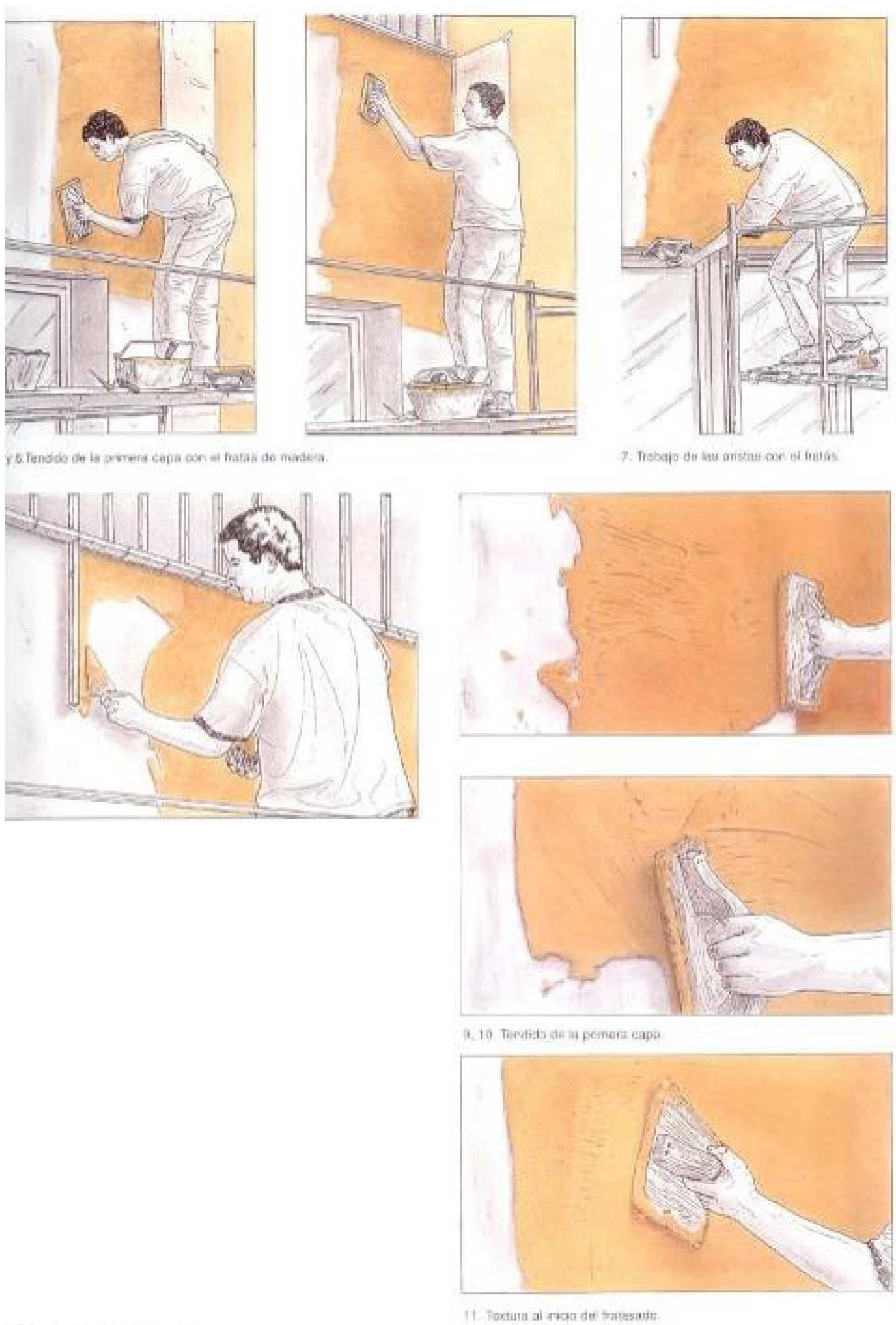


Fig. 3. Escuela-Taller San Isidoro, León, *Acabados*, Diputación de León, 1999.

4. Application of the second layer of lime and marble sand with granulometry of 0.8 mm.
5. Floating.
6. Render with lean lime mass and marble sand with 0.8 mm granulometry.
7. Floating to achieve a regular surface.
8. Application with the trowel of the third layer or coating of fat mass composed of lime, dust and marble sand with a granulometry of 0.8 mm.
9. Re-floating with the grout.
10. Washing the fresh facing with a trowel wet in water, plumb and level.
11. Burnished with esparto brush or brush, plumb and level.

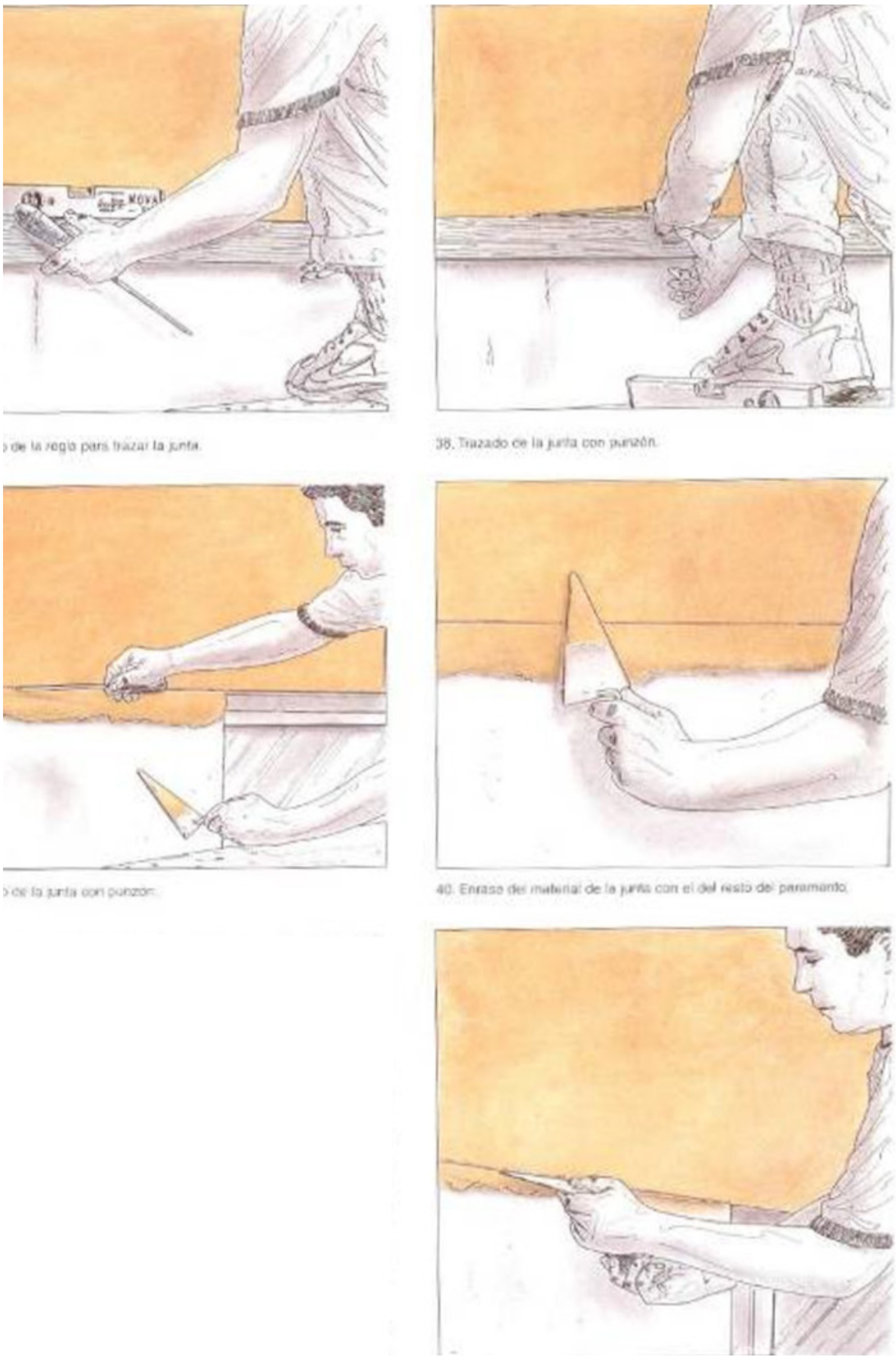


Fig. 4. Escuela-Taller San Isidoro, León, *Acabados*, Diputación de León, 1999.

IMITATION STUCCO

(2) Faux brick stucco can be executed with a red plaster with the joints cut with a knife. This type of stucco was very popular during the Baroque, and was even used to cover facades built with low quality brick.

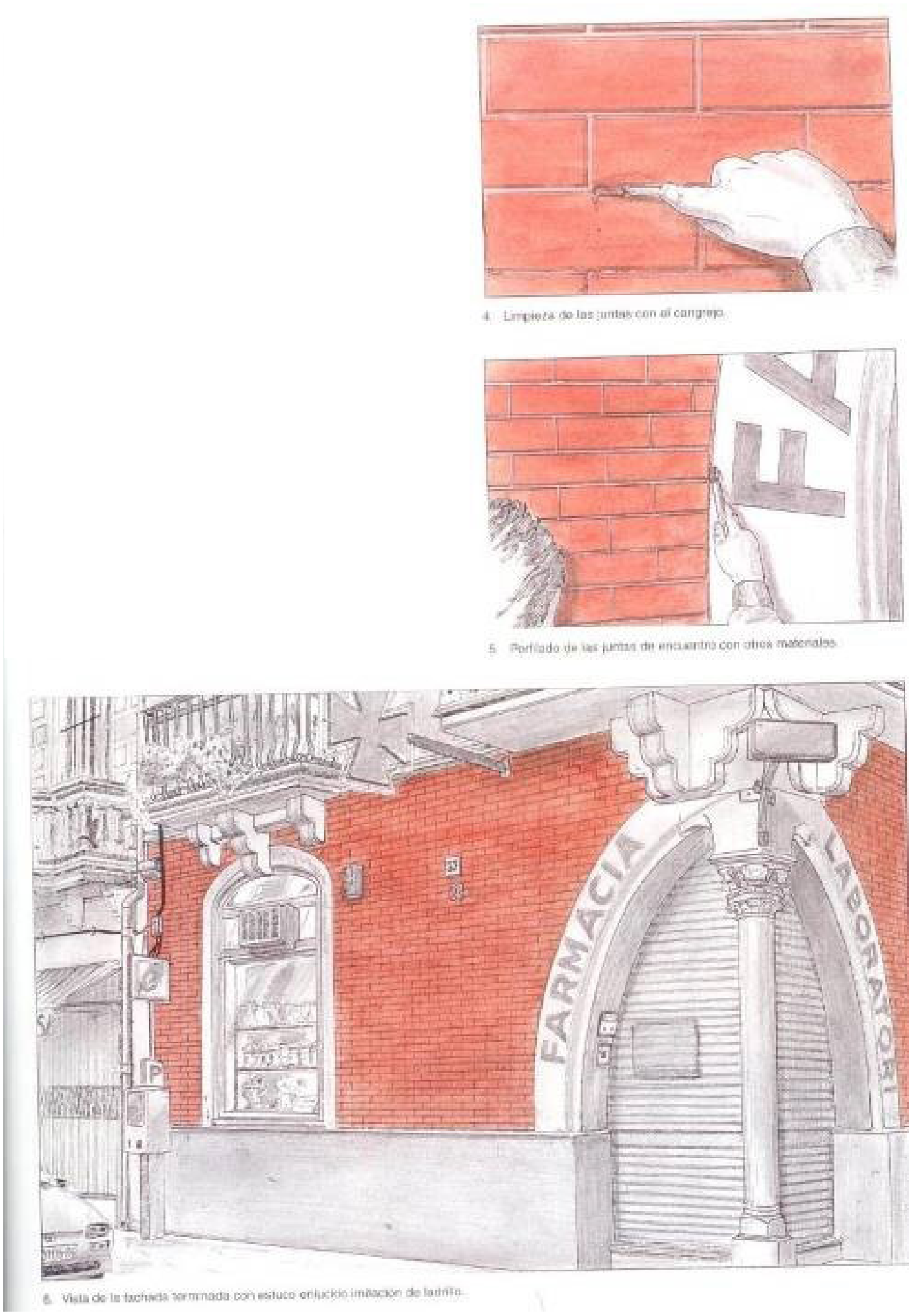
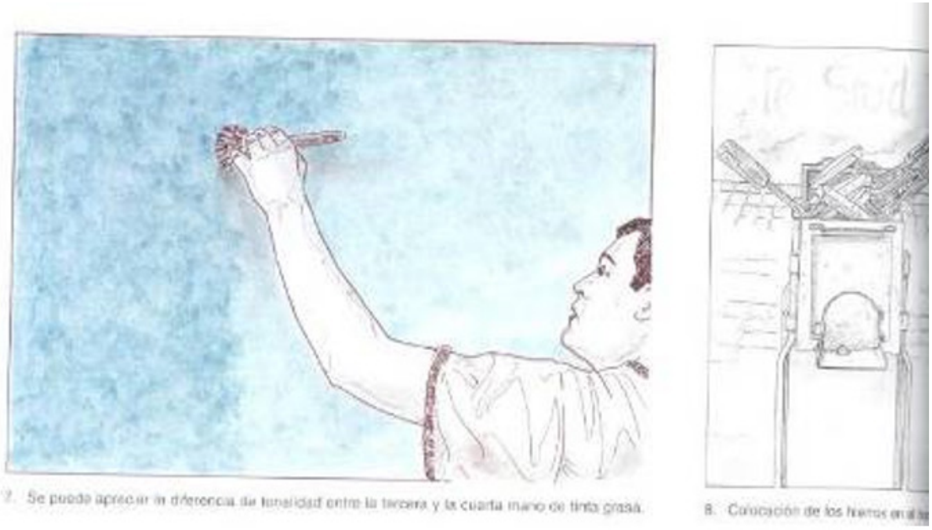


Fig. 5. Escuela-Taller San Isidoro, León, *Acabados*, Diputación de León, 1999.

TRADITIONAL LIME IRONED STUCCO

Ironed stucco, also called burnished, hot-ironed stucco or “by fire”, is a technique with which surfaces are obtained with an incredibly bright texture, achieved thanks to the heating, with special irons, of coconut soap mixed with water, lime and pigments.



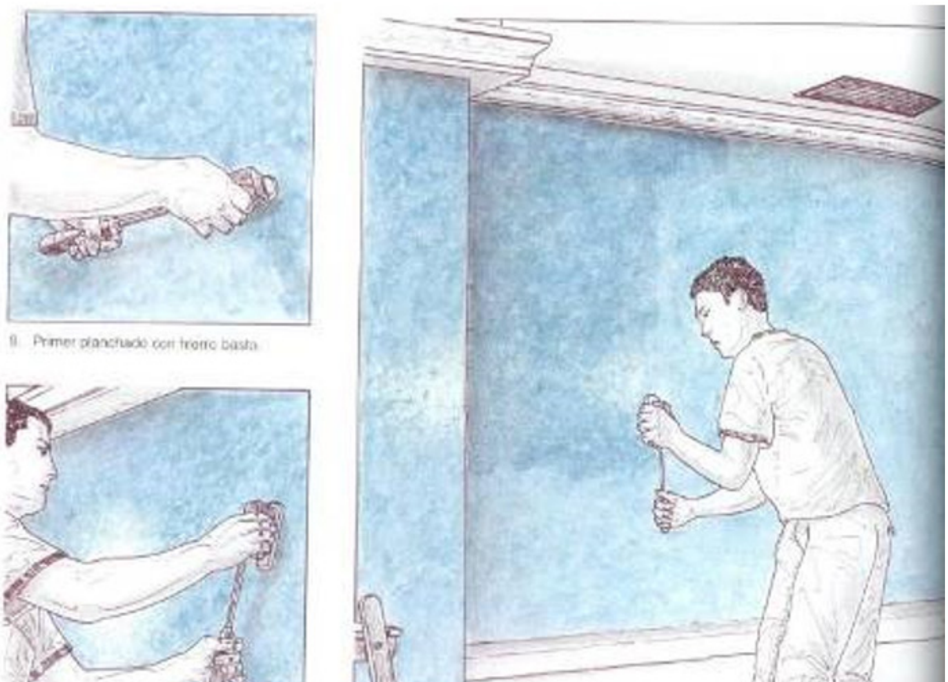


Fig. 6. Escuela-Taller San Isidoro, León, *Acabados*, Diputación de León, 1999.

There are many other ways of finishing the surface and also decoration elements with volume in plaster.

PAVEMENTS

OLD AND NEW JOINT

(3)

Figs. 7-8. Cloister of Santa María de Carracedo Monastry, Leon, Spain. Restoration by Susana Mora and Salvador P. Arroyo. Photos by Susana Mora.

Figs. 9-10. Pavement of Library of Santa María de Carracedo Monastry, Leon, Spain. Restoration by Susana Mora and S. Perez Arroyo. Photos by Susana Mora.

INTERIOR WOODWORK

DOORS WITH SIMPLE LINING WITH CROSS-TIES

(4)

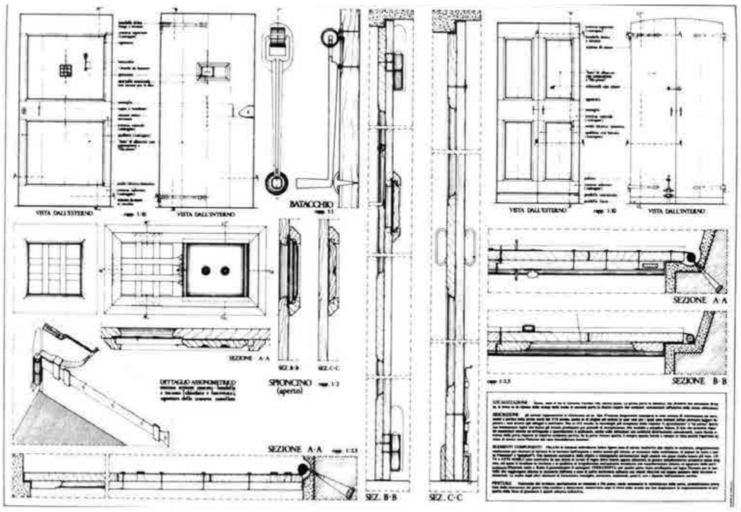


Fig. 11. Designs by G. Palmerio. From G. Carbonara, *Atlante del restauro architettonico,* V. II, Utet, Torino 2004, C.7, pp. 326, 331.

WINDOW OF MEZZANINE

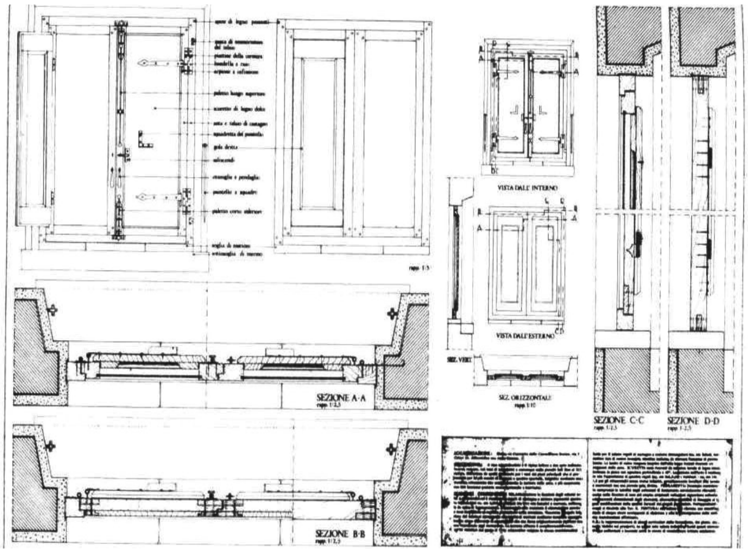


Fig. 12. Designs by G. Palmerio. From G. Carbonara, *Atlante del restauro architettonico,* V. II, Utet, Torino 2004, C.7, pp. 326, 331.

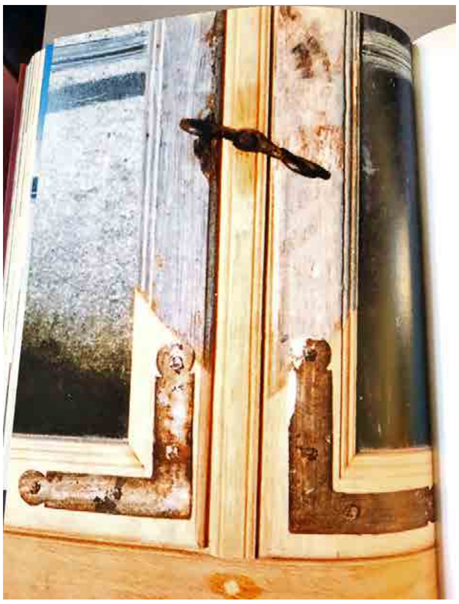


Fig. 13. From Donald Insall, *Living Buildings, Architectural Conservation: Philosophy, Principles and Practice*, Victoria, 2008.

NOTES

We have a essential historic bibliography: *Il colore nell'edilizia storica. Riflessioni e ricerche sugli intonaci e le coloriture*, in "Bollettino d'Arte". Suppl. n. 6, 1984; *La conservazione degli intonaci nel restauro architettonico: problemi metodologici e tecnici, dal rilevamento alle procedure di intervento*, study convention, Soprintendenza per i Beni Ambientali e Architettonici di Venezia e dal Save Venice Inc., (Venezia 5-6 octobre 1984), Venezia 1984; MORA L., MORA P., PHILIPPOT P., *Conservation of Wall Paintings*, London 1984; BISCONTIN S., (edited by), *L'intonaco, storia, cultura tecnologia, Acts of the study convention*, Bressanone 24-27 giugno,1985, Padova 1985, LAURENZI TABASSO M., *Le indagini scientifiche per la conservazione degli intonaci*, in Cardilli L., a cura di, *Coloriture e trattamenti degli edifici storici a Roma*, acts of the study convention Roma 27-28 maggio 1987, Quaderni di AU, Roma 1990; PHILIPPOT P., *Les coulors de Rome*, in Bullettin de L'Académie Royale de Belgique, Classe de Beaux Arts, series 5, LXX, 1988, 10-12, p. 260; *Caring for Your Historic House, Heritage preservation and National Park Service*, editor C. E. Fischer and H. C. Miller, New York 1998; see in particular Plaster; FALZONE P. (edited by), *Colore architettura ambiente, Esiti, problematiche, conoscenza, conservazione e progetto delle finiture dipinte e del colore nella città storica e nella città moderna in Italia e in Europa, acts of the study convention*, Genova 30 sep-1 oct, 2004, Roma 2008; AA.VV., *El Palacios de dos Aguas claves de su Restauracion*, sl. in Spain; GASPAROLI P., *Le superfici esterne degli edifici: degradi, criteri di progetto, tecniche di manutenzione*, Alinea Editrice, Firenze 2002; FEIFFER C., *La conservazione delle superfici intonacate: il metodo e le tecniche*, Skira, 1997;

1) ESPOSITO D., *Malte, intonaci e stucchi*, B.3, in *Atlante del Restauro Architettonico*, volume, pp. 75-101; and also see: ESPOSITO. D., *Finiture diverse*, C.8, in *Atlante del Restauro Architettonico*, volume, diretto da Carbonara G., Torino 2004, pp. 368-396;

2) PALMERIO G., *Elementi di finiture diverse*, sezione c.7, in *Atlante del Restauro architettonico*, volume, diretto da Carbonara G., Torino 2004, pp. 346-367;

3) Joining old and new pavements. Library in the Monasterio de Carracedo, Leon. The cloister with rest of old pavements and archeologic rests. (Project and direction of works S. Perez Arroyo and Susana Mora);

4) PALMERIO G., *Elementi*, C7, in *Atlante del Restauro Architettonico*, volume, diretto da Carbonara G., Torino 2004, pp. 312, 325-342.

M. BINNEY, *Save Britains Heritage 1975-2005. 30 years of companying*, London 2006.

F. MARMO, *L'innovazione nel consolidamento*, Roma 2003.

Paring - a guide the repair of historic buildings, advice series, published by Stationery Office, Dublin, Ireland 2015.

Windows - a guide to the repair of historic buildings, advice series, Dublin 2007.

Maintenance - a guide to the repair of historic buildings, advice series, Dublin 2007.

PART III

CONSTRUCTION APPLIED TO HERITAGE

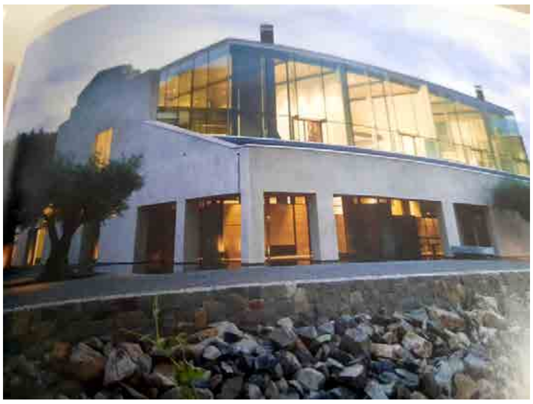
Construction Applied to Heritage may be a new construction course used to learn about close, aggregate and cover, new or even old spaces of historic buildings, to give architectonic solutions to historic remains, to make possible its interpretation and development over times.

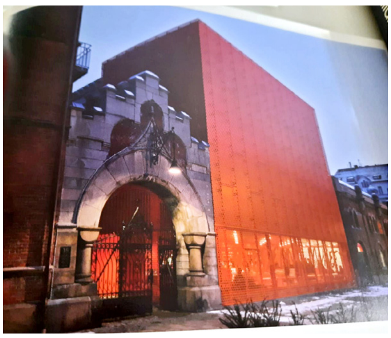











Previous page.
Some examples of new elements in construction applied to heritage.

CHAPTER 14. FOUNDATIONS: RETAINING WORKS, DRAINAGE AND SWERAGE SYSTEMS

FOUNDATIONS: INDEX

- OBJECTIVES (1)
- TYPOLOGY
- SHALLOW FOUNDATIONS: SHOES, SLABS AND PLATES
- DEEP FOUNDATIONS: WELLS, PILES
- EXECUTION PROCESS. QUALITY CONTROL

OBJECTIVES

The foundation is the constructive system responsible for supporting the weight of the entire building and transmitting it, well distributed, to the ground.

The foundation acts as an interface between the construction and the soil.

The scientific confrontation between both, determines the different constructive solutions obtained.

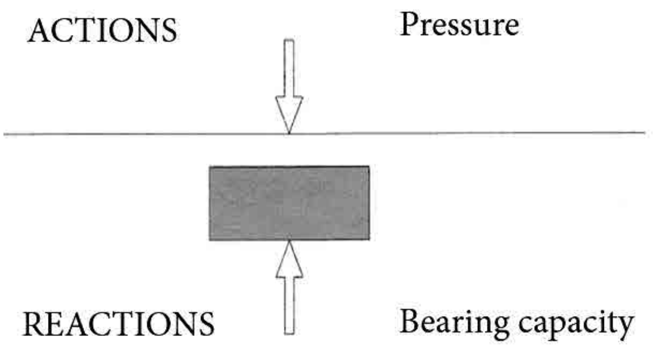


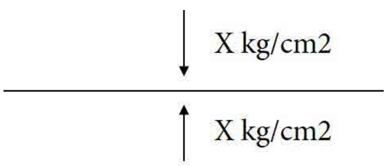
Fig. 1. Design by Fernando Ripollés and Susana Mora.

FUNCTION CONDITIONS

Evenly distribute the loads of the building on the ground that supports it.

The section of the foundation will be calculated in each case starting from the admissible load for the least resistant material, generally, the ground. As in each point of the foundation LOAD = REACTION

Waterproofing



TYPOLOGY

(1) CONSTRUCTION MATERIALS

– HISTORICAL FOUNDATIONS
 · Timber
 · Stone
 · Brick
 · Brick and stone
 · Mass concrete
 · Provisional foundations
  - Agregates
  - Agregates in boxes

– CURRENT FOUNDATIONS
 a) Made on site “in situ”
  · Concrete (in mass, reinforced, post-tensioned)
  · Concreted steel
 b) Precast
  · Concrete (prestressed, post-tensioned)
  · Steel

FUNCTION CONDITIONS

– MORPHOLOGY

– DEPTH OF THE FOUNDATION SOIL

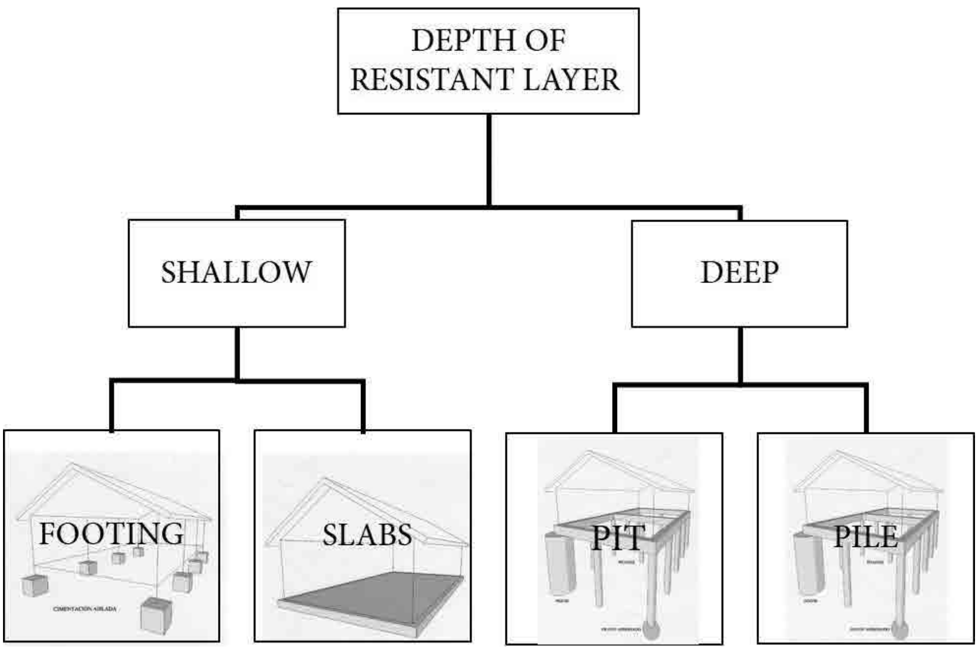


Fig. 2. Design by Fernando Ripollés and Susana Mora.

CHOICE OF TYPE OF FOUNDATION

It is a personal decision of the project author.

All possible combinations can be made, so it is common for more than one type of foundation to be used in the same building.

Each problem admits of a range of possibilities, among them the solution that is considered the most appropriate to the case is chosen.

CONDITIONING FACTORS

The characteristics of the building.

Its particularized way of generating actions.

The particularities of the terrain, especially its ability to dissipate loads.

The foundation's own capacity to function as an intermediate structure.

SHALLOW FOUNDATIONS

TYPOLOGY

– By work.
– By form.
– By plant layout.

DEFINITION

They are located at shallow depths. They occupy a lot of surface.

TYPES

– Footing foundation

– Raft foundation

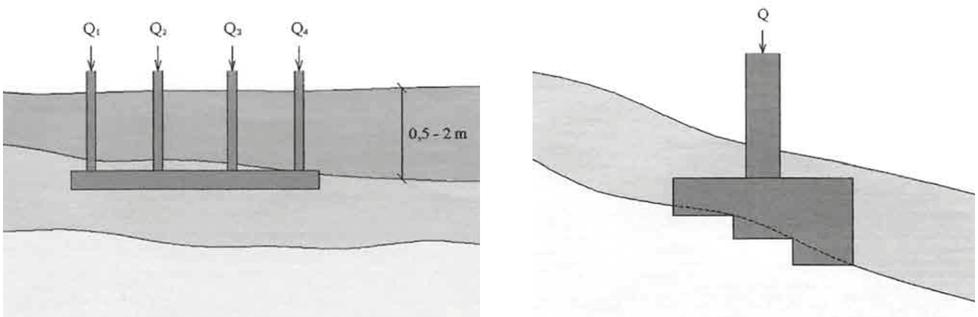


Fig. 3. Design by Fernando Ripollés.

FOOTINGS

Individual Footings

For isolated and concentrated loads on small surfaces.
Very economic foundation.
Small pressure bulb, so it affects shallow layers.

Strip Footings

For linear loads uniform or with point charges aligned, reasonably equal and close.

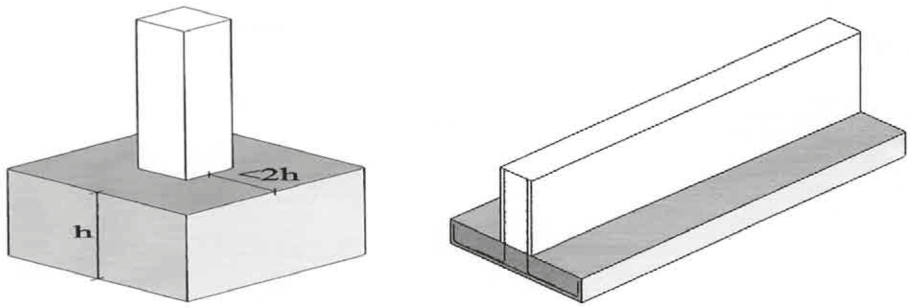


Fig. 4. Design by Fernando Ripollés.

For isolated loads For linear loads

INDIVIDUAL FOOTING TYPES

– Rigid
  They work in compression
  They are made of mass concrete
  Great width
  Without steel reinforcement
  With cast armor

– Flexible
  Bending stress
  They are made of reinforced concrete
  Small width
  With structural armor

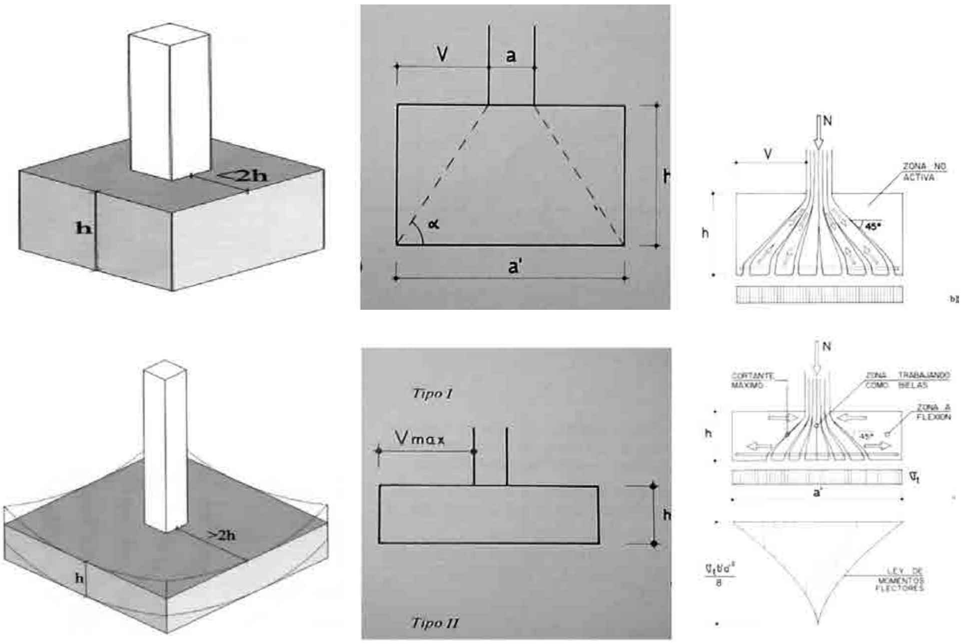
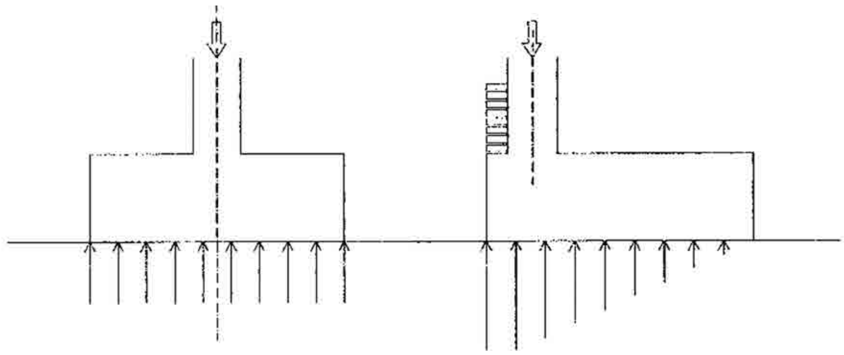


Fig. 5. Design by Fernando Ripollés.



Concentric footing Eccentric footing

Fig. 6. Design by Fernando Ripollés.

Footing types according to their section:
a) Straight b) Staggered c) “Ataluzada” d) Lightened or ribbed

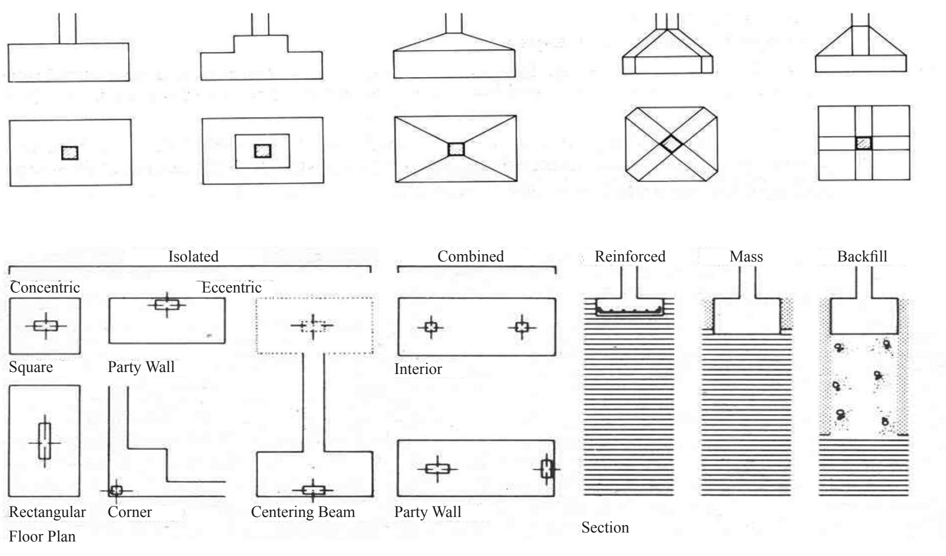


Fig. 7. Design by Fernando Ripollés.

REINFORCEMENT OF FLEXIBLE INDIVIDUAL FOOTINGS

– **Type I**: Rectangular plan
The main reinforcements are placed in the direction of maximum stress (generally in the direction of the greatest dimension).

– **Type II**: Rectangular or square plan, with off-center load
The reinforcements are placed in a similar way to the previous one.

– **Type III**: Square plan with centered load
The reinfocements are symmetrical in both directions.

COMBINED FOOTINGS

They are used on nearby pillars or on supporting pillars.
In any case, it is about defining the point of application of the result of the two or more pillars. Then the shoe is projected whose c.d.g. match the point of application of the resultant.
The bulb is equivalent to a continuous slab with the total width of the foundation.

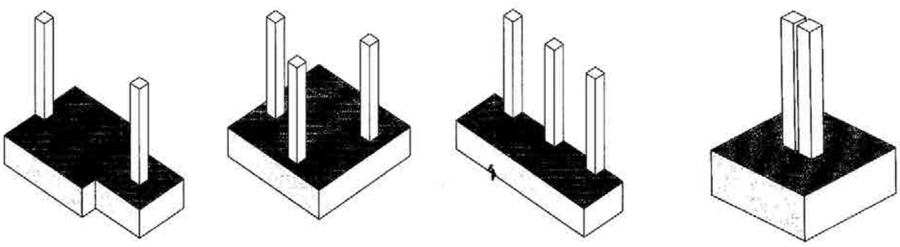


Fig. 8. Gaskets of structural dilation. Design by Fernando Ripollés.

Incidence of the bulb of pressures

– Isolated footings: 1.5 times the width of the footing
– Running shoes: 3 times the width of the ditch

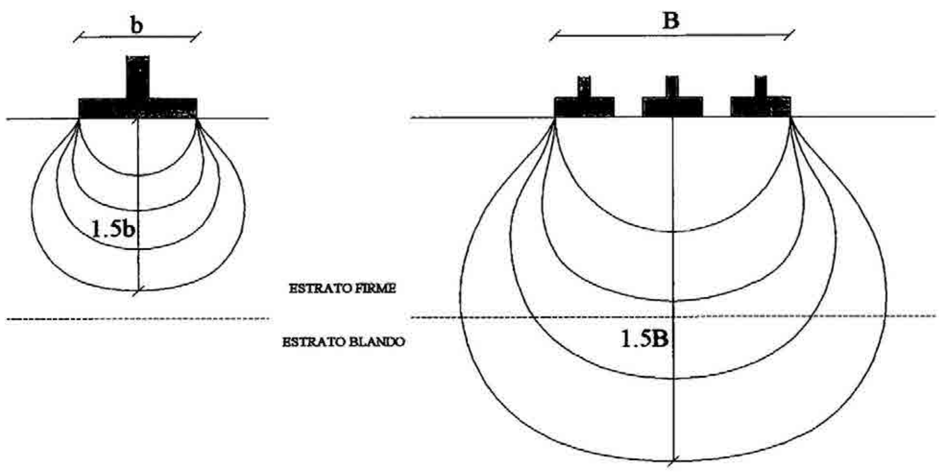


Fig. 9. Design by Fernando Ripollés.

ISOLATED FOOTINGS

Its purpose is to absorb the horizontal actions produced by the structure or the terrain, avoiding displacements and horizontal turns.

It is achieved by reinforced concrete beams, which connect the shoes, Minimum dimensions of the bracing beam: 30 x 35 cm.

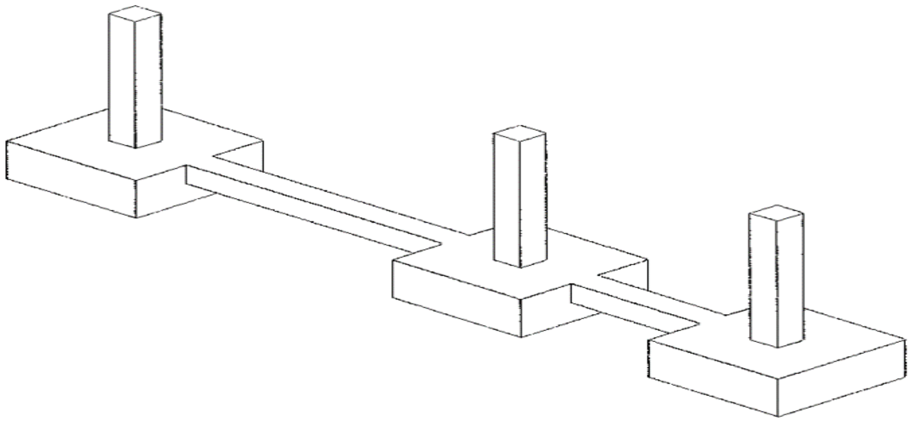


Fig. 10. Design by Fernando Ripollés.

CENTERING BEAMS

They are used to join shoes that receive off-center loads (dividing, corner, etc).

The centering beam is a mechanism capable of absorbing the bending moments generated by the eccentricity of the loads, in such a way that the eccentricity is minimal in the delivery to the ground.

Load centering beams.

Join beams.

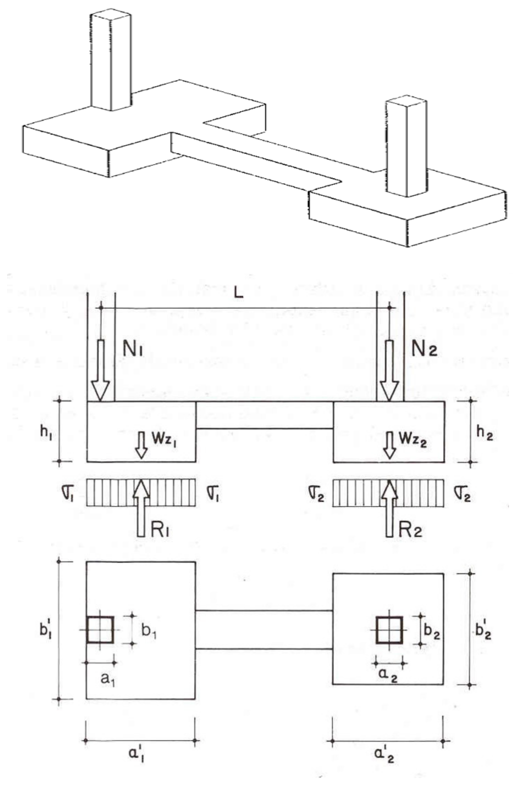


Fig. 11. Design by Fernando Ripollés.

– Reinforcement of Centering Beam:

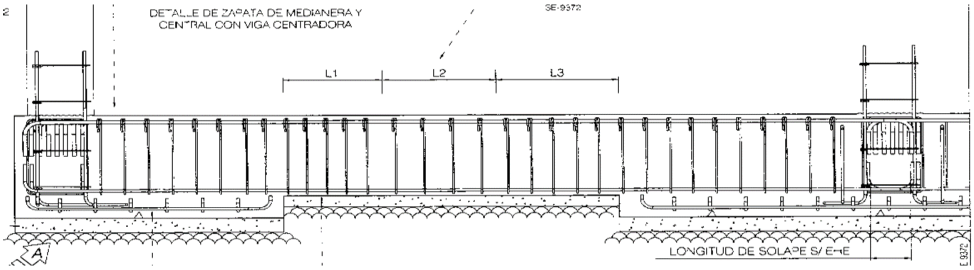


Fig. 12. Design by Fernando Ripollés.

– Bracing of Isolated Footings:

Fig. 13. Photos by Celia Barahona.

STRIP FOOTING (under walls)

– Rigid:
  · They work in compression
  · They are made of mass concrete
  · Great width
  · Without steel reinforcement
  · With cast armor

– Flexible:
  · Bending stress
  · They are made of reinforced concrete
  · Small width
  · With structural armor

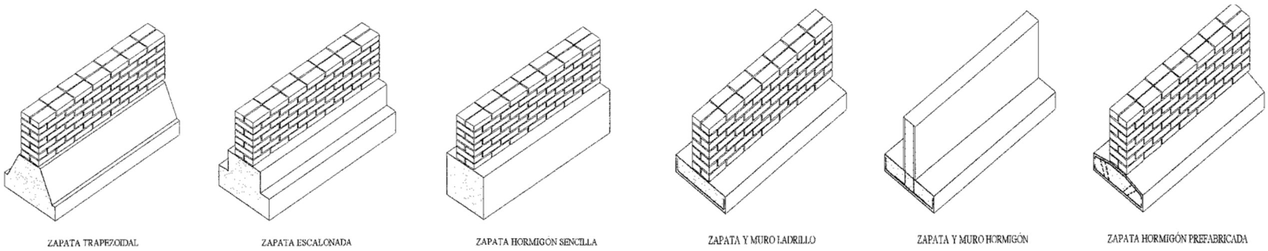
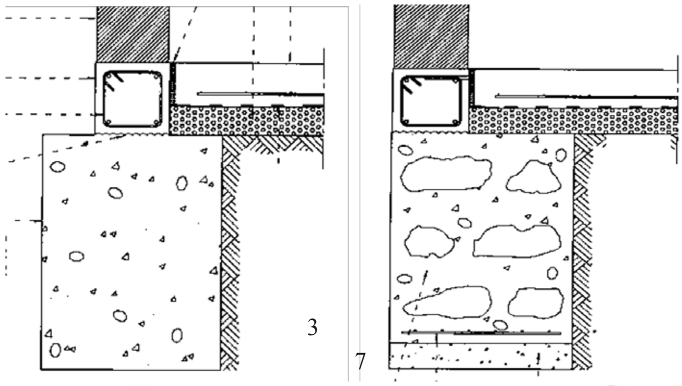


Fig. 14. Design by Fernando Ripollés.

Rigid Mass Concrete Strip Footings



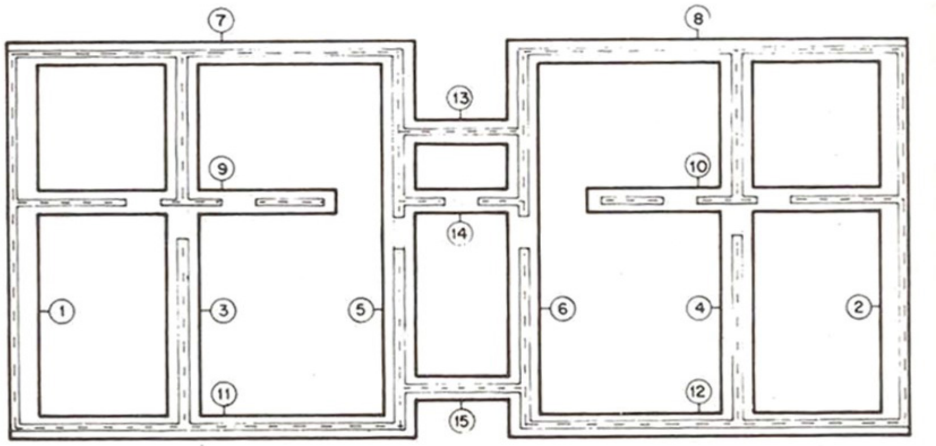


Fig. 15. Design by Fernando Ripollés.

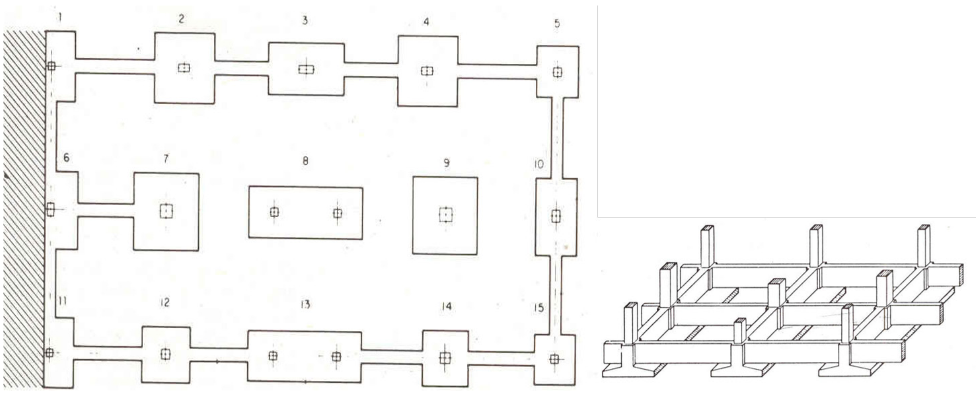


Fig. 16. Footing. Interelation between footings. Foundations plan. Design by Fernando Ripollés.

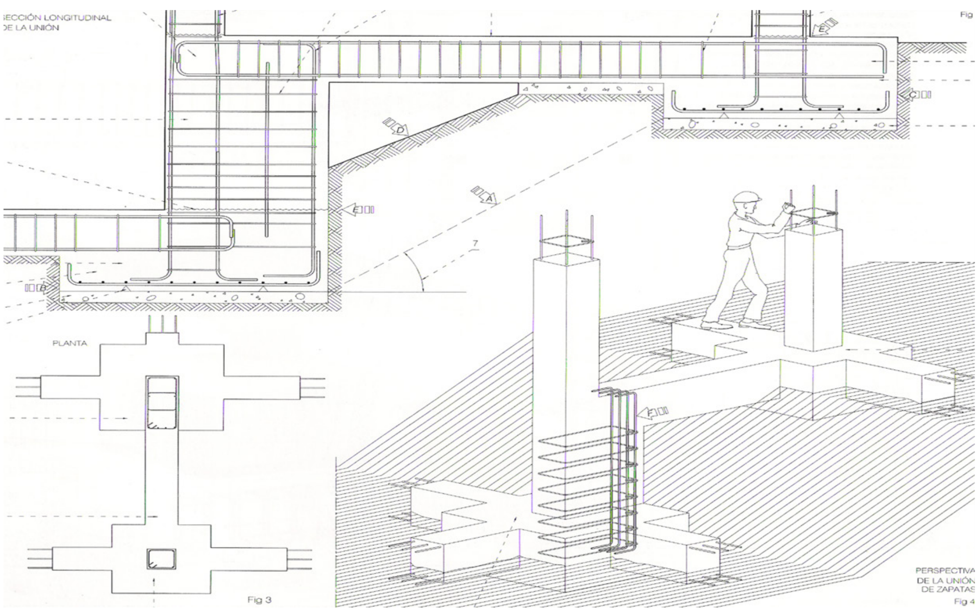


Fig. 17. Diferent levels of footing. Design by Fernando Ripollés.

RAFT OR MAT FOUNDATIONS

MAT FOUNDATIONS

Foundation system of continuous type, which is almost always executed on site.

Suitable for terrains with moderately resistant upper layers (good terrain).

Planar building subsystems for horizontal concrete placement in mass as sills.

It may contain a uniform assembly, usually an industrial mesh.

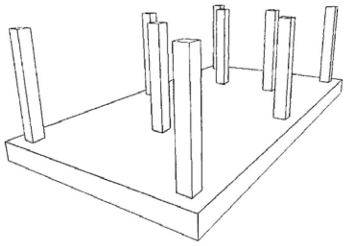


Fig. 18. Design by Fernando Ripollés.

RIBBED MAT FOUNDATIONS

a. Nerved: with reinforced rib lines, singularized, which can be:
   · Apparent or Hidden
   · Up or Down

b. With punctual reinforcements: they contain orthohedral elements, reinforced, singularized, which may be:
   · Embedded or Apparent
   · Up (abacus) or Down (bases)

c. "Fungiformes", with or without mushrooms they contain conical elements, reinforced, always apparent:
   · Up (abacus) or Down (bases)

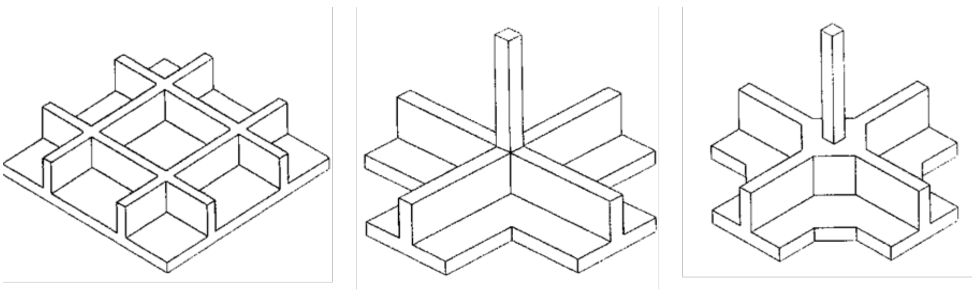


Fig. 19. Design by Fernando Ripollés.

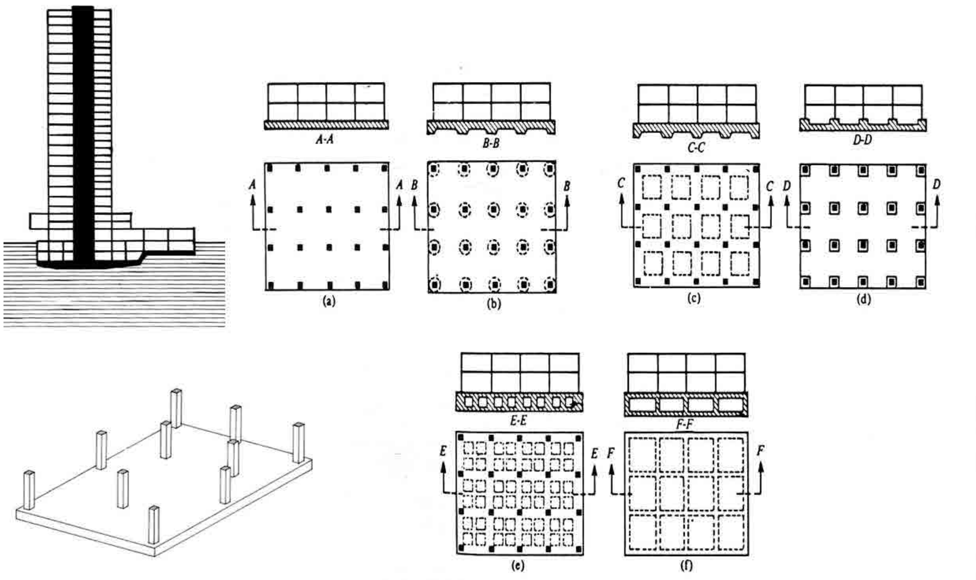


Fig. 20. Design by Fernando Ripollés.

OTHER SHALLOW FOUNDATIONS, SLABS

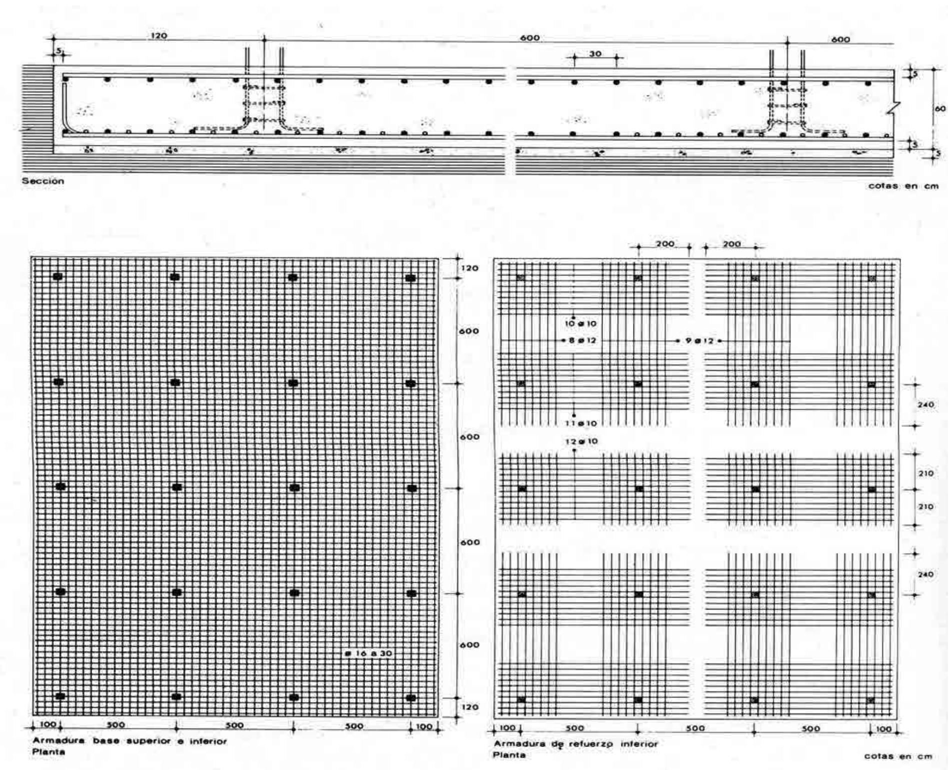


Fig. 21. All with the same reinforcement. Design by Fernando Ripollés.

DEEP FOUNDATIONS: WELLS, PILES

PILES

This type of foundation is strongly conditioned by the on-site execution that mainly depends on the machinery that can access the site, the conditions of the adjacent buildings, etc. So, each case should be independently studied and planned.

TYPOLOGY ACCORDING TO MECHANICAL PERFORMANCE

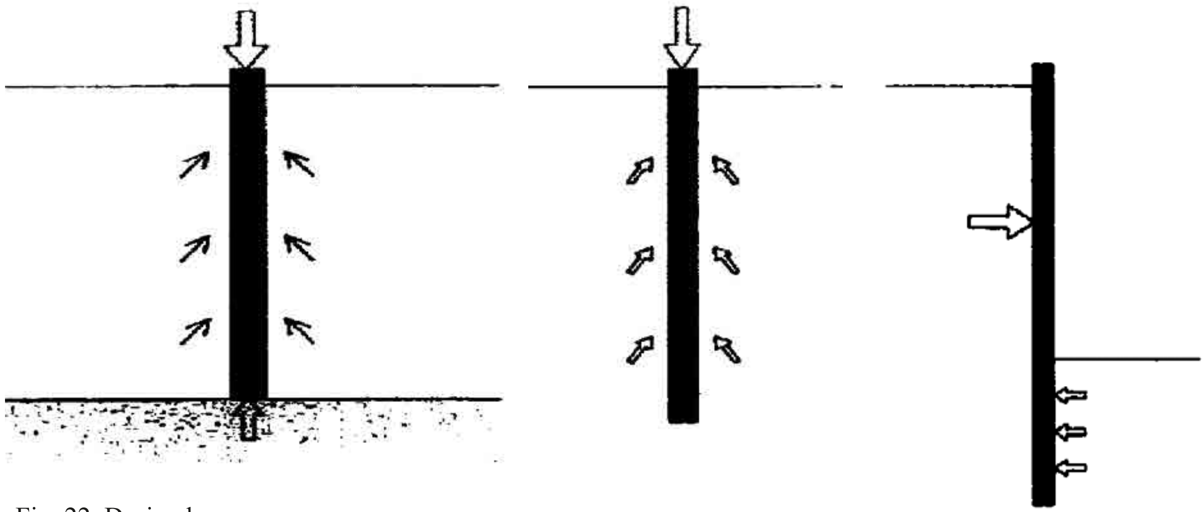


Fig. 22. Design by Fernando Ripollés.

TYPOLOGY ACCORDING TO EXECUTION PROCESS

- Cast-in place piles
- Precast piles
- Piles screen

CAST-IN PLACE PILES

Boring procedure
Retaining borehole walls procedure.

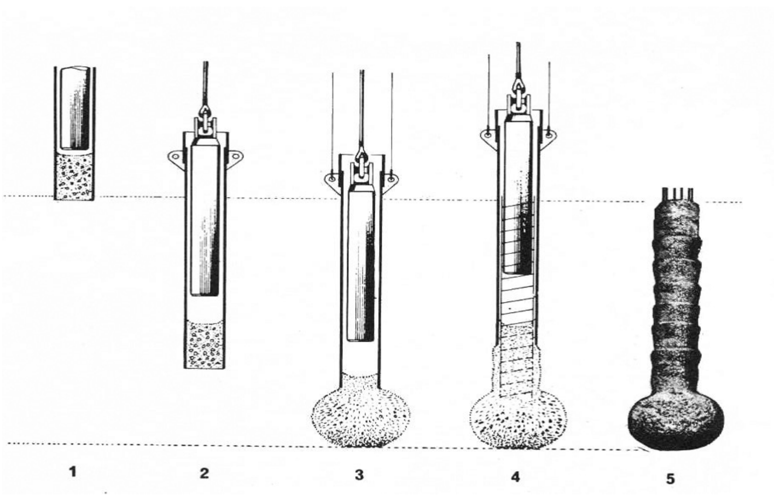


Fig. 23. Design by Fernando Ripollés.

CAST-IN PLACE PILES WITH EARTH EXTRACTION

(3)

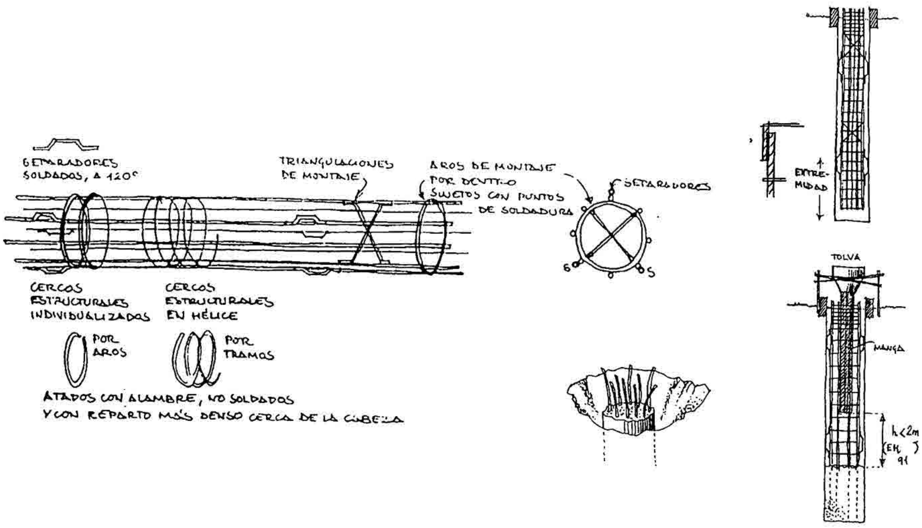


Fig. 24. Design by Fernando Ripollés and Susana Mora.

CAST-IN PLACE PILES WITHOUT EARTH EXTRACTION

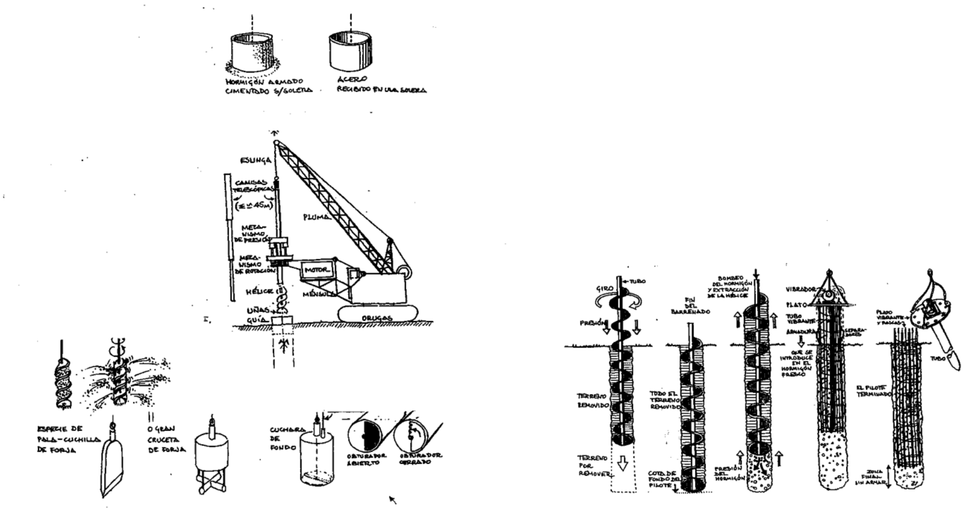


Fig. 25. Design by Fernando Ripollés and Susana Mora.

CONCRETE PILE FOOTINGS

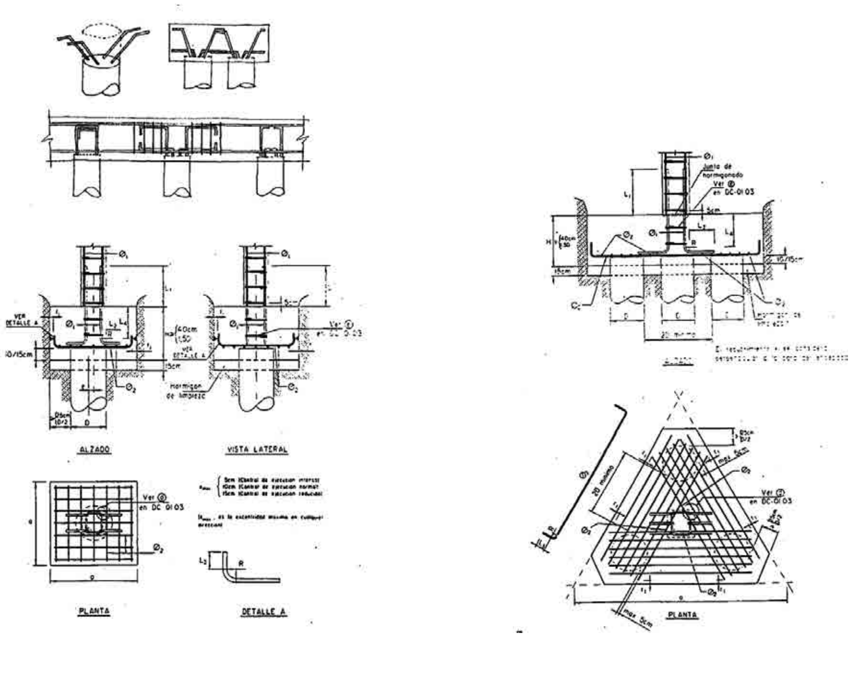


Fig. 26. Design by Fernando Ripollés and Susana Mora.

PROCESS WITH EARTH EXTRACTION

PROCESS WITHOUT EARTH EXTRACTION

PROCESS OF THE CONCRETE PILE FOOTINGS

Fig. 27. Photos by Fernando Ripollés and Celia Barahona.

RETAINING WORKS: INDEX

– OBJECTIVES AND FUNCTION CONDITIONS

– TYPOLOGY OF RETAINING WORKS:

· Basement Walls
· Slurry Walls
· Piles Screens

– EXECUTION PROCESS. QUALITY CONTROL.

OBJECTIVES AND FUNCTION CONDITIONS

MORPHOLOGY

DEPTH OF THE FOUNDATION SOIL

LOAD-BEARING WALLS have a basically supporting function. They receive vertical loads from other elements of the building.

BRACING OR RIGIDITY WALLS, basically, have a stabilising function. They brace the horizontal loads from other walls or structural elements.

RETAINING WALLS have a double function: as load-bearing wall and bracing wall. They suppport vertical loads from gravity and horizontal loads from earth pressure.

TYPOLOGY

BASEMENT WALLS

– EXECUTION

· Walls
- General characteristics
Medium changes in level
Massive elements
Executed after the excavation has been carried out

- Classification
According to work conditions
According to construction material
According to execution system

· Slurry walls

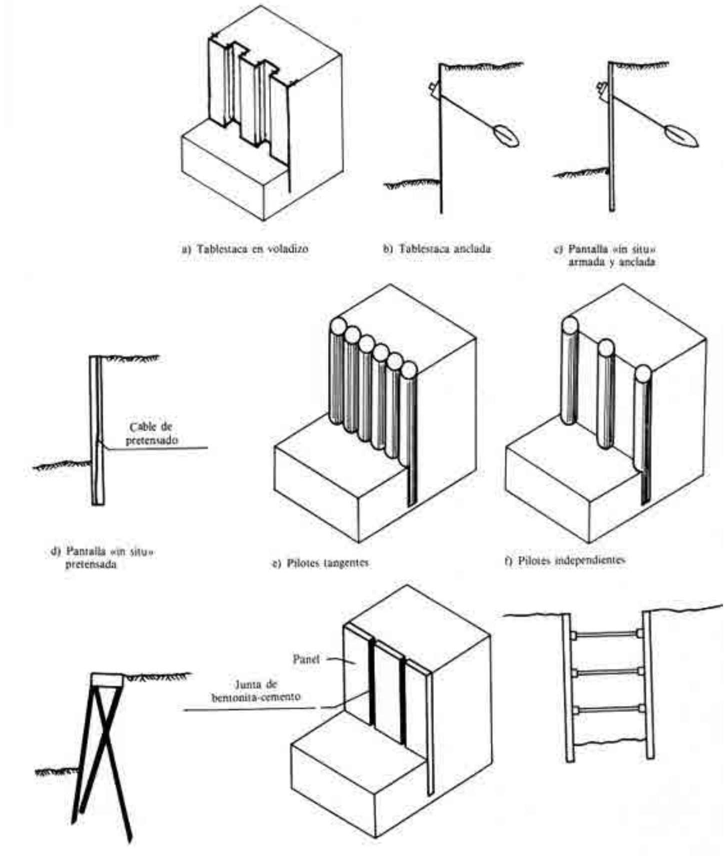


Fig. 28. Slurry walls. Designs by Fernando Ripollés.

ACCORDING TO WORK CONDITIONS

· Mechanical aspects

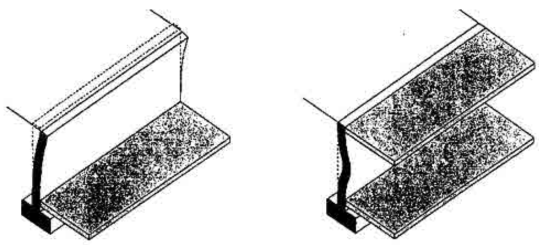


Fig. 29. Design by Fernando Ripollés.

· Working on gravity

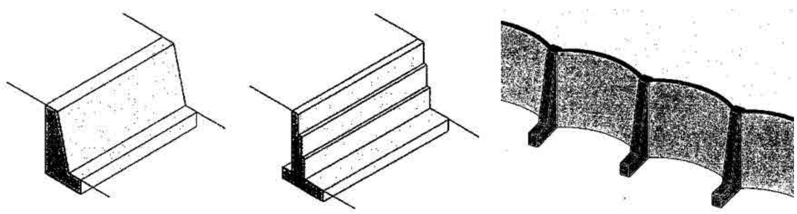


Fig. 30. Design by Fernando Ripollés.

· Reinforced (capable to support bending stress)

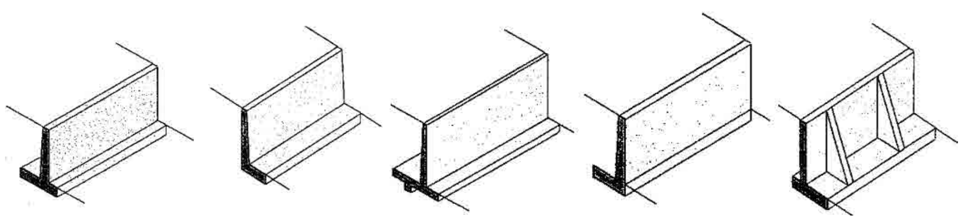


Fig. 31. Design by Fernando Ripollés.

ACCORDING TO CONSTRUCTION MATERIAL

· Stone work: ashlars or rubbles.
· Brick work.
· Massive concrete.
· Reinforced concrete.
· Reinforced earth.

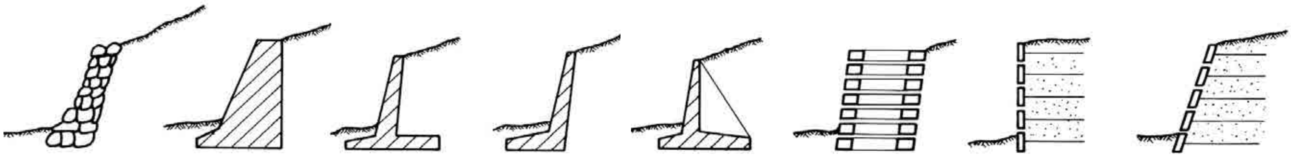


Fig. 32. Design by Fernando Ripollés.

ACCORDING TO EXECUTION SYSTEM

· By trenchs

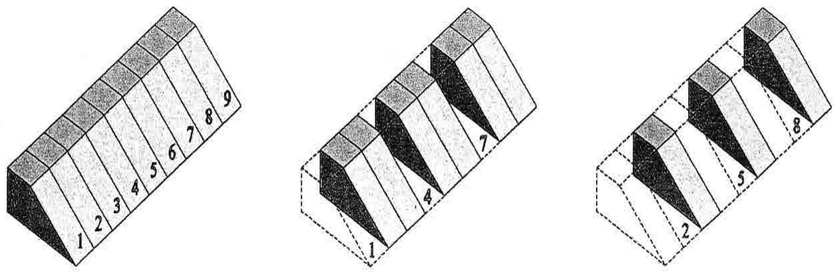


Fig. 33. Design by Fernando Ripollés.

· On a leveling process (Double side formwork).

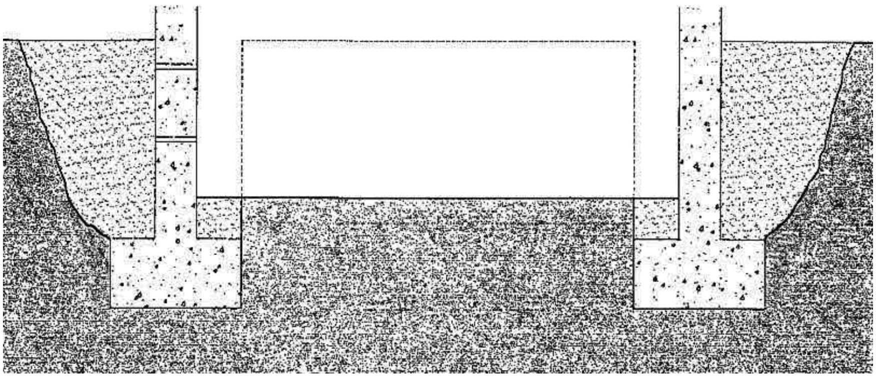


Fig. 34. Design by Fernando Ripollés.

· In basements (Formwork on one face).

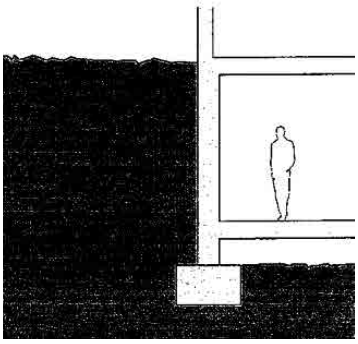


Fig. 35. Design by Fernando Ripollés.

DIAPHRAGM OR SLURRY WALLS

GENERAL CHARACTERISTICS

· Used when there is a medium-high difference of earth levels.
· Always executed before carrying out the excavation.
· They are slender elements.
· They can serve as a retaining wall and perimeter foundation as well.

MECANICAL ASPECTS

· They resist only flexion stress.

CLASSIFICATION

· According to the mechanical performance:
· Fixed or built-in.
· Supported.
· According to the execution system:
· Continuous.
· Executed in tranches
· Composed of panels
· Discontinuous.
· Piles screens

EXECUTION PROCESS

· Guide walls
· Trench excavation. Execution in panels
· Earth retaining
· Joints

A deep trench excavation is executed using a clamshell or grab suspended by cables to a crane. The grab can easily cut through soft ground and bentonite is introduced.

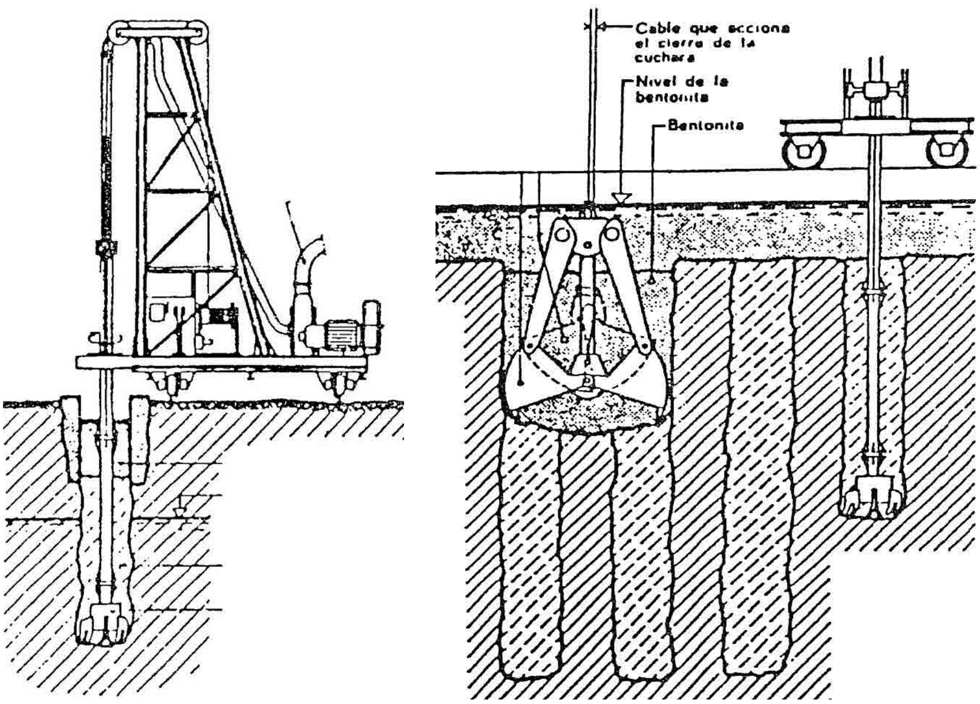


Fig. 36. Design by Fernando Ripollés.

Steel reinforcement is inserted in the form of a steel cage. Overlapping on different sections to reach the full length may be required.

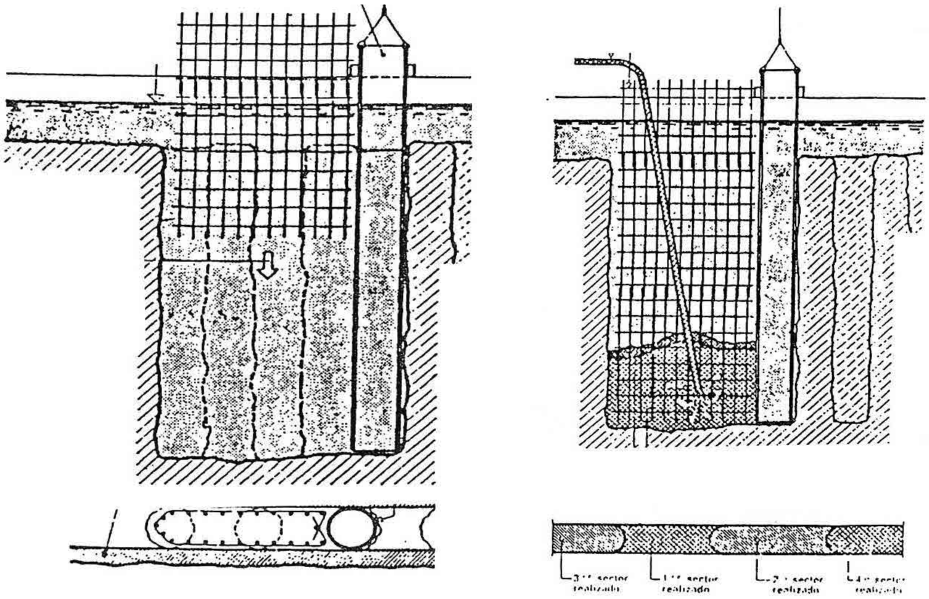


Fig. 37. Design by Fernando Ripollés.

Concreting using tremie pipes to avoid the segregation of concrete. As concrete is being poured down, bentonite will be displaced due to its lower density. Bentonite is then collected and reused.

Fig. 38. Photos by Fernando Ripollés and Celia Barahona.

JOINTS

Fig. 39. Photos by Fernando Ripollés and Celia Barahona.

REINFORCEMENTS

Fig. 40. Photos by Susana Mora.

ANCHORAGES

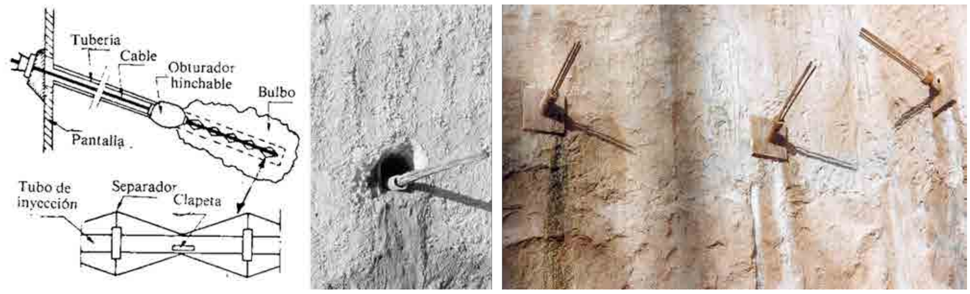


Fig. 41. Photos and design by Susana Mora.

PILES FOUNDED SCREEN

· Attached piles
· Separated piles

Fig. 42. Photos by Susana Mora.

DRAINAGE AND SEWERAGE SYSTEMS: INDEX

- DRAINAGE
- DRAINAGE NETWORK
- SEWERS

DRAINAGE

- Objective
- Elements

OBJECTIVE

To remove water in the vicinity of the foundation elements.
To remove water from the ground.

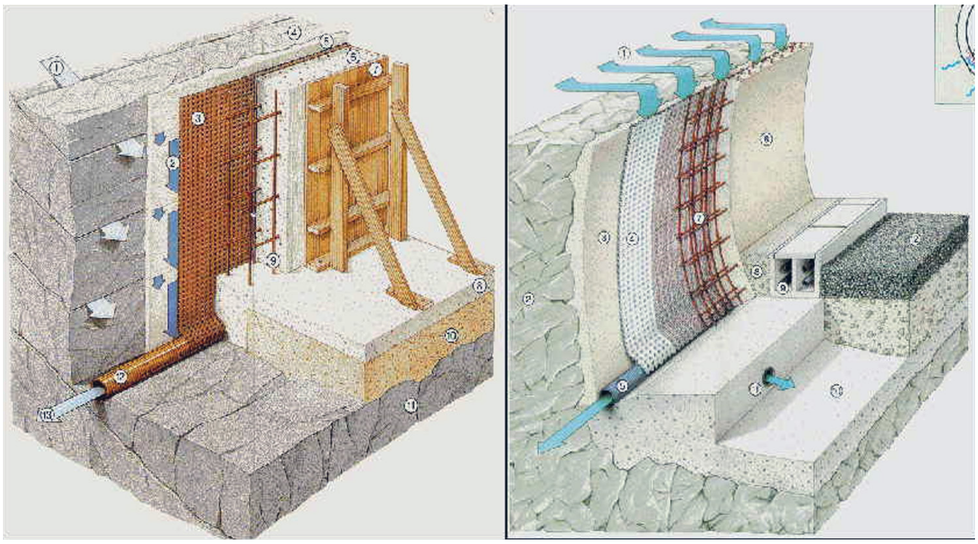


Fig. 43. Design by Fernando Ripollés.

WATER-TABLE

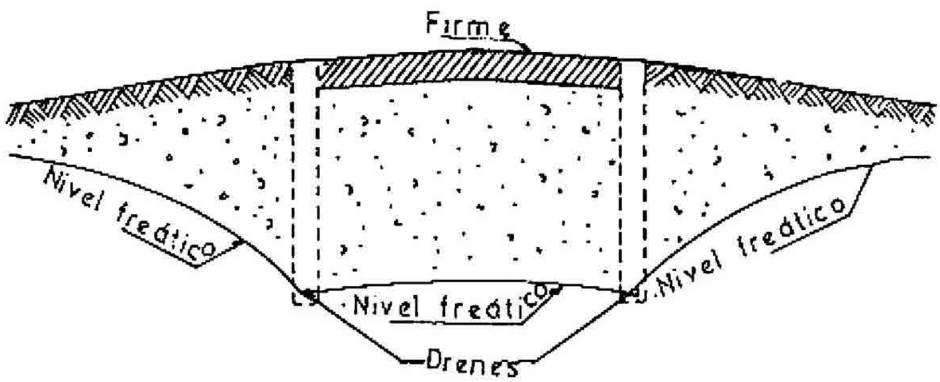


Fig. 44. Drainage pipes to lower the groundwater level. Design by Fernando Ripollés.

UNDERGROUND WATER FLOW

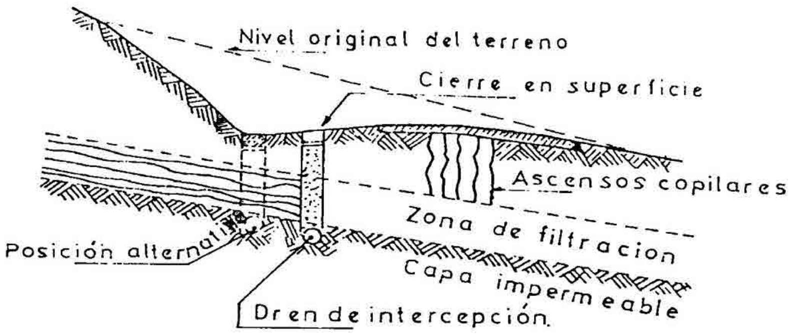


Fig. 45. Design by Fernando Ripollés.

MORE:

Rainwater or water from irrigation: to try to evacuate the filtered water.
Water from lower layers of the soil rising by underpressure: try to drain the rising water.
In frozen soils the depth of the foundation must be deeper than 80 cm.
In basements with a water table above 30 cm, FLOATING FOUNDATION is required.

DRAINAGE ELEMENTS

– DRAINAGE PIPES
  Elements which collect and transport water. There are two types:
    · Linear
    · Superficial
– CATCH BASINS
  Junction boxes between linear drainage pipes at each encounter or change of direction.
– CESSPITS
  Drainage pipes leading to the drainage network.
– DRAINAGE
  (Usually, the sewer network)

LINEAR DRAINAGE PIPES

They are pipes that allow the passage of the water through their walls.
They sit in a ditch and wrap themselves in a granular filter material.
They transport the water to a ground water drain or a storm drain.

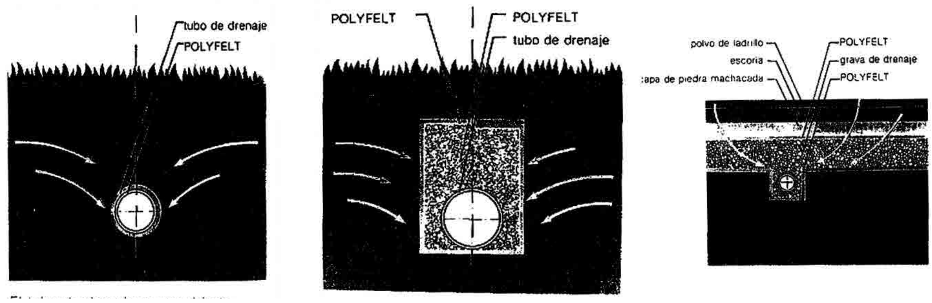


Fig. 46. Design by Fernando Ripollés.

SUPERFICIAL DRAINAGE PIPES

They are filter layers prepared to capture the water and transport it to a linear drain. There are two types:

Porous slurry walls: porous plates joined together vertically or slightly inclined, with the lower edge supported by a drain. They end with a layer of filtering material that separates them from the undisturbed soil.

Hardcore bed: layers of filtering material on the undisturbed soil, with slope towards the linear drainage pipes.

SEWERAGE SYSTEMS

NETWORK

· Sewers
· Catch basins
· Drainage wells

A. UNDERGROUND SYSTEMS

– Located:
  · Under the whole building
  · Under non occupied areas close to the building
  · Directly on the formation level
– Minimum slope 1-2%
– Very widespread use

B. HANGING SYSTEMS

– Hung from ground floor or basement levels ceilings
– Minimum slope 1%
– Favourable use:
  · When the sewer system is at a higher level than the ground floor or basement.
  · When it is desired to leave some level totally free of downpipes.
  · When an horizontal sewerage network easily inspectable and registable is required.

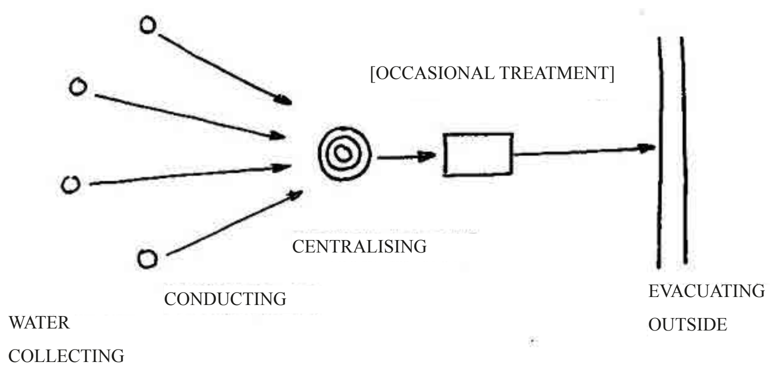


Fig. 47. Design by Susana Mora.

NETWORK TYPES

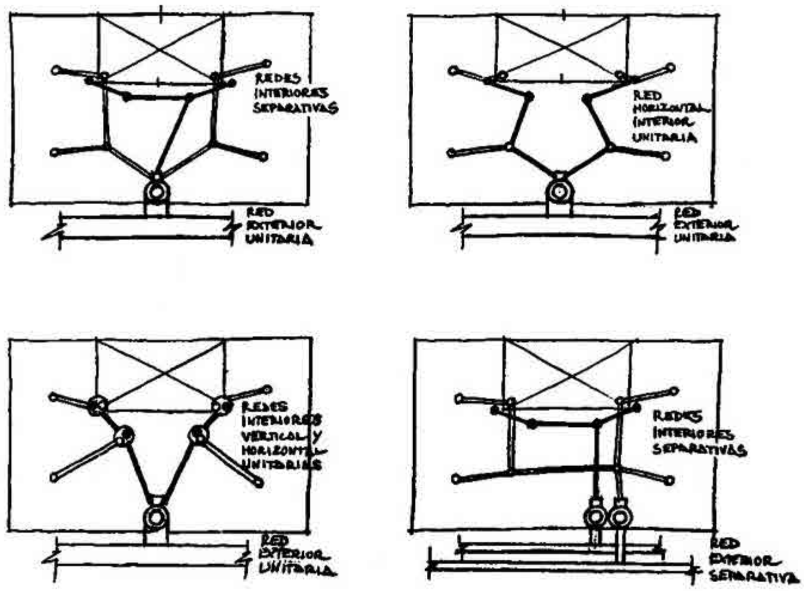


Fig. 48. In horizontal direction. Design by Fernando Ripollés and Susana Mora.

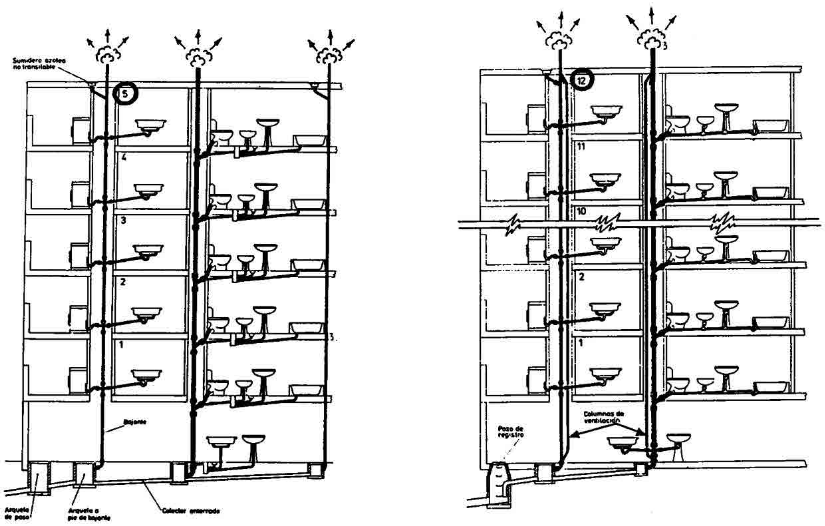


Fig. 49. In vertical direction. Design by Fernando Ripollés and Susana Mora.

POINTS OF DISCHARGE

- General sewerage network
  - · Treatment system
  - · Manhole
- Septic tank
  - · Handcrafted (masonry work)
  - · Prefabricated
- Cesspit

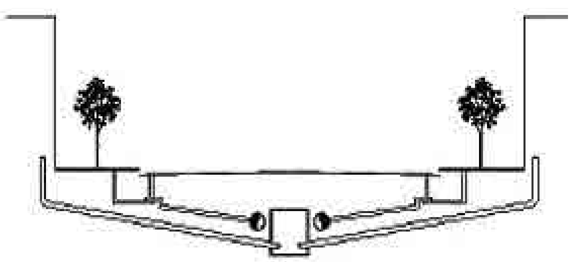


Fig. 50. Design by Fernando Ripollés and Susana Mora.

CATCH BASINS

Placed before the discharge into a manhole and/or general sewer system.

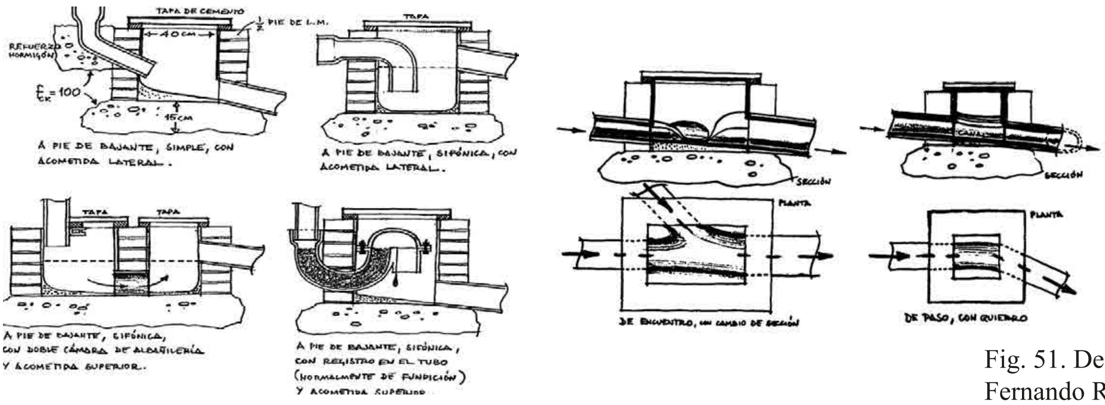
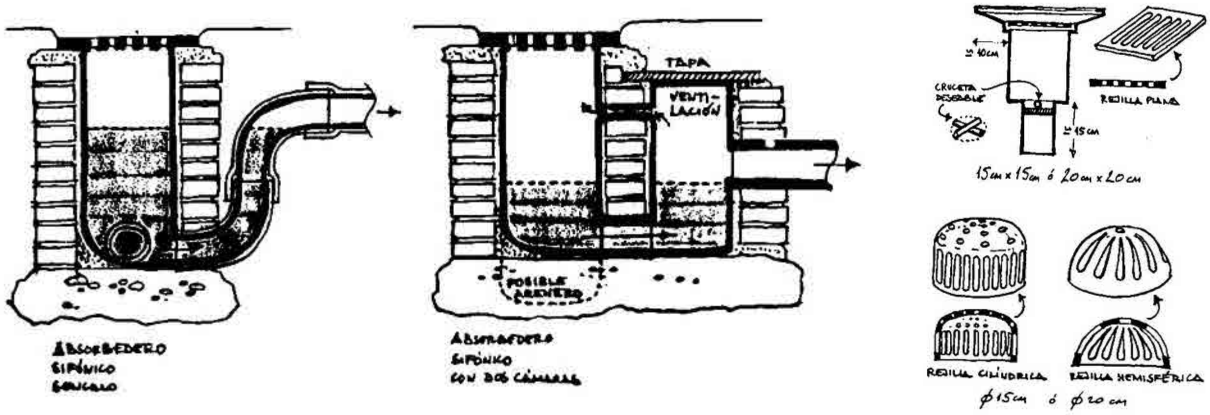


Fig. 51. Design by Fernando Ripollés.

ABSORBERS



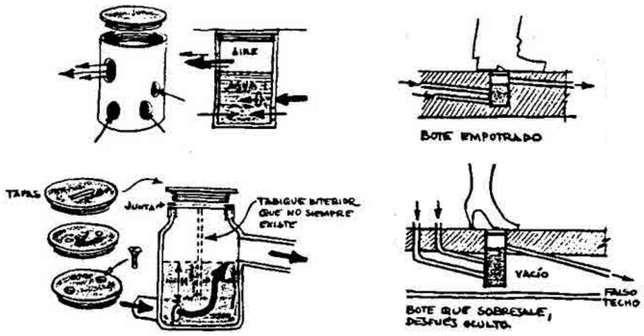


Fig. 52. Above left: Pluming absorbers. Above right: Gully heads. On the left: Siphon traps Designs by Fernando Ripollés.

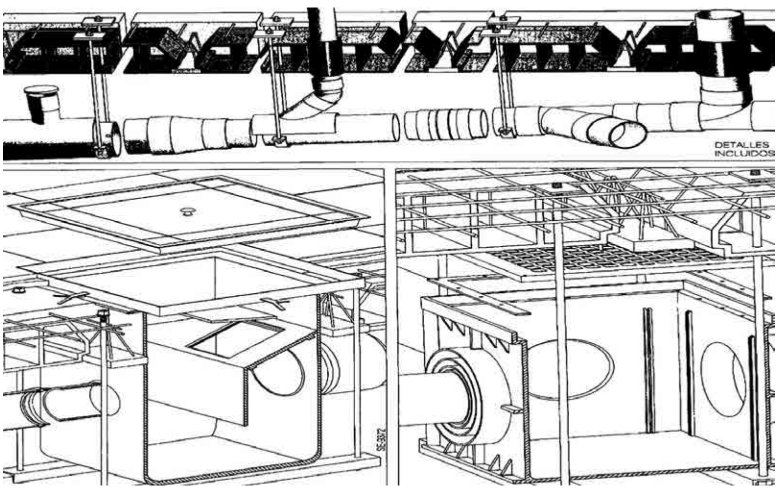


Fig. 53. Prefabricated basins. Design by Susana Mora.

MANHOLES

They are like catch basins of great size, but circular in shape and of sufficient diameter so that a man can go down easily (1,20 m).

– *MATERIALS FOR MANHOLES*
  - · Traditional handcrafted
  - · Massive bricks masonry work
  - · Prefabricated
  - · Precast concrete
  - · Fiber cement

MANHOLES SPECIFICATIONS

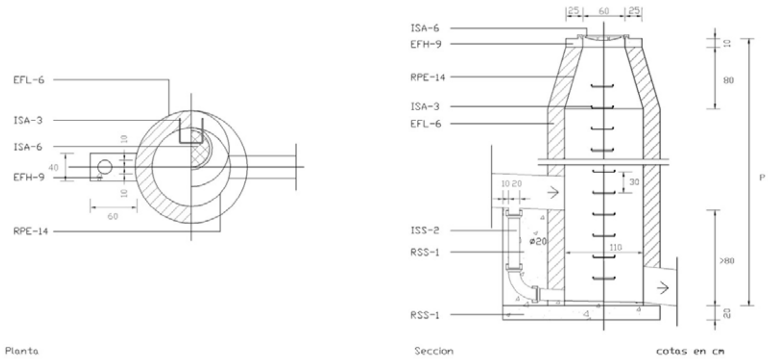


Fig. 54. Circular drainage well. Design by Fernando Ripollés.

Fig. 55. Circular drainage well. Photos by Celia Barahona.

MATERIALS FOR DRAINAGE PIPES

– VISITABLE PIPES
  - · Spun concrete
  - · Reinforced concrete
  - · Fibercement
  - · Cast iron
  - · PVC

– NON-VISITABLE PIPES
  - · Reinforced concrete
  - · Masonry handcrafted

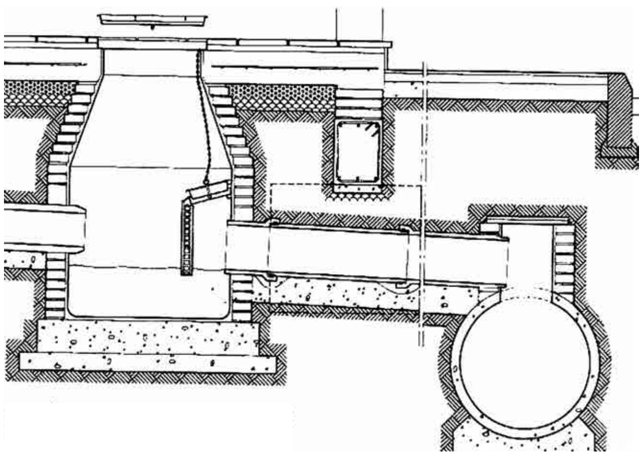


Fig. 56. Section of sewer connection with masonry manhole. Design by Fernando Ripollés.

NOTES

1) A big part of these lessons are usually explained in construction courses at ETSAM (UPM). The full professor has been Fernando Ripollés Rodríguez. I want to thank him and also companions as Celia Barahona, Miriam Cámara, Antonio Rolando, Felipe Pérez-Somarriba and Pedro Galindo and Alfonso García Santos;

2) Important to see Jose Luis González Moreno-Navarro, "Clases para construir" 1, UPC, 1999;

3) Don't forget about the works of Jose María Rodríguez Ortiz for ETSAM (UPM).

ARAUJO ARMERO R., *La Arquitectura como técnica*, ATC ed., Madrid 2007.

MÖNCK W., ERLER K., *Schäden an Holzkonstruktionen. Analyse und Behebung*, Huss Medien, Berlin 2004.

TORROJA E., *Razón y ser de los tipos estructurales,* Inst. Torroja, 4º ed., Madrid 1957.

CHAPTER 15. THE POROUS LOADBEARING SYSTEM. GRID STRUCTURES AND SHELLS. THE COMPACT LOADBEARING SYSTEM

THE POROUS LOADBEARING SYSTEM AND GRID STRUCTURES

– STRUCTURAL WALLS: load, containment and bracing. Visible and hidden systems:
  · Homogeneous and modular systems;
  · Reinforced concrete;
  · Brick;
  · Stone masonry blocks.

– REINFORCED CONCRETE STRUCTURES:
  · On site;
  · Prefabricated.

– GRIDS

STRUCTURAL WALLS

They are active constructive elements from a mecanical point of view. Resistance and stability is required:

· Resistance in order to support their own weight and the vertical loads (compression stress).

· Stability to supporting horizontal loads and horizontal pressures from wind and seismic activity.

– LOAD-BEARING WALLS: have a basically supporting function. They receive vertical loads from other elements of the building.

– BRACING OR RIGIDITY WALLS: basically, have a stabilising function. They brace the horizontal loads from other walls or structural elements.

– RETAINING WALLS: have a double function: as load-bearing wall and bracing wall. The suppport vertical loads from gravity and horizontal loads from earth pressure. HOMOGENEOUS WALLS: There is continuity in the material. There is coincidence between the element and the constructive unit.
  · Simple: isotropic performance.
  · Compound: anisotropic performance.

– MODULAR WALLS: They are obtained by the union of small elements.
  · Based on irregular pieces.
  · Based on regular pieces.

CONNECTION OF MASONRY WALLS

Walls will be conected in corners, convertion or crossing. They must be joined and executed at the same time if possible.

STABILITY OF THE GROUP

In order to assure the stability of the group as a whole, walls perpendicular to load-bearing walls must be disposed.
Symmetrical or the most balanced possible layouts are convenient, mostly in high seismic acceleration areas.

SEEN AND HIDDEN WALLS. According to the material:

- Earth walls;
- Stone walls;
- Bricks masonry walls;
- Reinforced masonry walls;
- Ceramic blocks walls;
- Reinforced concrete walls;
- Concrete blocks walls.

EARTH WALLS: Adobe (sun-dried brick)

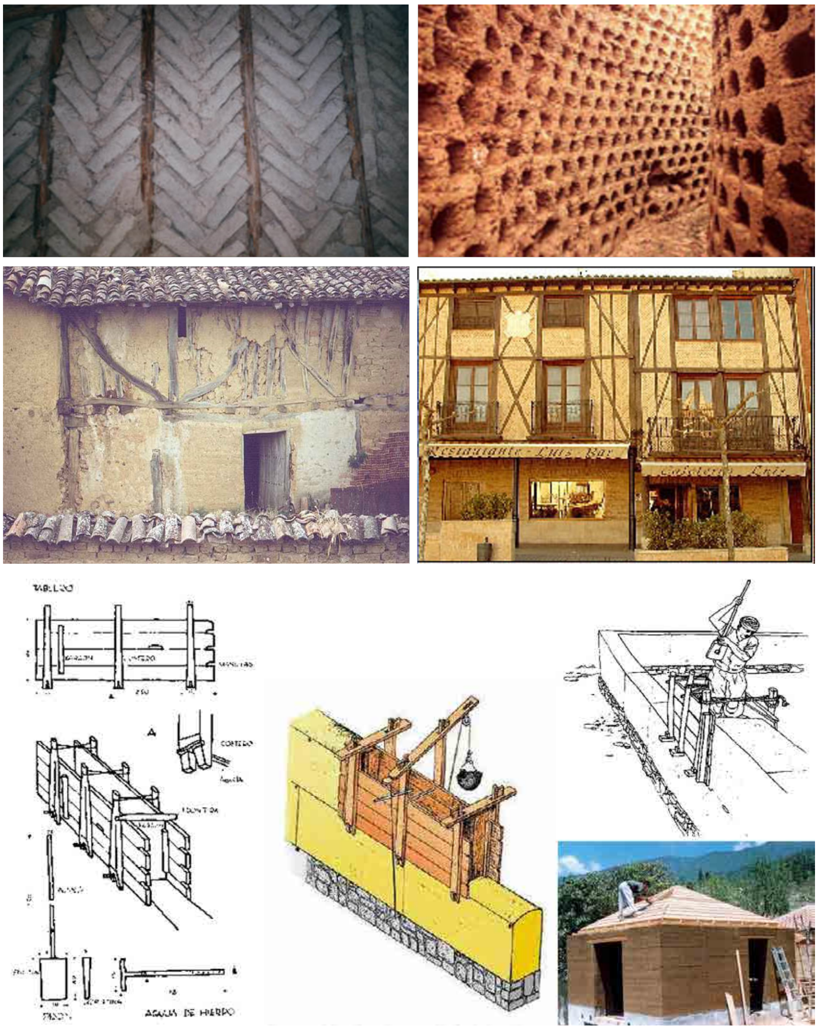


Fig. 1. Mudwall Construction method. Photos and designs by Fernando Ripollés and Alfonso García Santos.

STONE WALLS

Fig. 2. Photos and designs by Fernando Ripollés.

(1)

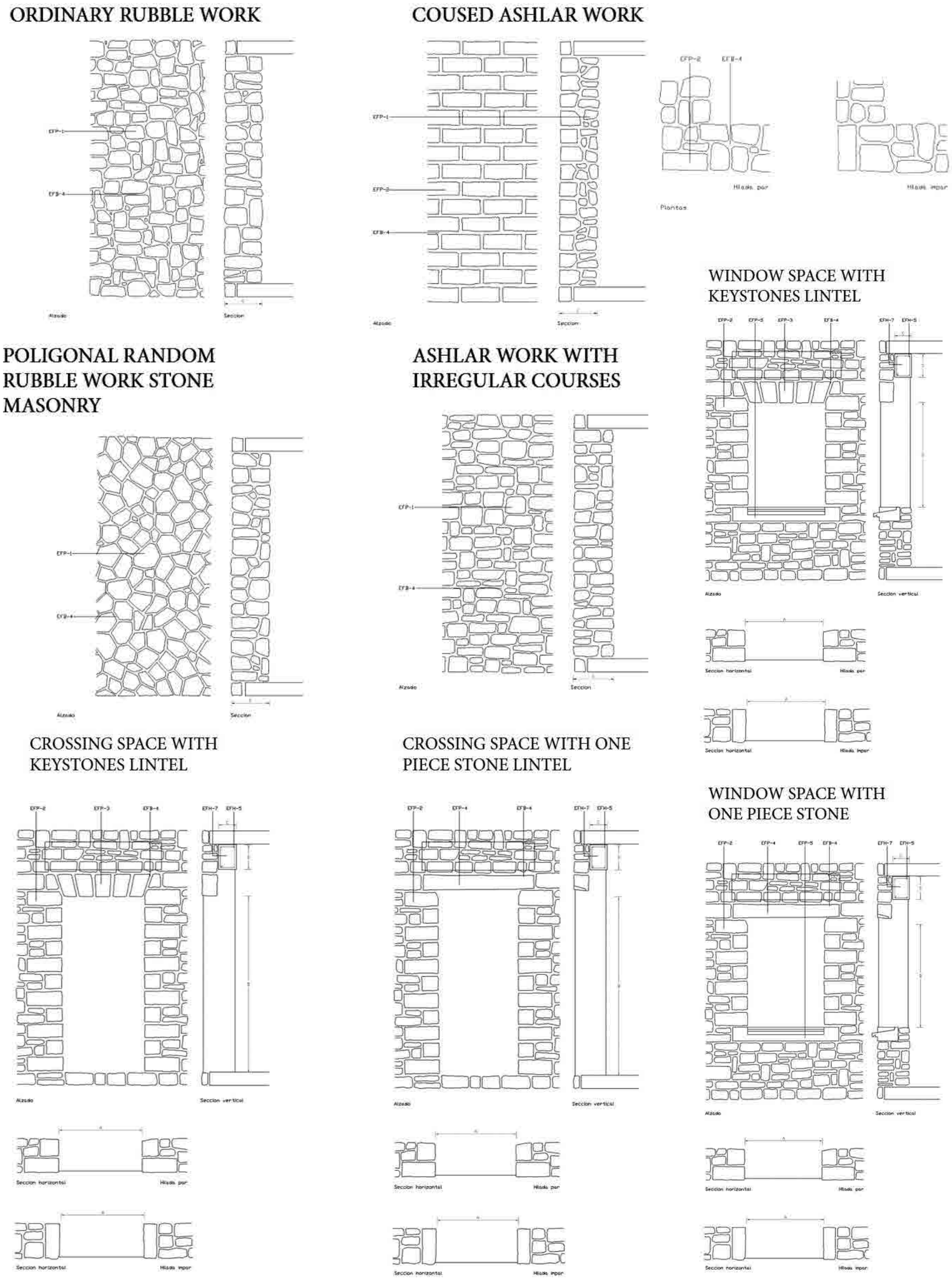
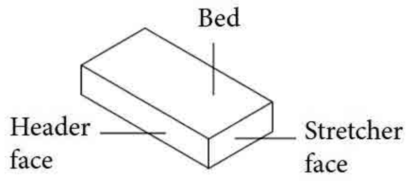


Fig. 3. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

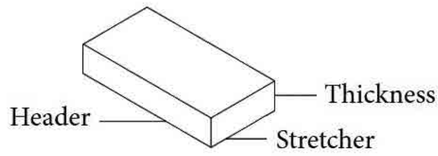
CERAMIC MASONRY BRICKWORK WALLS

(2) – Naming of bricks:

· The faces are called:
- Bed;
- Stretcher face;
- Header face.



· The edges are called:
- Stretcher;
- Header;
- Thickness.



· The joints are:
- Horizontal joints, usually continuous;
- Vertical joints, discontinuous.

– According to the constructive display, walls are classified as:

· Brick Bonded Walls: are bonded for its entire thickness with only one type of construction element.

· Mixed Bonded Walls: elements alternate with others which are more resistent and allow for steel reinforcement.

· Double Course Wall: two layers – same or different kind of constructive element – and elements that bond them such as courses of different material, metal wall ties or anchors.

· Cavity Wall: two layers – same or different kind of constructive element – with an internal cavity and elements that bond them such as courses of different material, metal wall ties or anchors.

· Piers Wall: bonded wall with piers.

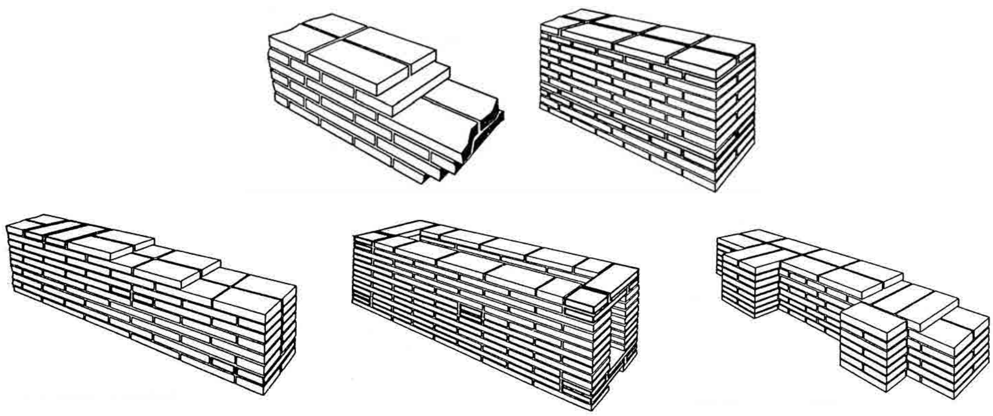


Fig. 4. Design by Fernando Ripollés and Susana Mora.

– Expansion Joints:

Disposed to avoid cracking caused by shrinkage of mortars and hygrometric variations. Straight walls should have expansion joints every:
- 30 m in continental climate;
- 40 m in maritime climate.

If the plan layout has I or U shape or protruding forms, the expansion joints will be disposed in every joint or encounter point of the different wings.

– Pointing Types:

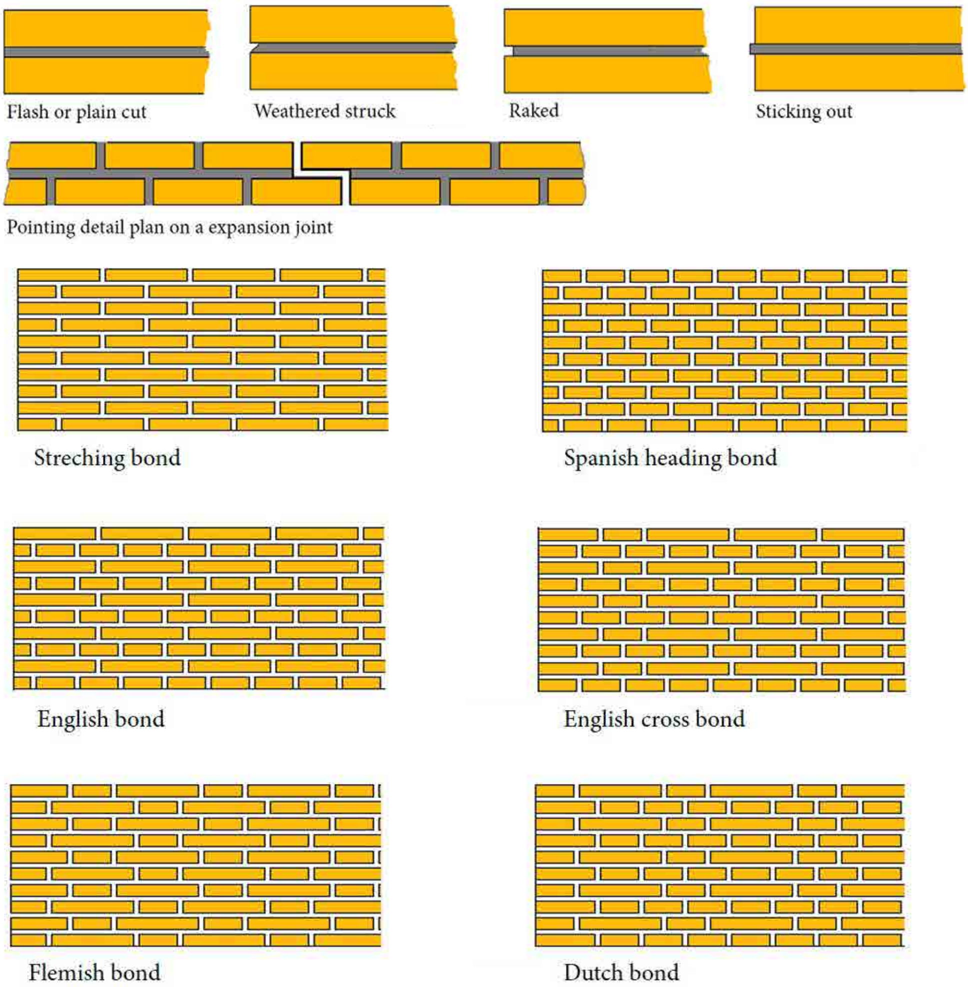


Fig. 5. Design by Fernando Ripollés.

– Types:

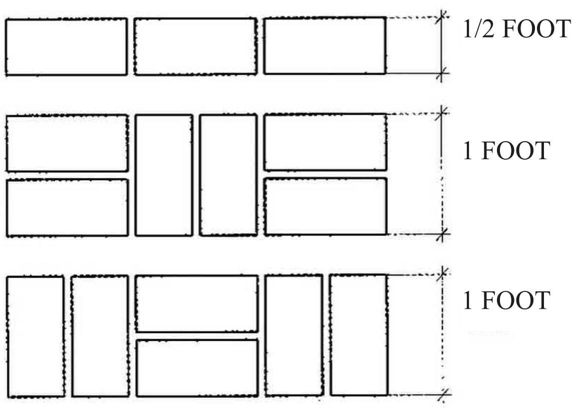


Fig. 6. Design by Fernando Ripollés.

CERAMIC MASONRY BRICKWORK WALL FINISHINGS

· Common brick for masonry brickwork with external cladding.
· Facing brick for masonry brickwork without external cladding.

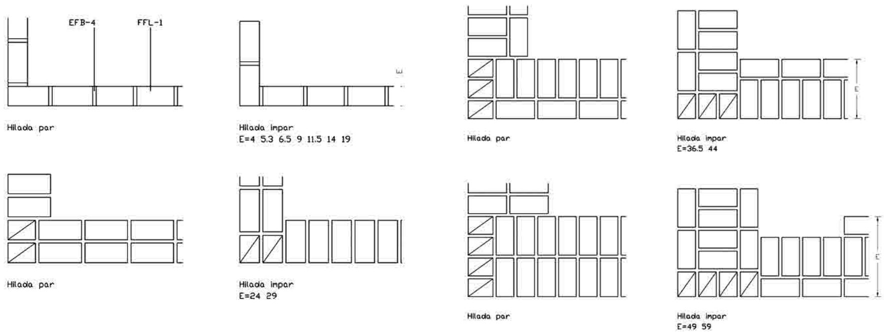


Fig. 7. Designs by Fernando Ripollés.

– Minimum Overlapping:

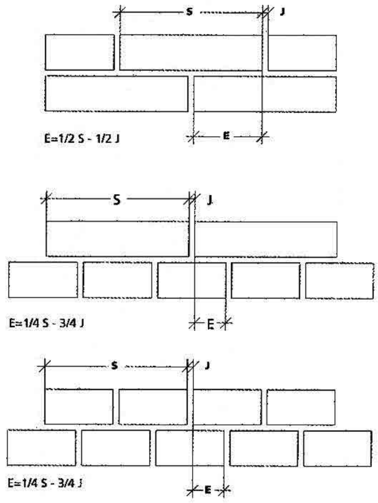


Fig. 8. Designs by Fernando Ripollés.

– Steel Wall Ties:

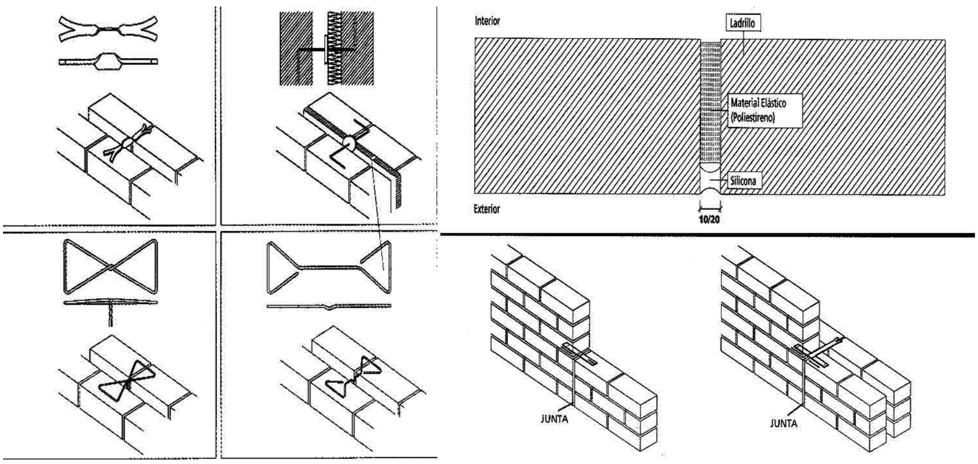
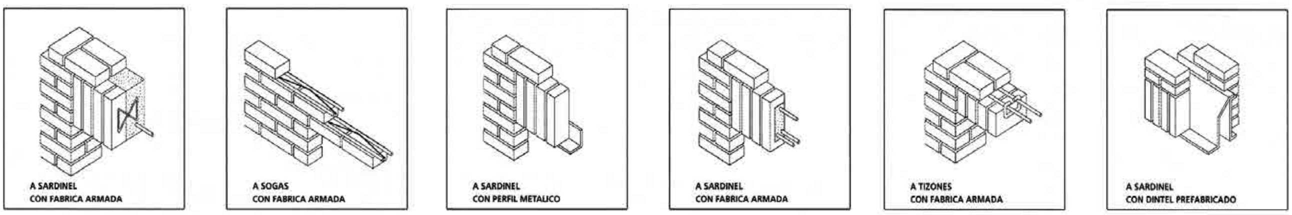


Fig. 9. Designs by Fernando Ripollés.

Fig. 10. Designs by Fernando Ripollés.

– Types Of Lintels:



REINFORCED MASONRY BRICKWORK WALLS

(3)

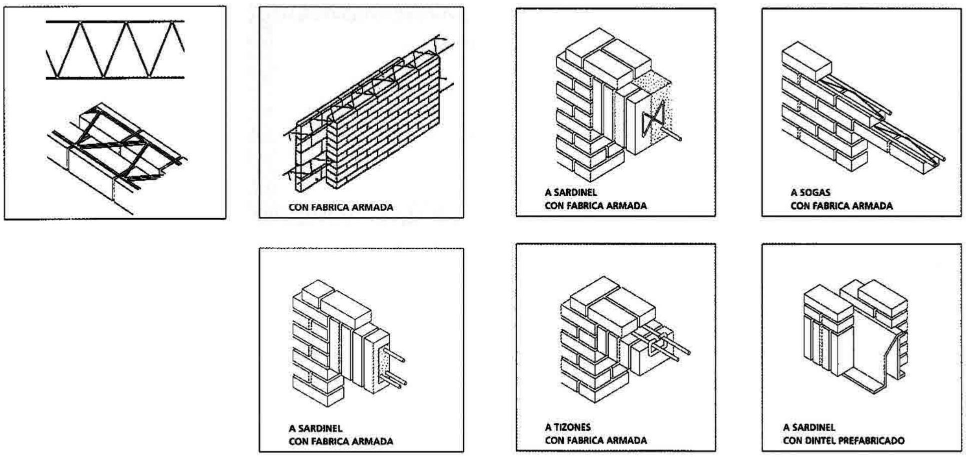


Fig. 11. Designs by Fernando Ripollés.

CERAMIC BLOCK MASONRY WALLS

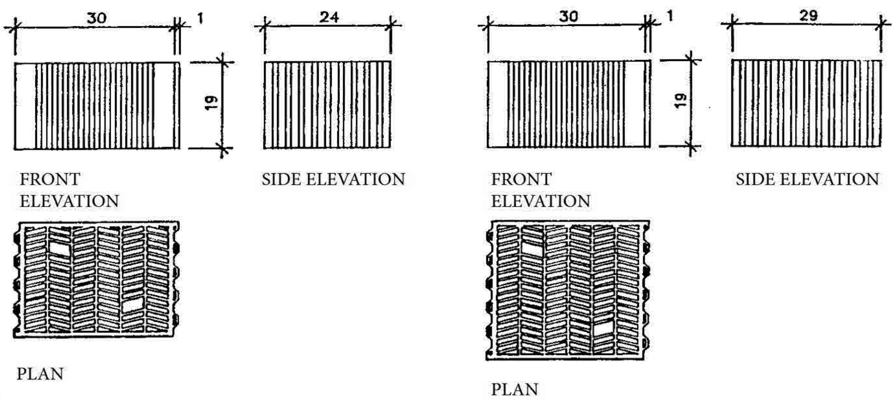


Fig. 12. Designs by Fernando Ripollés.

– Block Types:

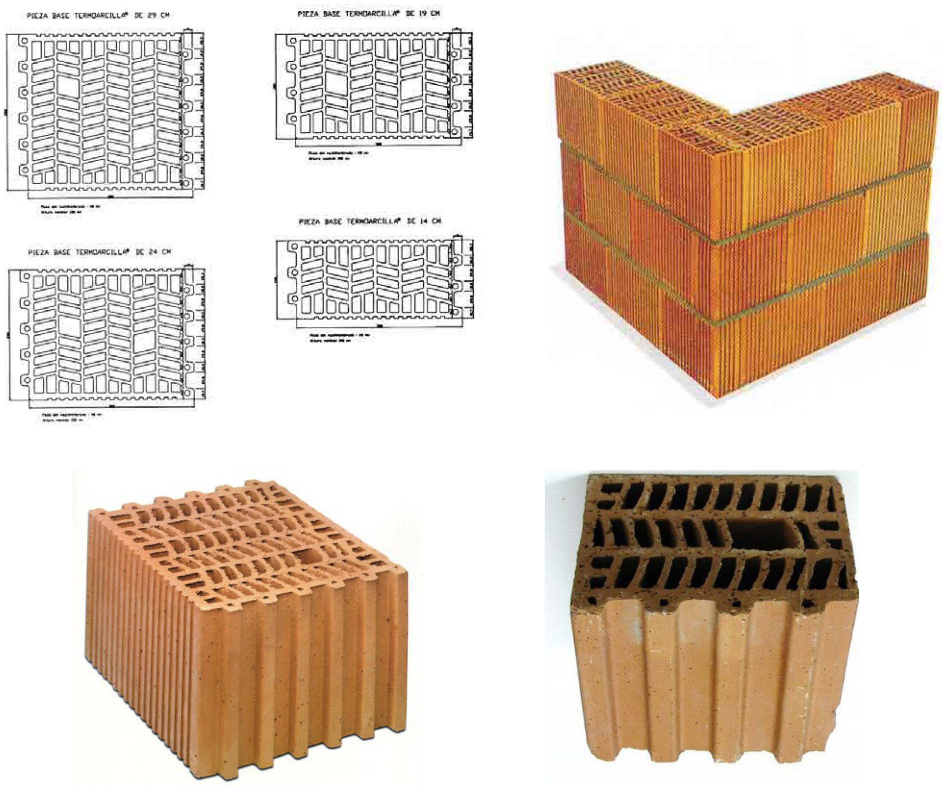


Fig. 13. Designs and photos by Fernando Ripollés.

– Execution Criteria:

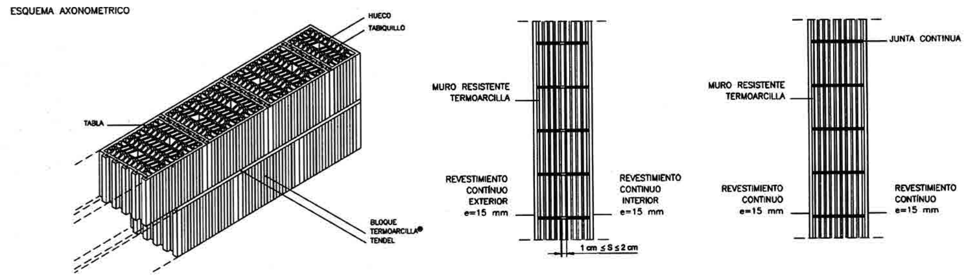


Fig. 14. Designs by Fernando Ripollés.

– Corner Detailing:

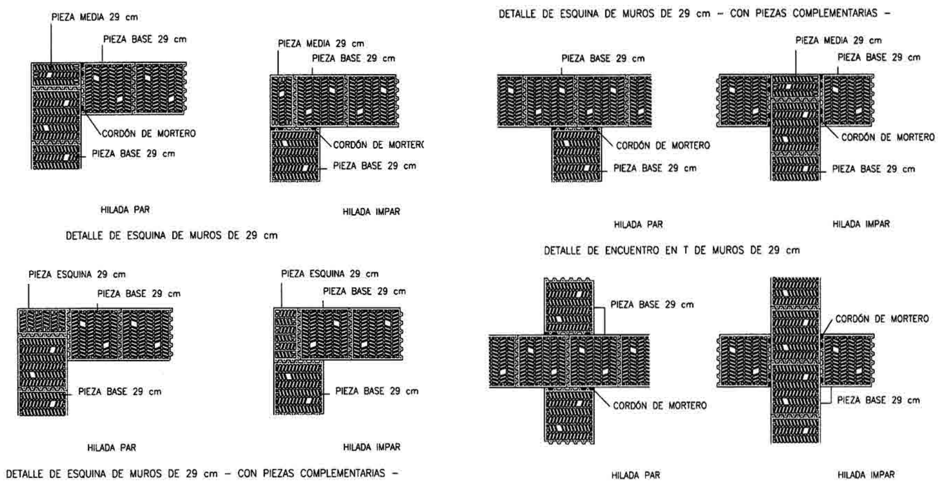


Fig. 15. Designs by Fernando Ripollés.

– Wall Joints:

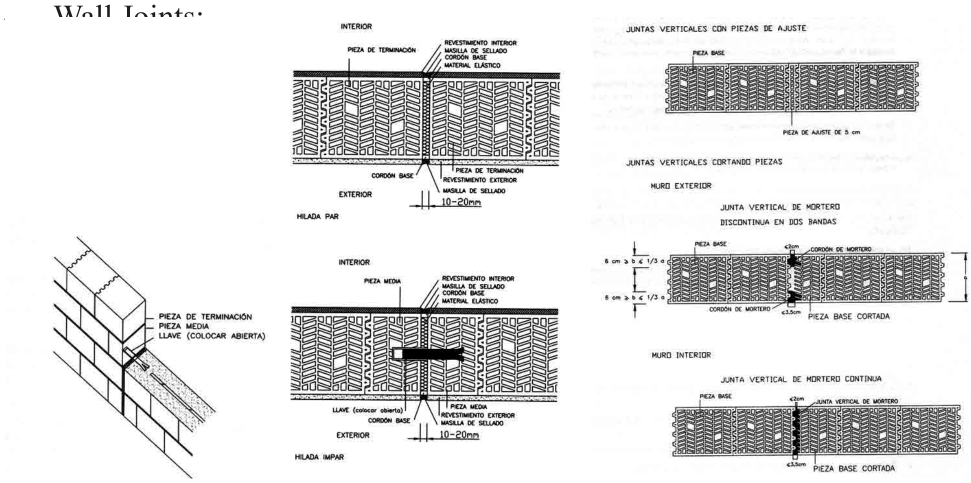


Fig. 16. Designs by Fernando Ripollés.

– Lintel And Conection To The Structure

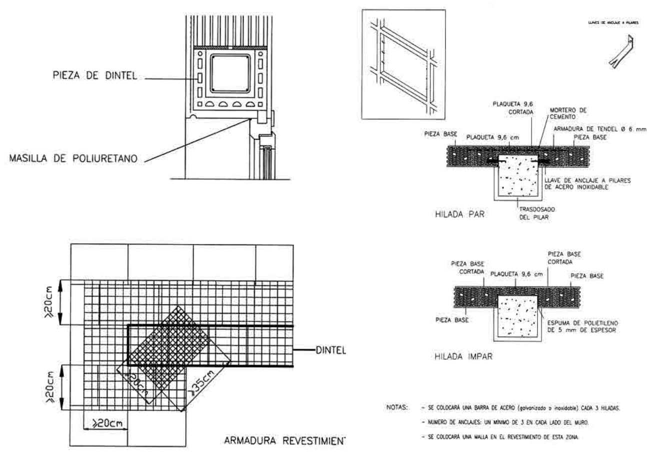


Fig. 17. Designs by Fernando Ripollés.

REINFORCED CONCRETE WALLS

TYPES OF JOINTS (4)

– Structural expansion joints
Every 30 m along and through the whole building, except in the foundation.
– Expansion joints
Every 10-20 m or at shorter distances on perimeter walls exposed to sun or frost.
– Working joints
They depend on the workplan and timing.
– Retraction joints
Maximun every 25 m along and through the whole building. They can be:
· Orthogonal:
- Allow orthogonal dilatation to the joint.
- Width from 2 to 2.5 cm.
- The joint is empty or can be curdled with soft insulation.
- On the outside it can be covered with metal or plastic flashing.
· Glissade:
Allow expansion movements only parallel to the joint.

JOINTS LOCATION

In general, they are placed where they do not interfere (behind downpipes, in corners, etc.).
They must be left uncoated to avoid deterioration of the linings or cladding.

JOINTS SEALING

Materials used to seal them depend on the circumstances of each case.

REINFORCED CONCRETE FAÇADES

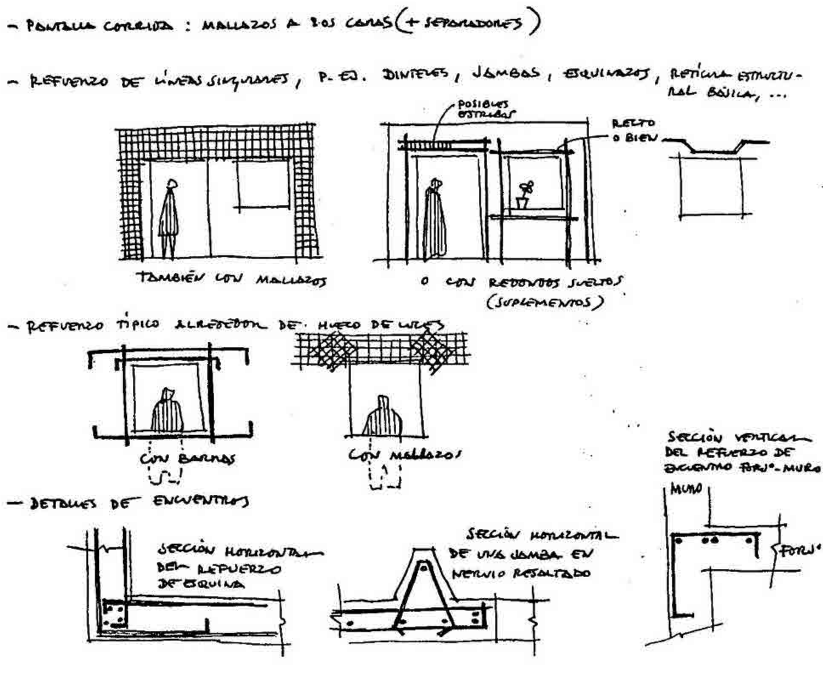


Fig. 18. Designs by Fernando Ripollés.

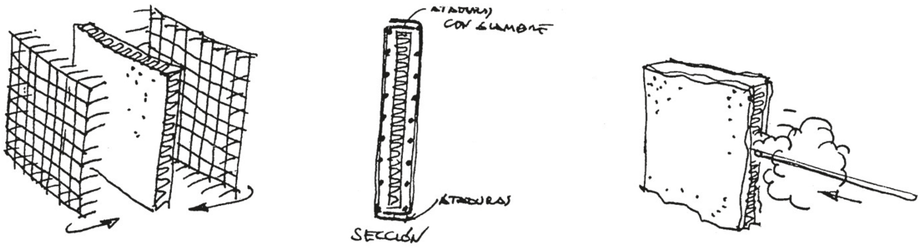


Fig. 19. Designs by Fernando Ripollés.

REINFORCED CONCRETE WALLS

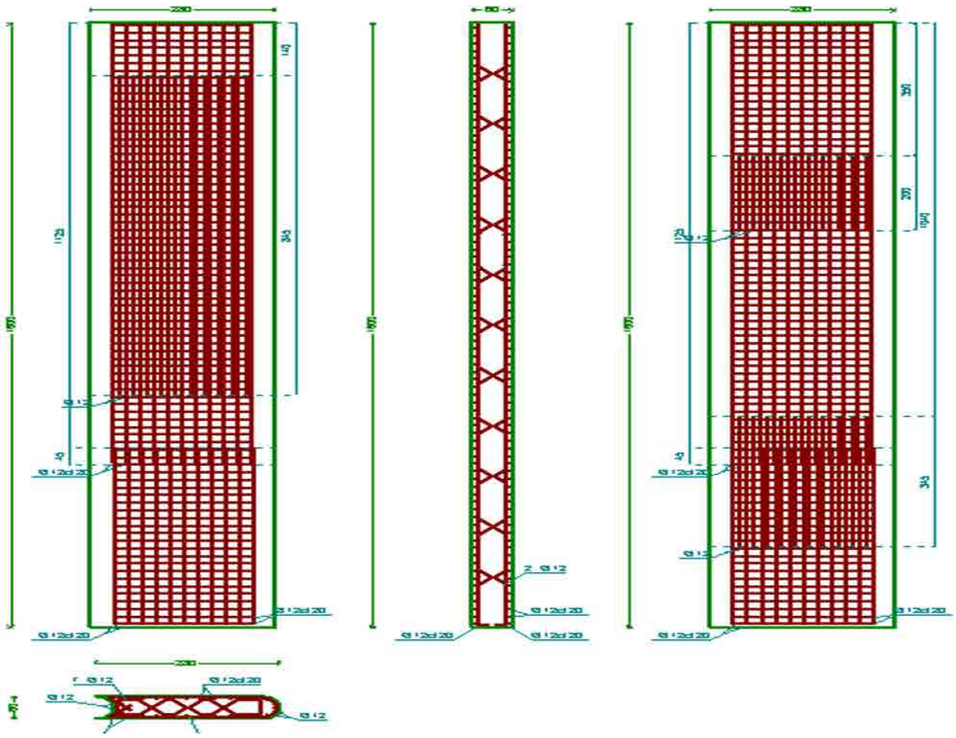


Fig. 20. Designs by Fernando Ripollés.

Fig. 21. Photos by Fernando Ripollés.

BEAMS

– Steel Reinforcement for Wallbeams.

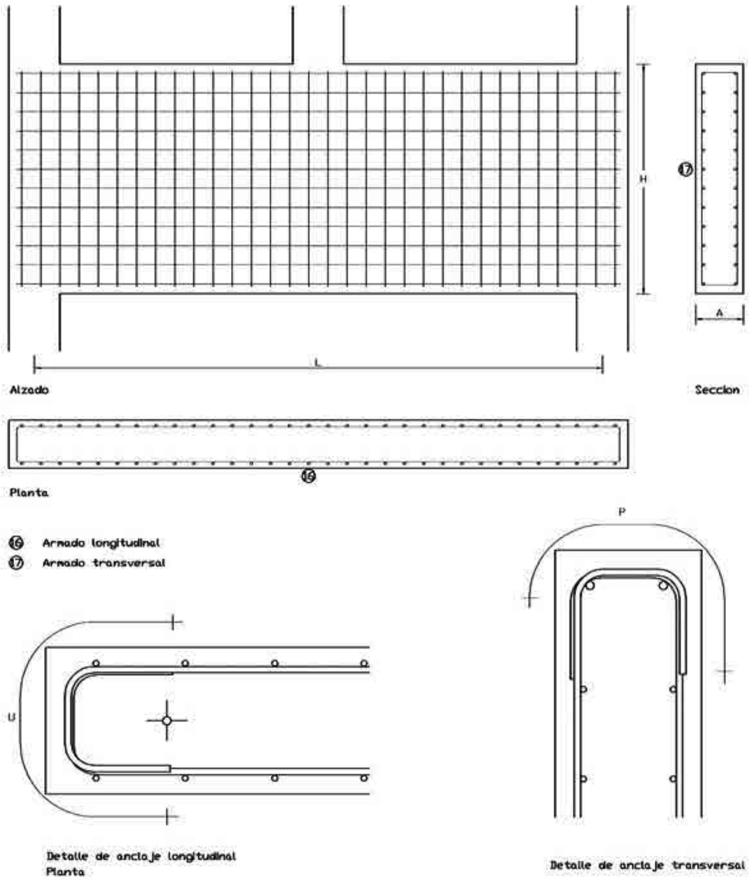


Fig. 22. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

– Complementary Load or Support Steel Reinforcement for Wallbeams.

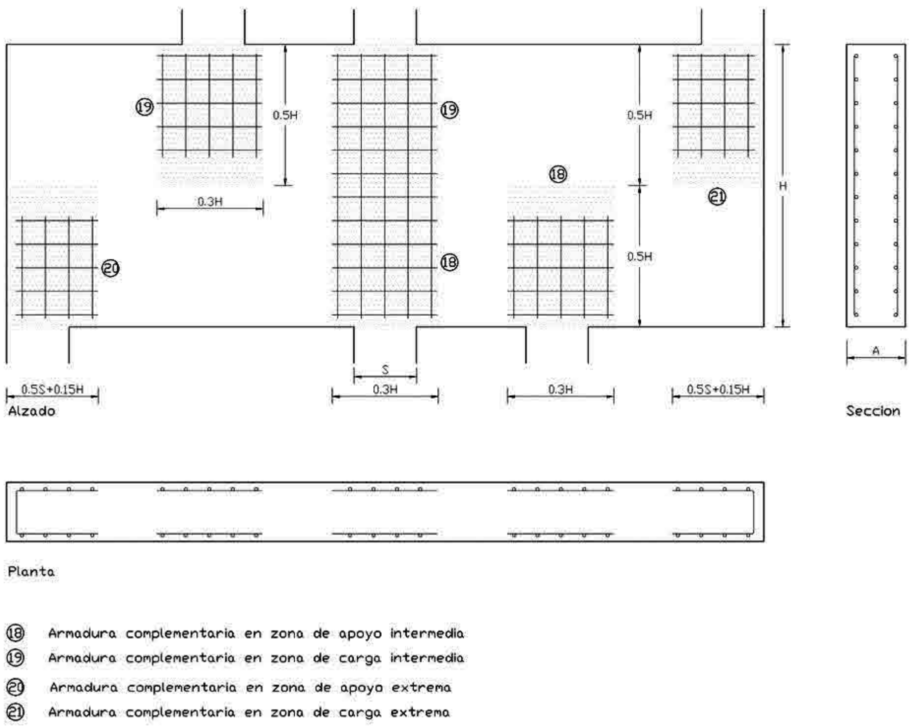


Fig. 23. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

– Complementary Hanging Reinforcement for Wallbeams.

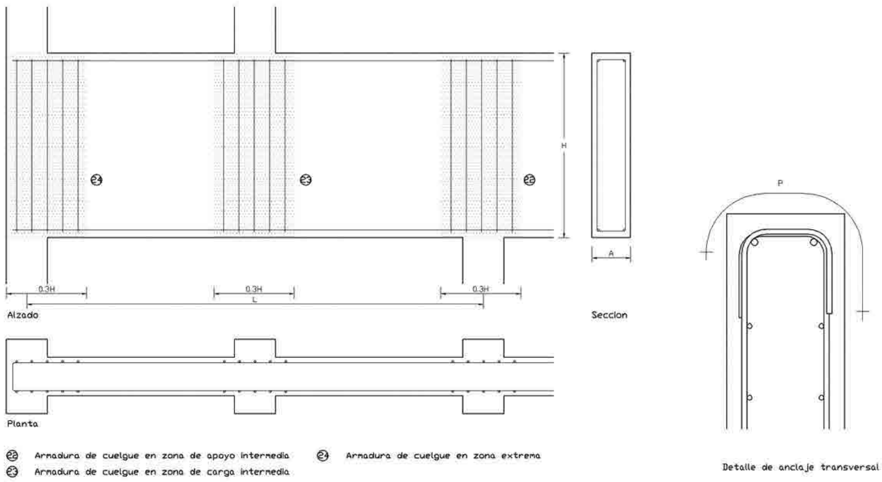


Fig. 24. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

– Placement of Concrete for Wallbeams.

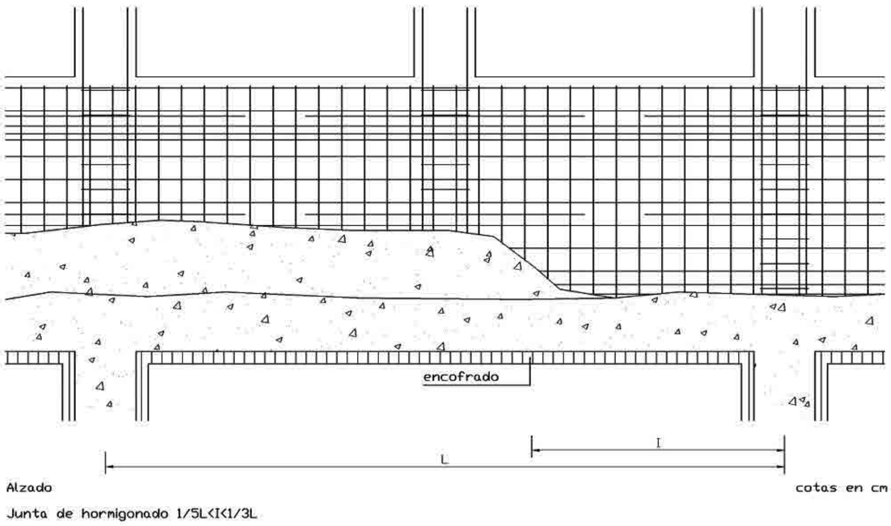


Fig. 25. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

– Inner Section of Wallbeam.

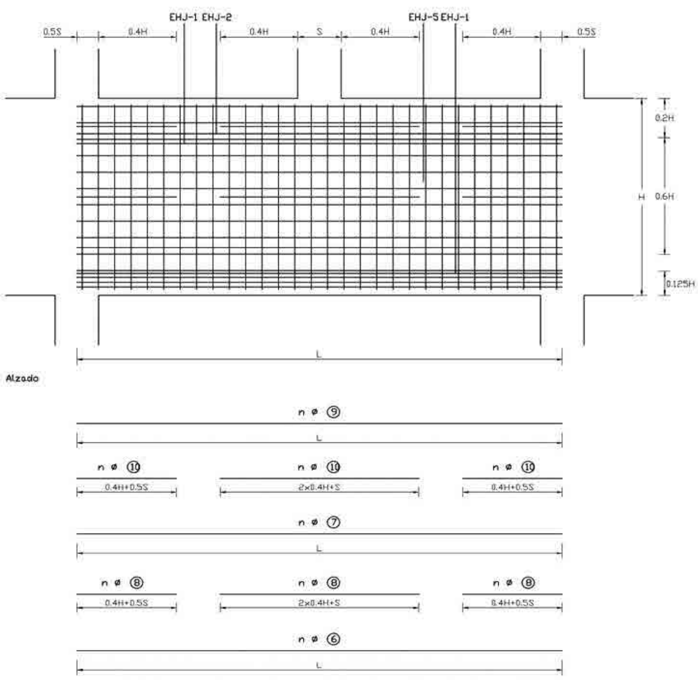


Fig. 26. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

CONCRETE MASONRY BLOCKWORK WALLS

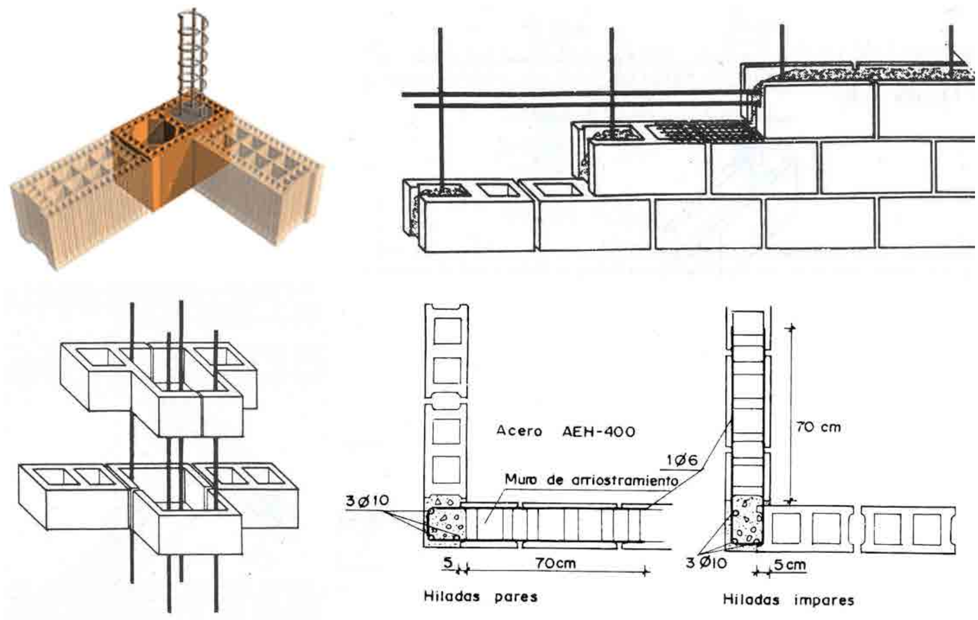


Fig. 27. Designs by Fernando Ripollés.

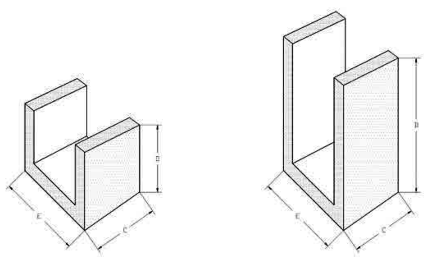


Fig. 28. Lintel Piece Block. Designs by Fernando Ripollés.

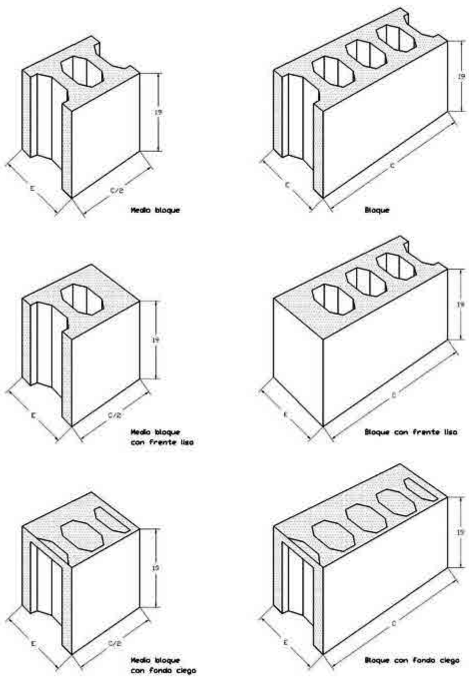


Fig. 29. Hollow Blocks. Designs by Fernando Ripollés.

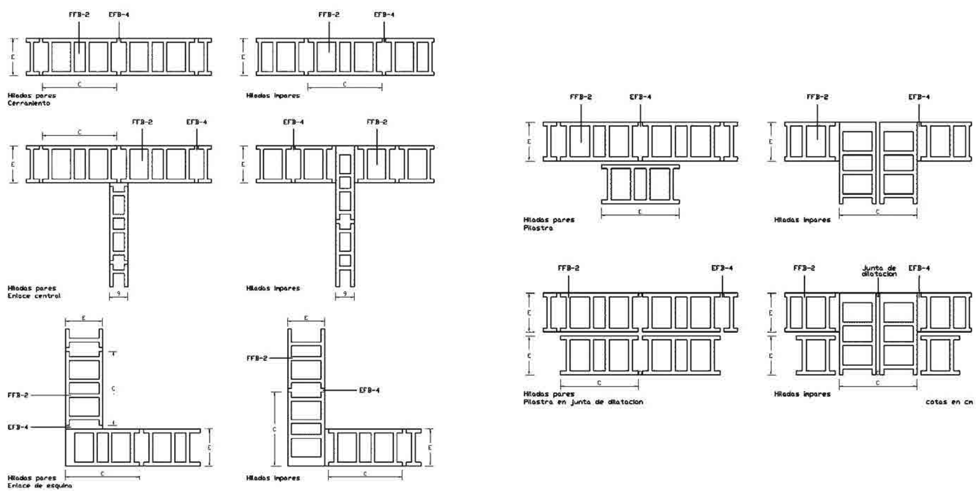


Fig. 30. Designs by Fernando Ripollés.

FASTENINGS AND JOINTS

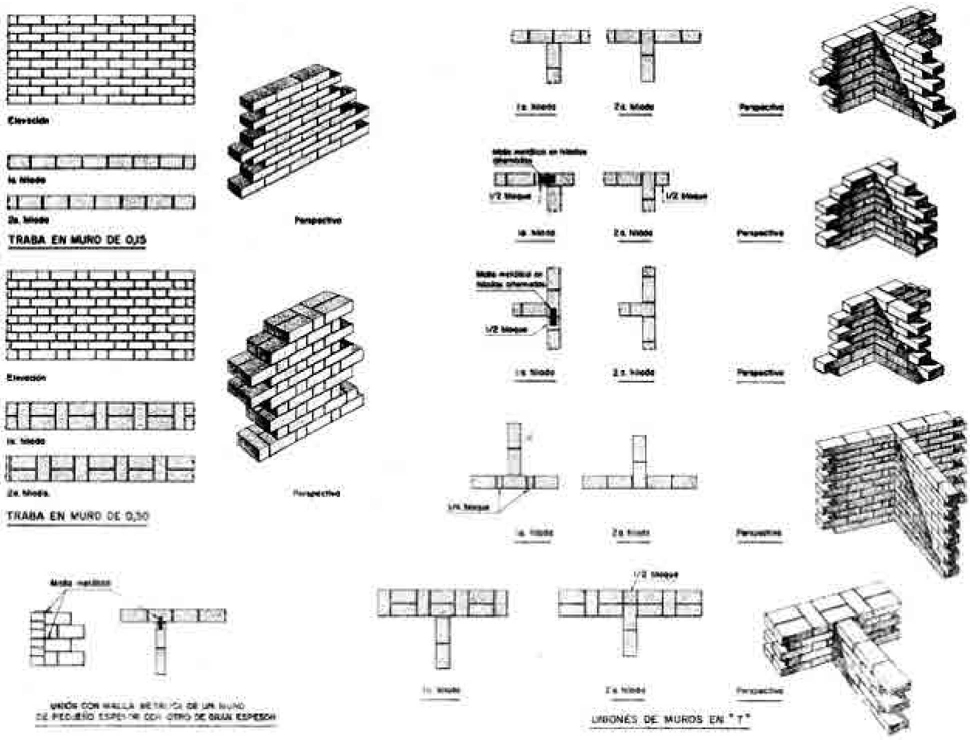


Fig. 31. Designs by Fernando Ripollés.

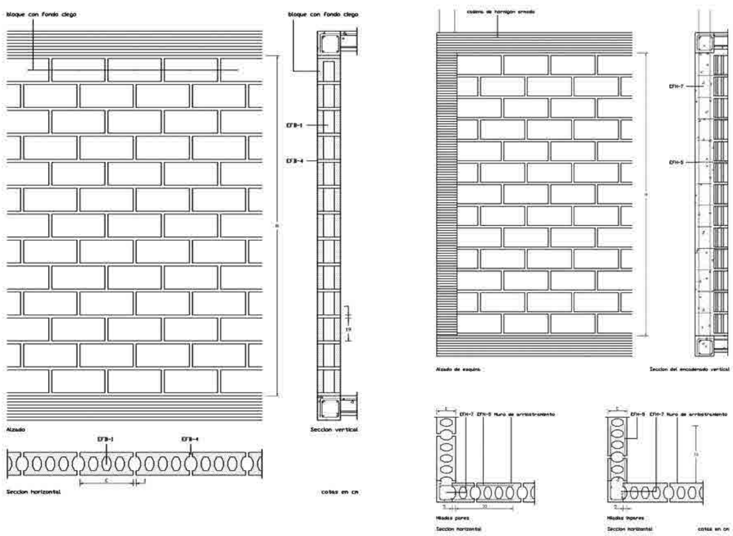


Fig. 32. Hollow blocks masonry brickwork and corner joint. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

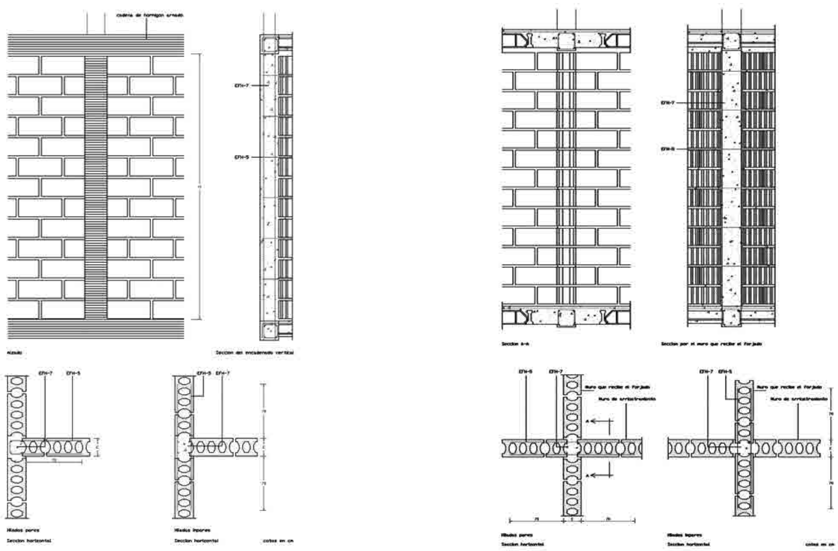


Fig. 33. On the left: Single connection with hollow blocks.
On the right: Double connection with hollow blocks.
Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

PRE-CAST CONCRETE STRUCTURES

– CHARACTERISTICS:
  · Each union of elements is a gasket.

– ADVANTAGES:
  · Economy of moulds;
  · Concreting and factory curing;
  · Control of materials;
  · Quick assembly;
  · Quality control.

– DISADVANTAGES:
  · Transport difficulties (weight and dimensions);
  · Execution problems in unions and joints.

«ON-SITE» FABRICATED REINFORCED CONCRETE STRUCTURES

They are active constructive elements from a mecanical point of view.
Resistance and stability is required:
  · Resistance in order to support their own weight and the vertical loads (compression and bending stresses).
  · Stability to support horizontal loads and horizontal pressures from wind and seismic activity.

Fig. 34. Photos by Alfonso García Santos.

1. Material:
  · Compound material based on a hydraulic porous matrix reinforced with steel;
  · Analogous expansion coefficients between components;
  · Possible use of additives.
2. Vertical elements:
  · Piers or pillars.
3. Horizontal elements:
  · Beams.
4. Joints.

MAIN TYPES:
  · Formworks
  · Props And Scaffolding

PROPERTIES:

- · Removable. Lightweight
- · Loading Process
- · Long-term Risk of Overtemperature
- · Inspection

FORMWORK:

Mould formed with boards or metal plates to which the concrete is poured until it forges. After that, the mould is disassembled.

Fig. 35. Photos by Alfonso García Santos.

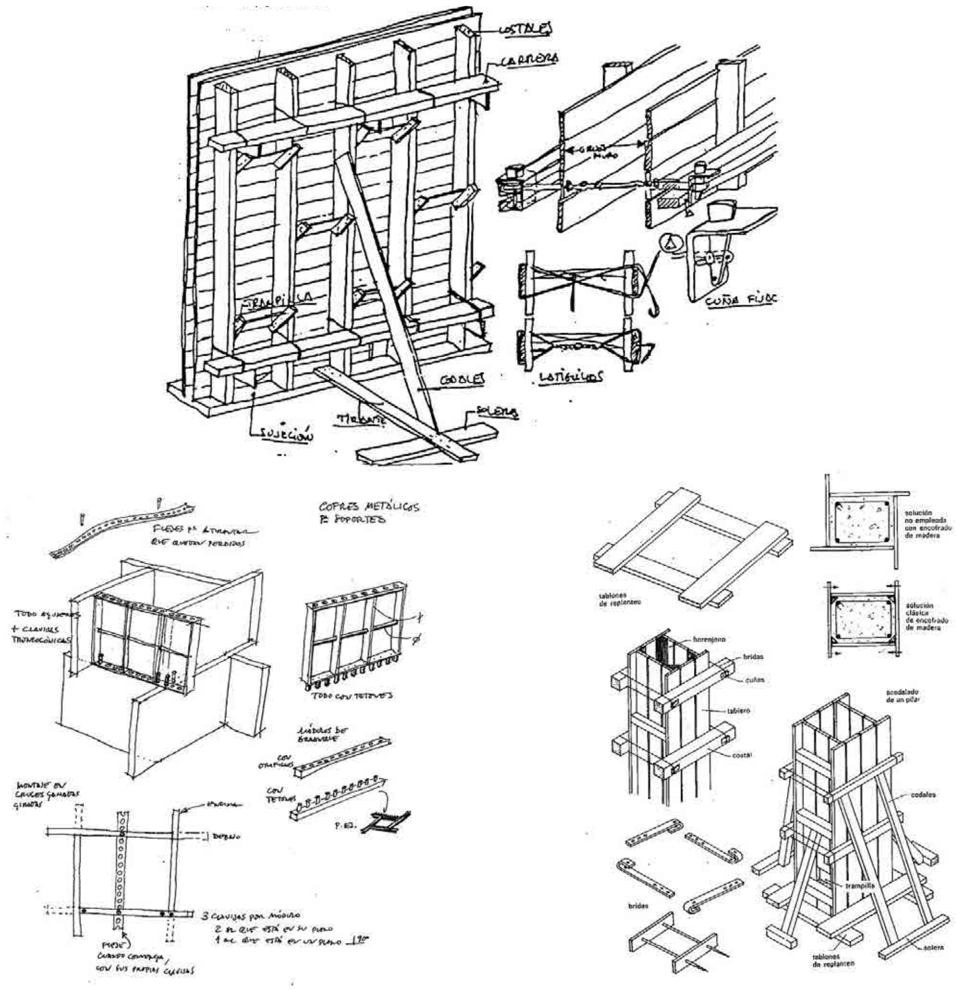
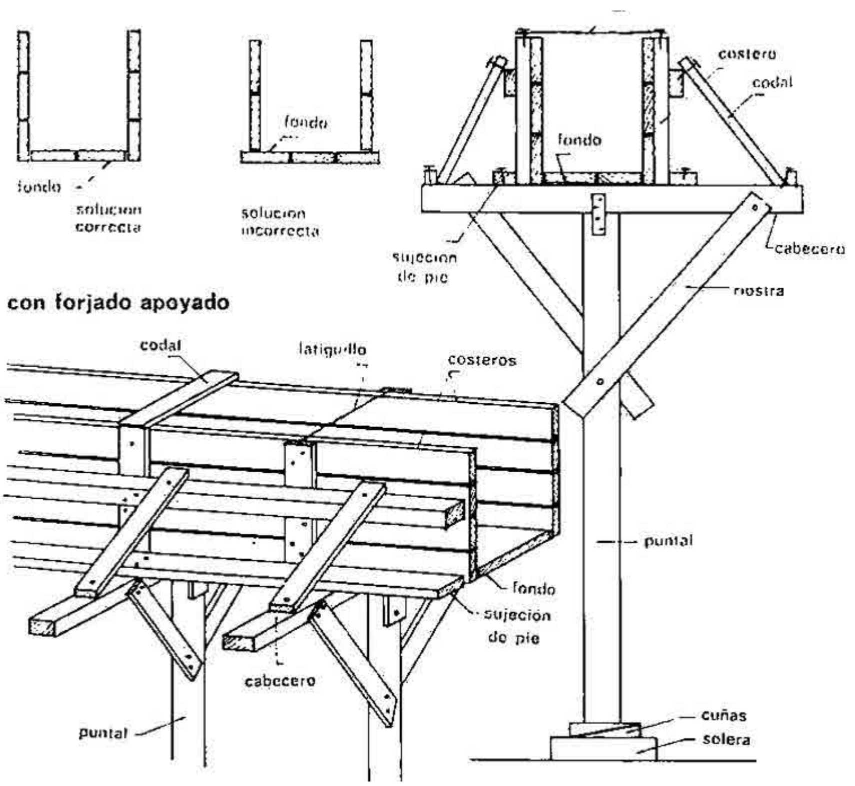
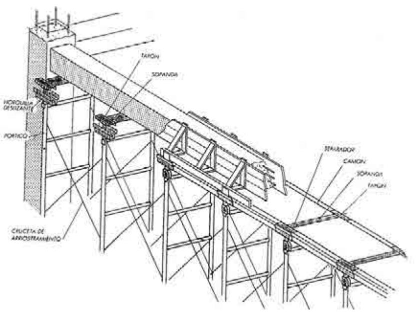


Fig. 36. Designs by Fernando Ripollés.

AUXILIARY STRUCTURES FOR TEMPORARY USE





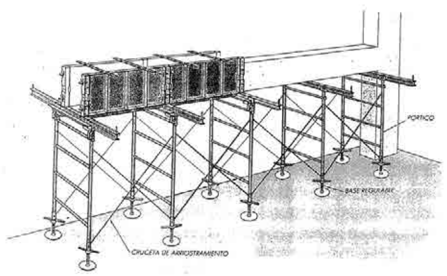
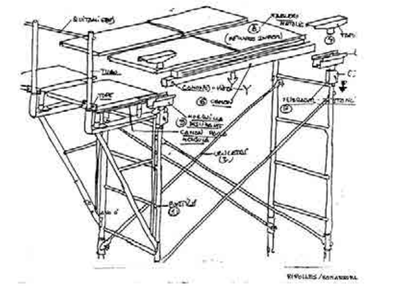


Fig. 37. Designs by Fernando Ripollés.

REUSABLE FORMWORKS



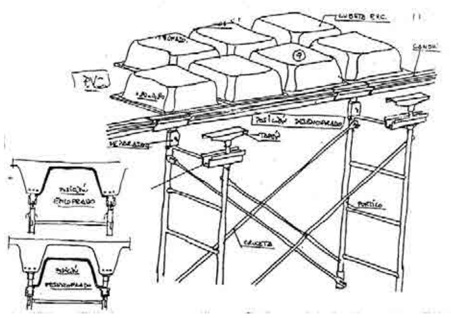


Fig. 38. Designs by Fernando Ripollés.

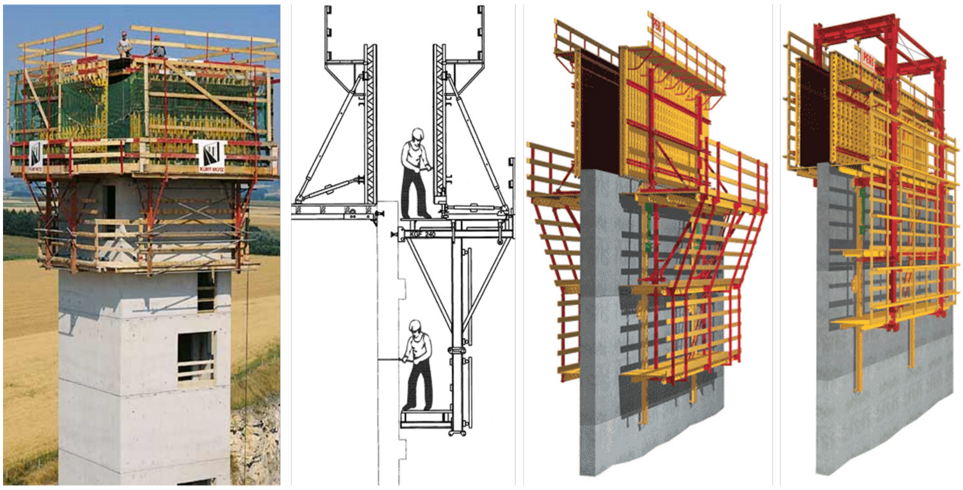


Fig. 39. Photos courtesy of Alfonso García Santos.

FALSEWORKS: Temporarily support parts of the building.

- · Metallic
    - - Steel props
    - - Aluminium props
- · Wooden

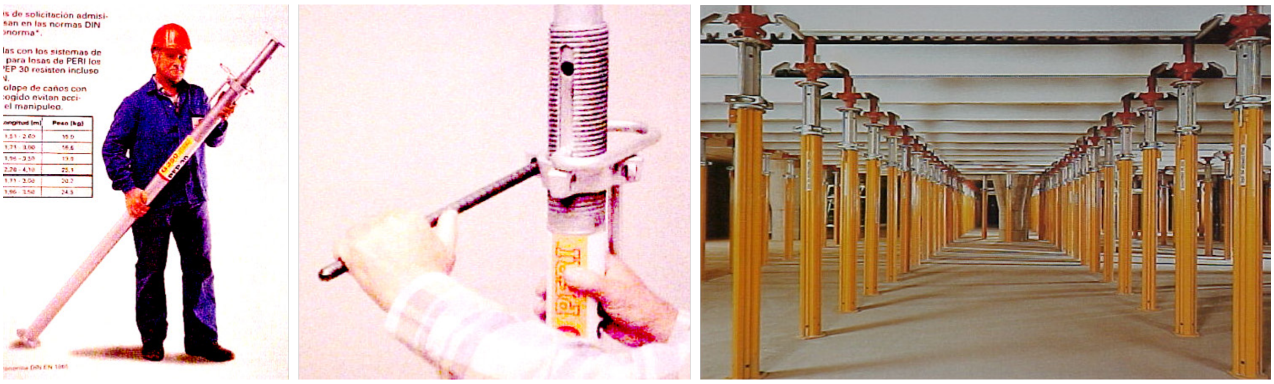


Fig. 40. Photos courtesy of Alfonso García Santos.

The Porous Load-Bearing System

- Reinforced concrete structures, fabricated «on-site» and precast.

- Execution process.

- Auxiliary structures for temporary use: workforms. Scaffolding.

«ON-SITE» FABRICATED REINFORCED CONCRETE STRUCTURES

REINFORCED CONCRETE STRUCTURES

- They are active constructive elements from a mecanical point of view. Resistance and stability is required:

· Resistance in order to support their own weight and the vertical loads (compression and bending stresses).

· Stability to support horizontal loads and horizontal pressures from wind and seismic activity.

1. Material.

- Compound material based on a hydraulic porous matrix reinforced with steel.
- Analogous expansion coefficients between components.
- Possible use of additives.

2. Vertical Elements: Piers or Pillars.

3. Horizontal Elements: Beams.

4. Joints.

PILLAR REINFORCEMENT

– Longitudinal:
  · They absorb compressive and possibly tensile stresses;
  · The cover serves to promote solidity of the work and prevent corrosion of the steel.
  Minimun number of reinforcements:
    - 4 in square section pillars;
    - 6 in round section pillars.
– Transverse:
  · Tie bars;
  · They create a cage of sufficient rigidity to allow them to be moved and put on site;
  · They are closed and sometimes helical;
  · They reduce buckling;
  · They cooperate in the absorption of shear forces.

TYPES OF PILLARS

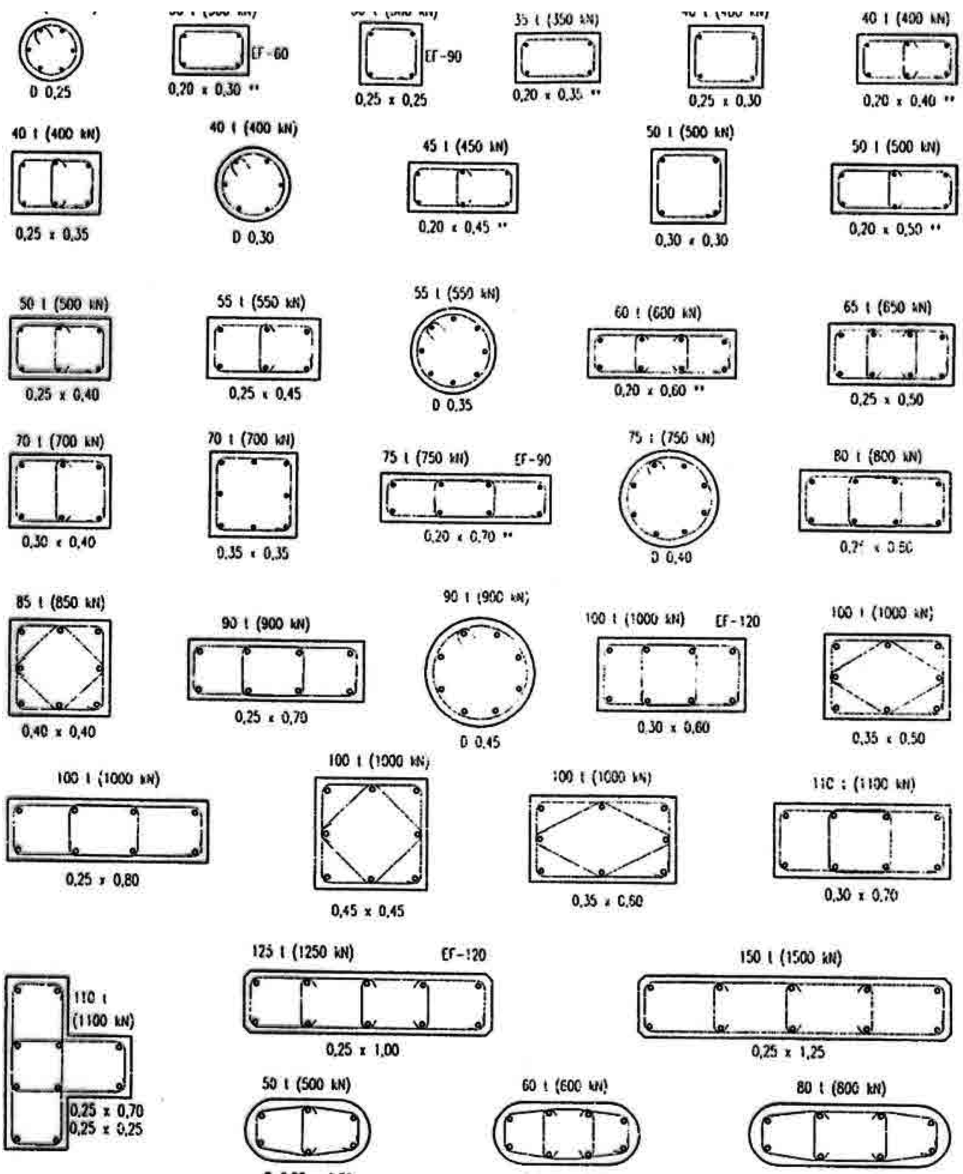


Fig. 41. Designs by Fernando Ripollés and Susana Mora.

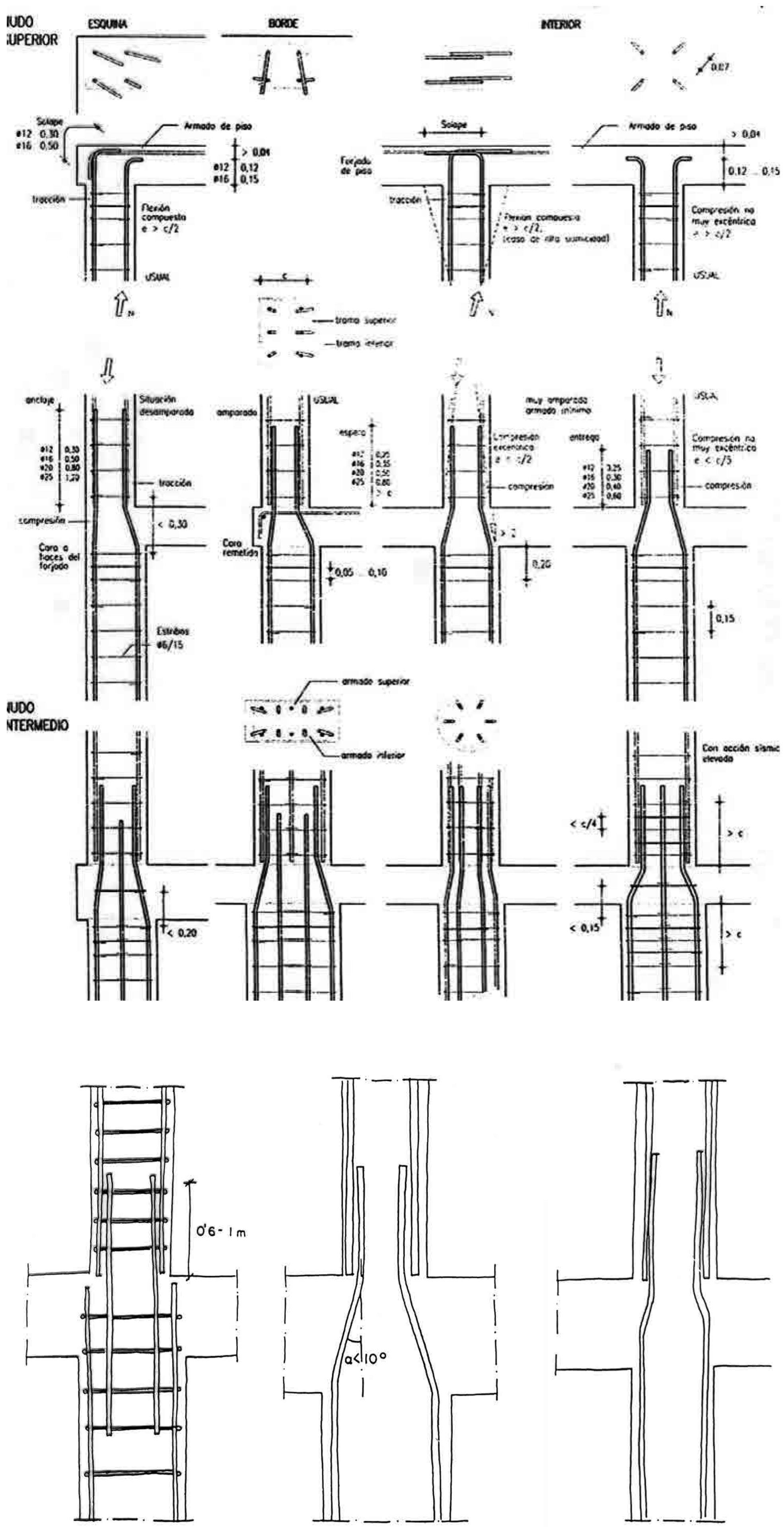


Fig. 42. Designs by Susana Mora. Also in NTE (Normas Tecnológicas de la Edificación).

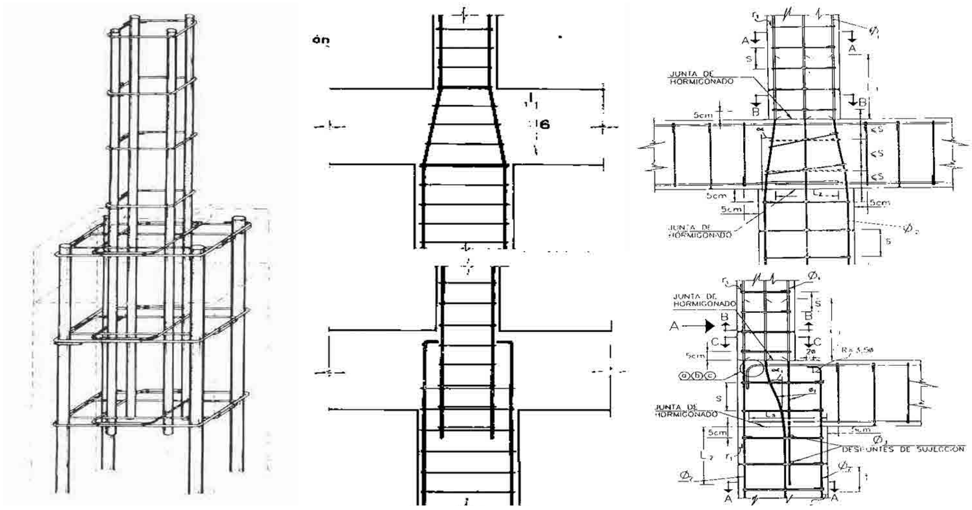


Fig. 43. Changes of section. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

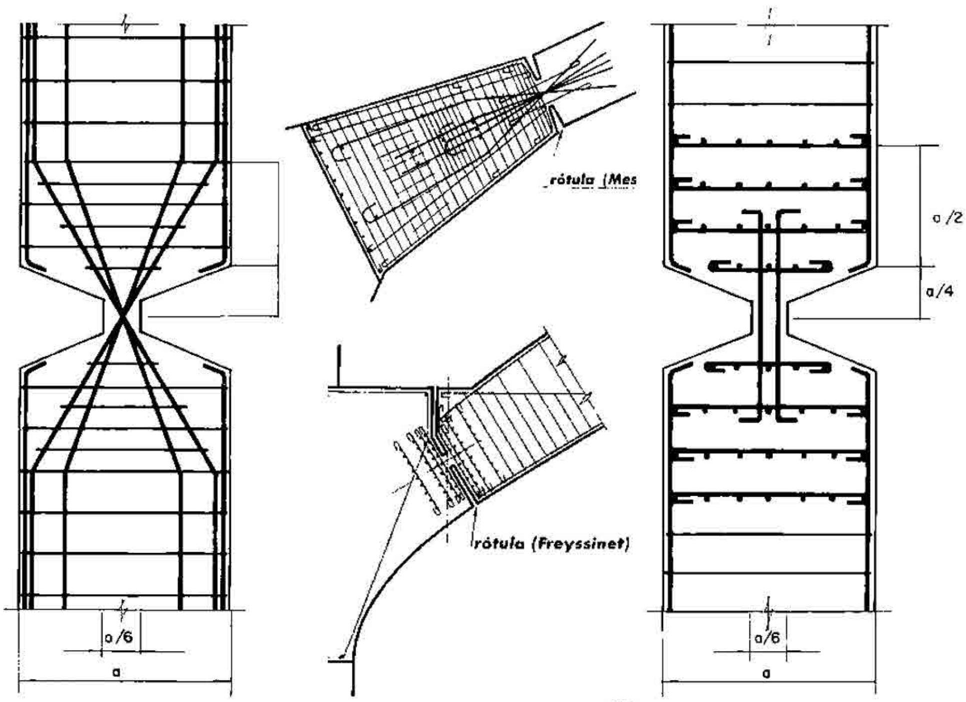


Fig. 44. Articulations. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

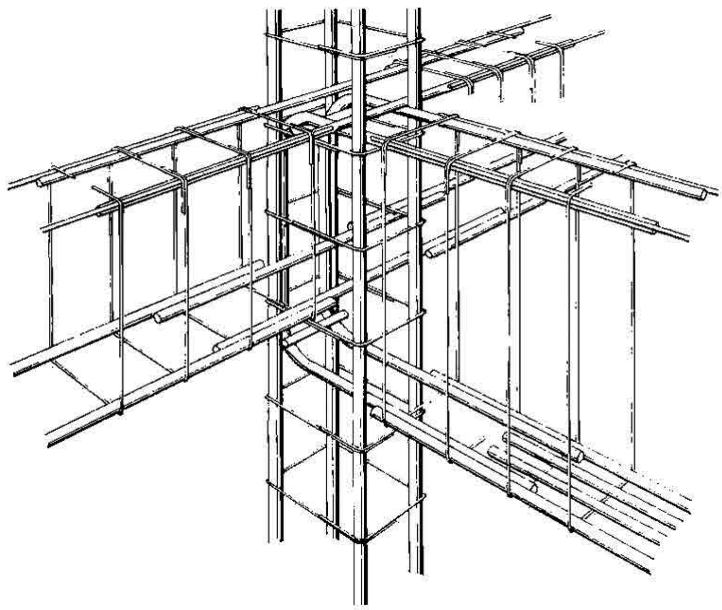


Fig. 45. Pillar and beams connection. From F. Casinello, *Hormigonería*, Reverte, 1996, Madrid.

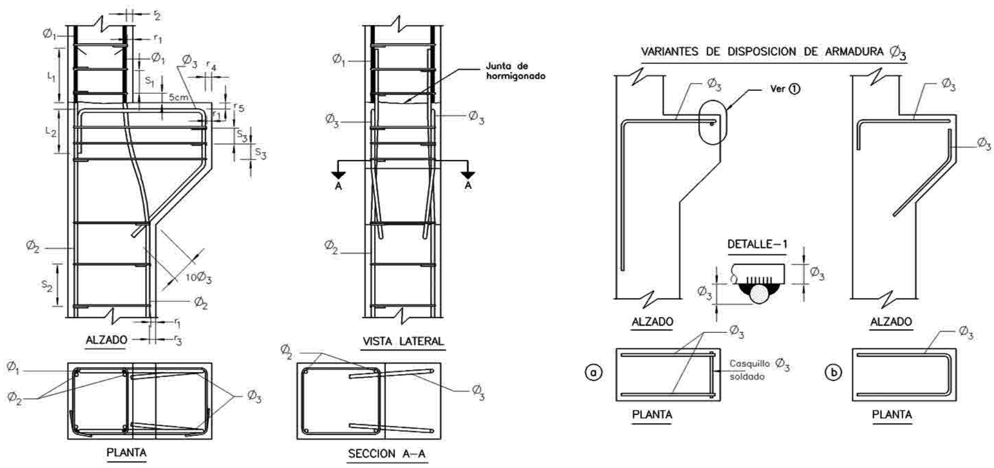


Fig. 46. Expansion joints. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

BEAMS

- Upper Reinforcement
- Lower Reinforcement
- Shear Reinforcement

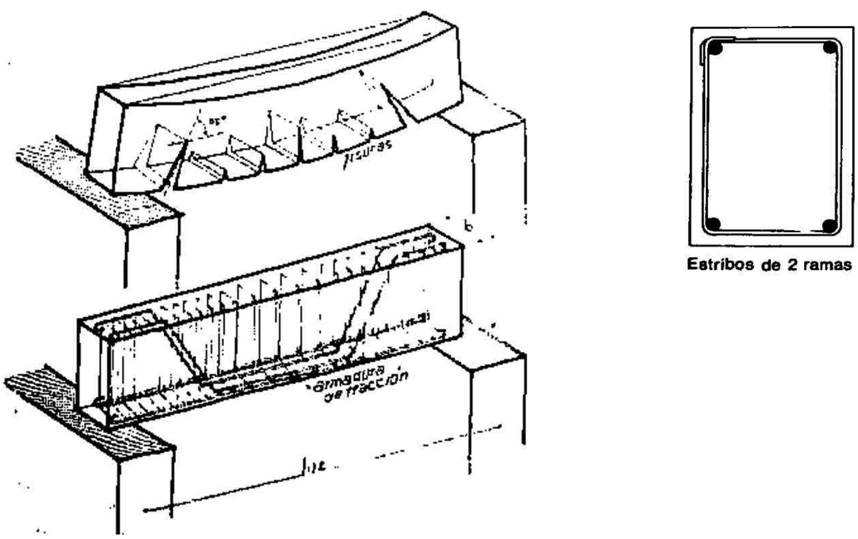


Fig. 47. Designs by Fernando Ripollés.

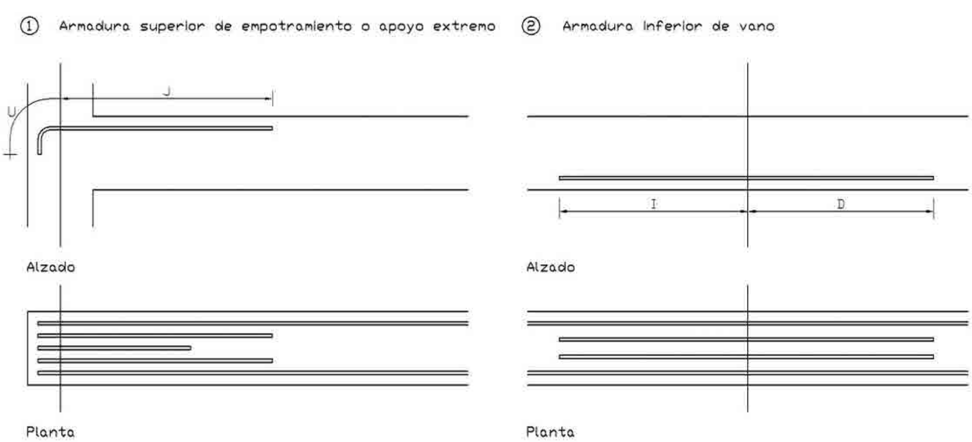


Fig. 48. Longitudinal reinforcement for beams. Designs by Fernando Ripollés. Also in NTE (Normas Tecnológicas de la Edificación).

EXECUTION PROCESS

Setting Out:

· Setting out of the pillar giving references to previously fixed points.
· Placement of the formwork. Plumb alignment checking.

On-site:

· Placement of reinforcement. Cover.
· Pouring of the concrete from a low height.
· Concreting by layers, usually three, so that it consolidate correctly.
· Consolidation methods: punching, ramming and vibration.
· Apply more energy in the last layer.

Fig. 49. Design by Fernando Ripollés and photos by Celia Barahona.

AUXILIARY STRUCTURES

– Main types:
  · Formworks
  · Props and scaffolding
– Properties
  · Removable.Lightweight
  · Loading process
  · Long-term risk of overtemperature
  · Inspection

FORMWORKS

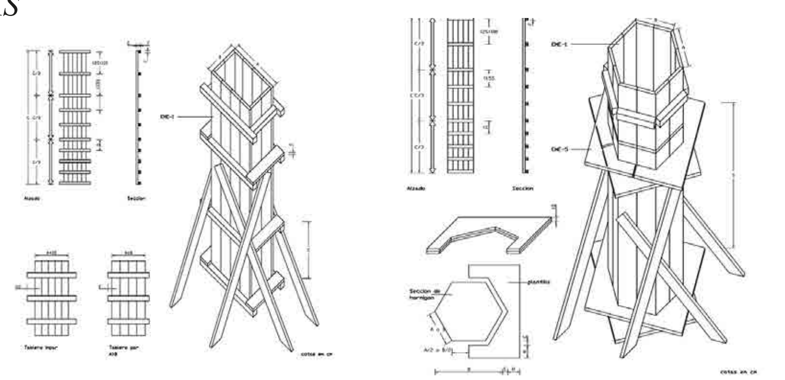
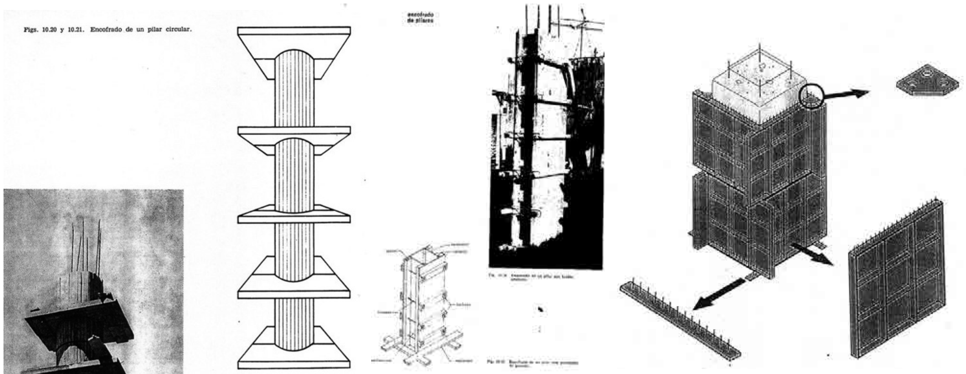


Fig. 50. Four sides formwork, Multiple sides formwork. Designs by Fernando Ripollés.



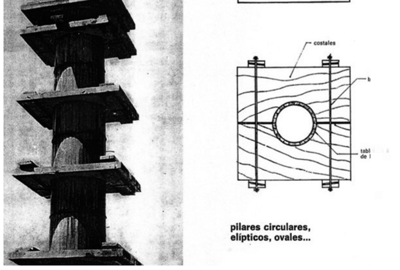


Fig. 51. Designs by Fernando Ripollés.

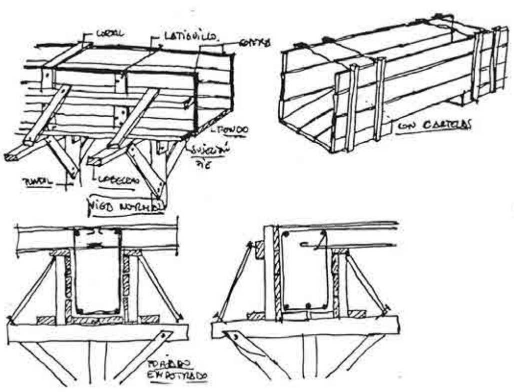


Fig. 52. Designs by Pedro Galindo.

FALSEWORKS

Temporarily support parts of the building
  · Metallic
    - Steel props
    - Aluminium props
  · Wooden

Fig. 53. Designs by Susana Mora.

PRE-CAST CONCRETE STRUCTURES

– Characteristics.
  Each union of elements is a gasket.

– Advantages:
  Economy of moulds;
  Concreting and factory curing;
  Control of materials;
  Quick assembly;
  Quality control.

– Disadvantages:
  Transport difficulties (weight and dimensions);
  Execution problems in unions and joints.

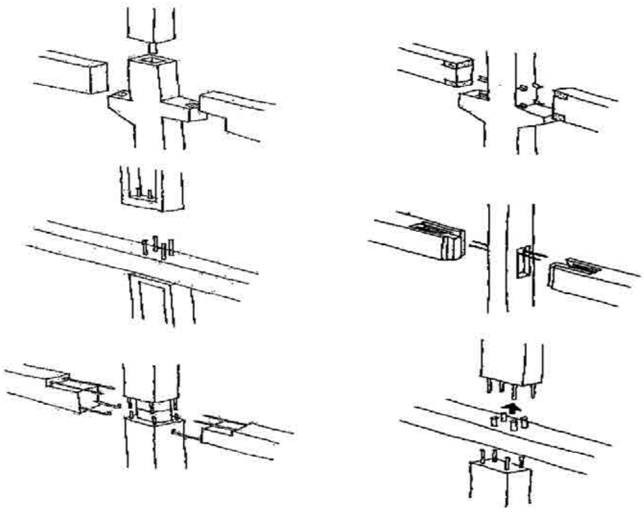
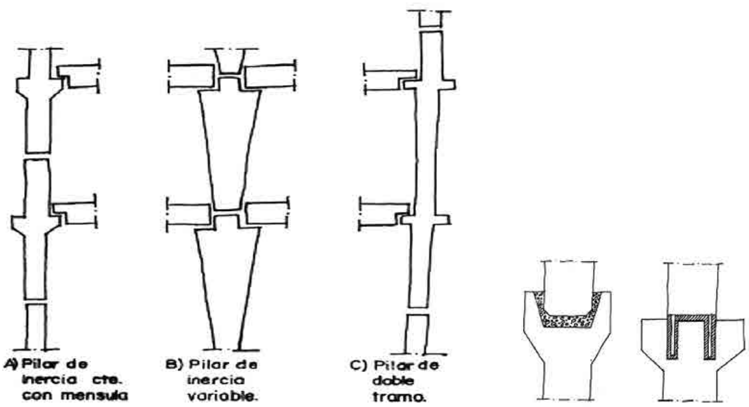


Fig. 54. Designs by Fernando Ripollés.

TYPES OF JOINTS



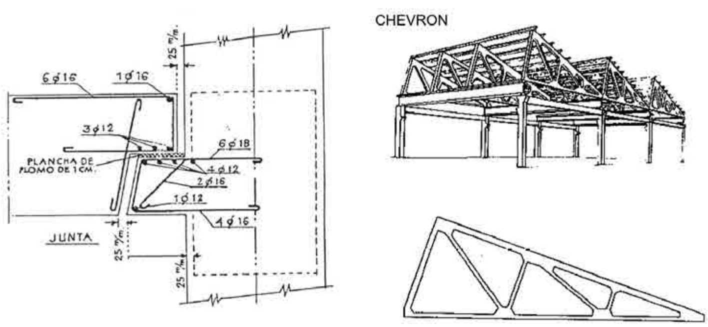


Fig. 55. Precast beams. Designs by Fernando Ripollés.

THE COMPACT LOADBEARING SYSTEM: INDEX

– Steel reticular structures. (5)

– Light structural systems.

– The joining system: welding and screwing. Criteria for use. Methods and execution process. Execution process. Quality control. Penetrating liquids, ultrasound, X-rays.

METALLURGY COMPANIES MANUFACTURE PRODUCTS

Laminated | Conformed | Hollow Profiles and Screws

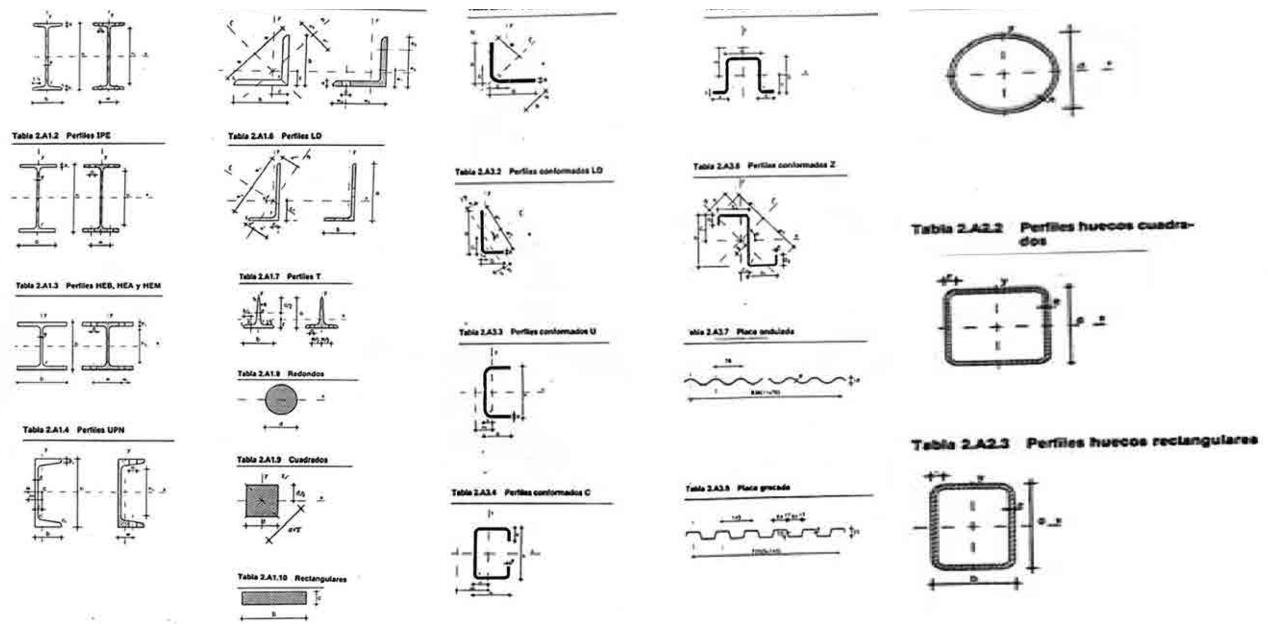


Fig. 56. Designs by Fernando Ripollés. Also in Prontuario Ensidesa, Bilbao 1978.

Metallurgy companies publish compendiums containing the following data:
· Section Area
· Modulus of Toughness
· Radius of gyration
· Weight per linear metre
· Profile's span a function of load and permissible deflection
· Diameter of bolts and rivets and boring lines.

In this type of structures the following issues must be taken into account:
· Continuity, by means of through bars, crosses, etc.
· Clutches, by means of bushes and linings.
· Movement limitations, by means of reinforcements.
· The stiffening, by means of plates.
· Lightning effects, by means of the Faraday cage, earth connection.
· Effects of the electric current:
  - Telluric derivation
  - Earth connection
  - Sacrificial anodes.
· Corrosion, by means of intumescent paint, internal cooling.

TYPOLOGY

A. REMOVABLE OR DEMOUNTABLE SYSTEM ("AMERICAN" SYSTEM)
B. NON REMOVABLE SYSTEM ("EUROPEAN" SYSTEM)

A. REMOVABLE OR DEMOUNTABLE SYSTEM ("AMERICAN" SYSTEM)

– Articulated systems.
– Quite frequently used. The bars are joined with a simple fastener.
– There are two types of fasteners:
  · HIGH-STRENGTH BOLTS
  · SCREWS

ADVANTAGES:

– It allows small turns in the bases.
– The bars only work with traction or compression stress.
– Easy and quick assembly.
– Easy maintenance.

DISADVANTAGES:

– It does not transfer moments.
– Danger of total collapse due to breakage of a single fastener.
– It requires of gradual and meticulous control.

B. NON REMOVABLE SYSTEM ("EUROPEAN" SYSTEM)

– Rigid and semi-rigid systems

a. WITH RIVETS. Semi-rigid knots. The bars are joined directly with rivets or through distribution plates, trying to achieve the maximum possible rigidity.

ADVANTAGES:

– Non-deformability.
– Transmission of side effects
– Admits the failure or breakage of some rivets.

DISADVANTAGES:

– Perforations weaken the piece.
– Requires larger sections , usually 4-15% heavier than articulated systems.
– Requires gusset plates, linings, etc.
– Inequality in the way the rivets work, increasing damages in the vicinity of the knot or joint.

b. WITH WELDING: Rigid knots. This is a direct, very economical, corrosion-resistant joint, which make it possible to obtain smooth surfaces without weakening holes and which allows sections to be easily reinforced.

ADVANTAGES:

- Rapidity
- Accuracy
- Neatness at the junction
- Quiet execution process

DISADVANTAGES:

- High tech
- Highly skilled workforce
- Very severe work control

PROCEDURES:

- Alloy Welding:

A different metal or alloy that forms an alloy with the former is interposed on the surface of the joint.

- Fusion Welding (autogenous):

A same nature metal is interposed so that when the parts in contact are melted, the matter of one is mixed with that of the other, with the pieces forming a unique whole, after cooling.

TYPES:

- Oxy-fuel Welding (oxyacetylene):

Alloy welding. Normally, the filler metal is a pure metal or an alloy with a fixed composition. It uses fuel gases and oxygen to weld and cut metals. Oxyacetylene is the most commonly used type of torch.

- Electric Welding:

The most commonly used system is the electric arc. This procedure causes an electric arc between the piece that carries out the welding and an electrode that constitutes the material of contribution. The developed heat produces the fusion of the electrode that deposits a bead of melted material in the joint to be welded, called the welding bead.

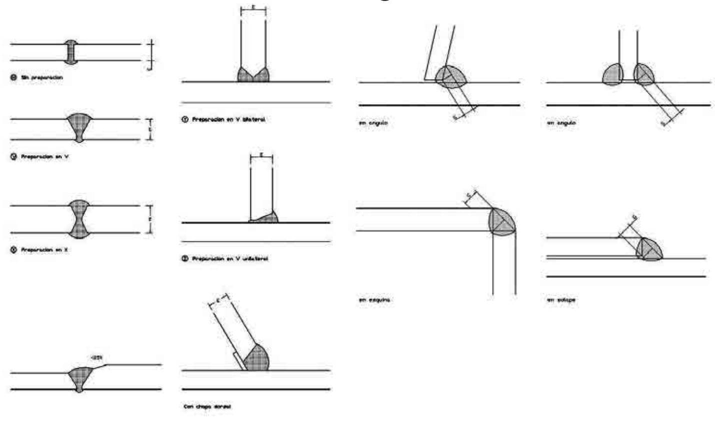
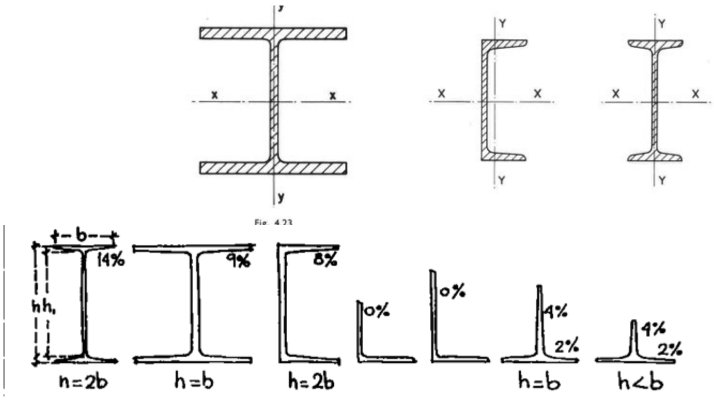


Fig. 57. Steel structures. Welding. Designs by Fernando Ripollés.

LAMINATED STEEL STRUCTURES. PIERS

– Simple:



– Compound Pillars:

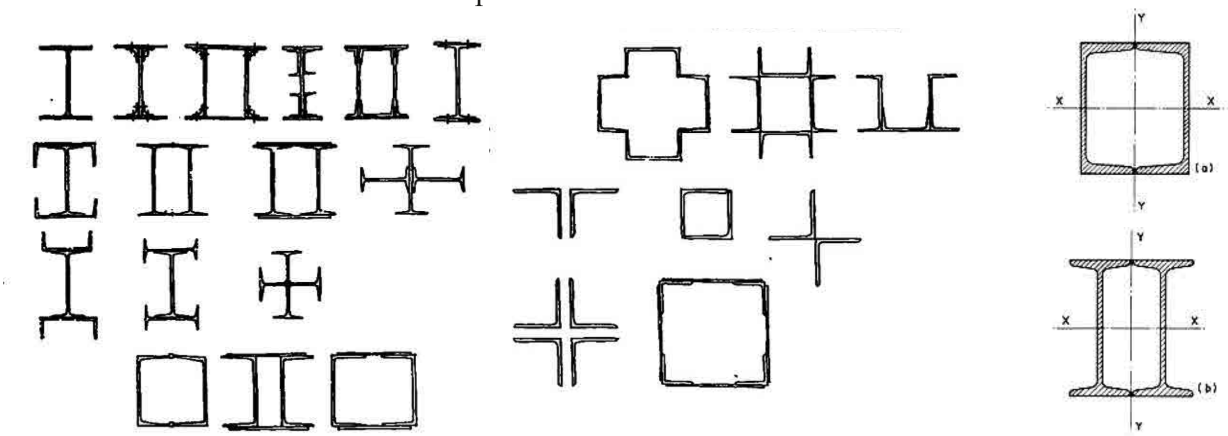


Fig. 58. Designs by Fernando Ripollés and Susana Mora. Also in Prontuario Ensidesa, Bilbao 1978.

– Staples Compound Pillars:

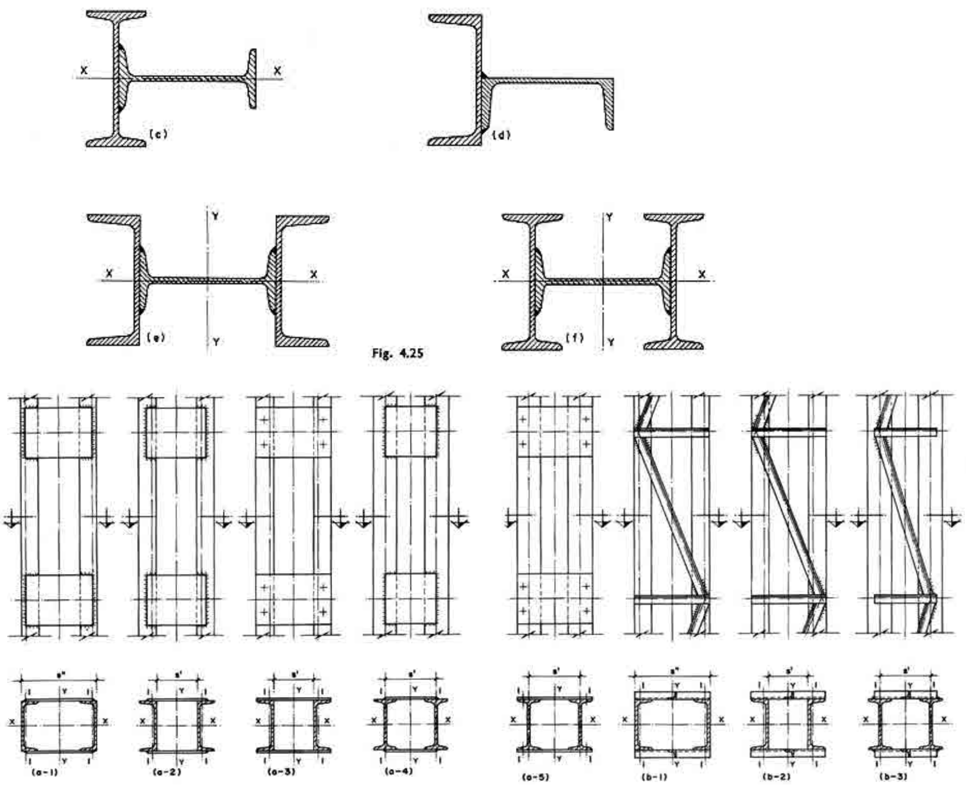


Fig. 59. Designs by Fernando Ripollés. Also in Prontuario Ensidesa, Bilbao 1978.

PLATES AND ANCHORS

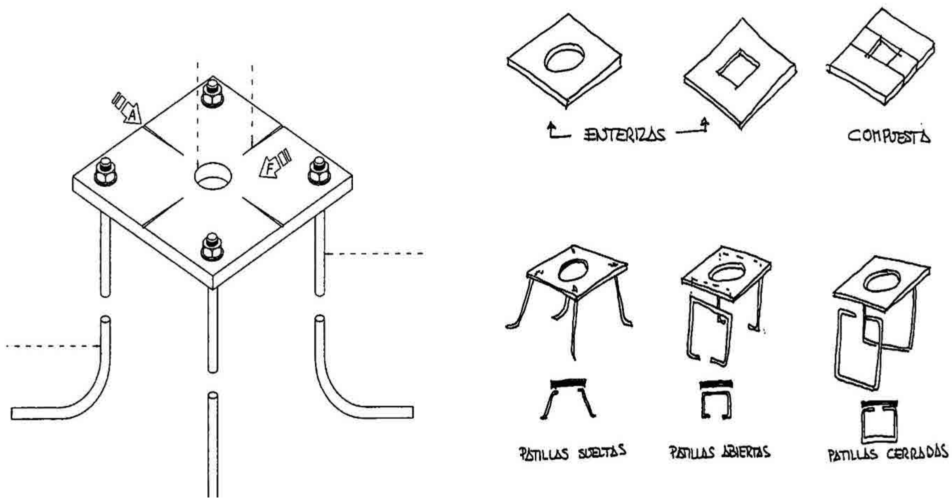


Fig. 60. Designs by Fernando Ripollés.

STEEL STRUCTURES. PLATES

Reinforced:

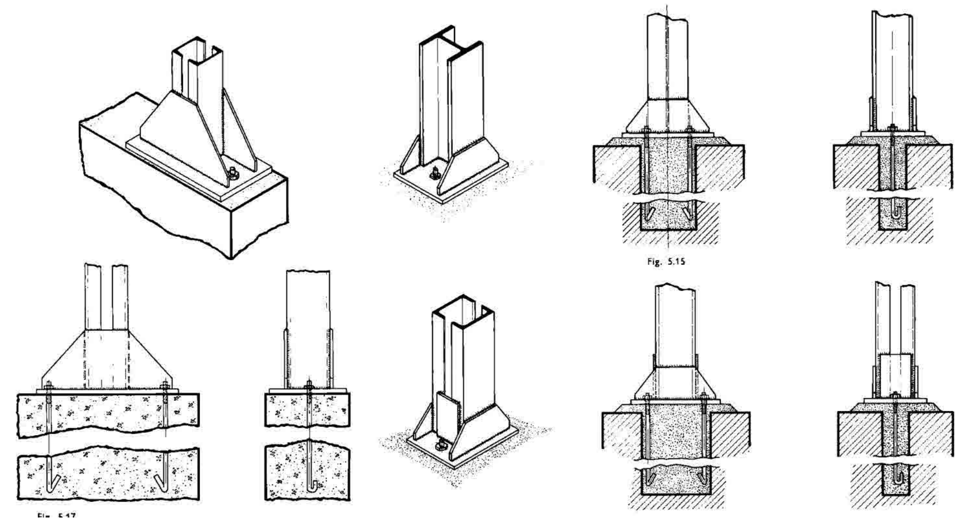


Fig. 61. Designs by Fernando Ripollés.

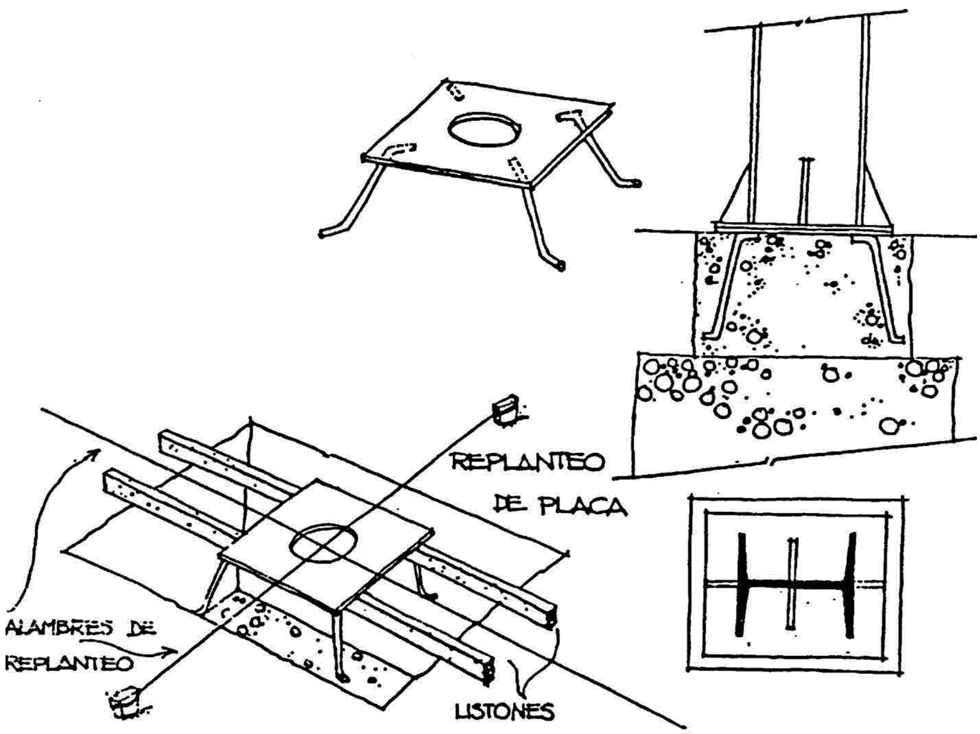


Fig. 62. Designs by Fernando Ripollés.

A. SUPPORT ALLOWING EXPANSION

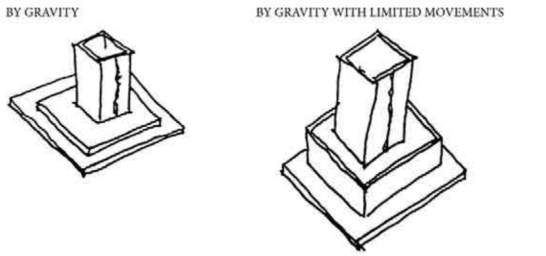
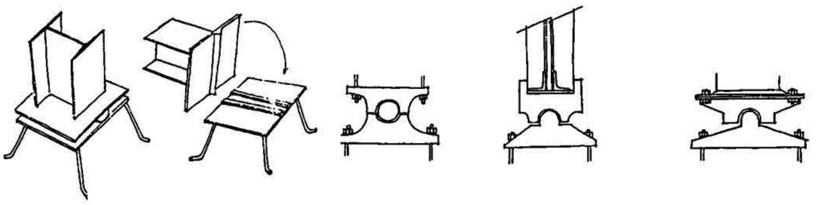


Fig. 63. Designs by Fernando Ripollés.

B. HINGED SUPPORT



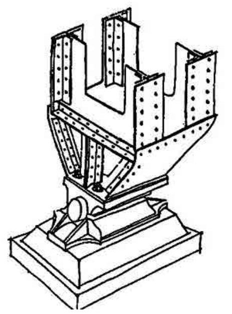
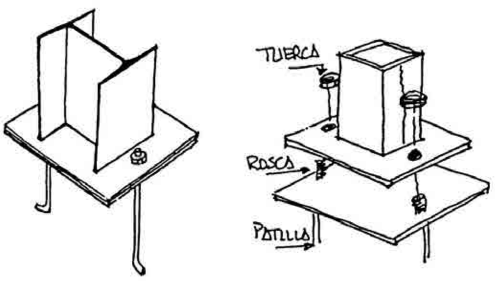
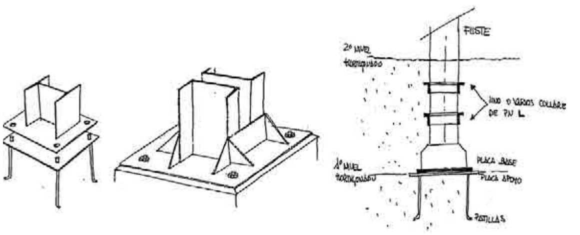


Fig. 64. Designs by Fernando Ripollés.

C. HALF-HINGED OR HALF-FIXED



D. FIXED SUPPORT



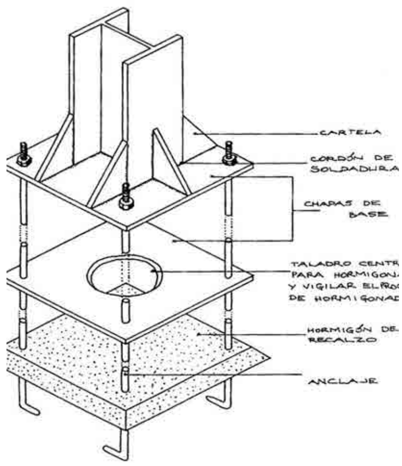


Fig. 65. Designs by Susana Mora.

PLATES FOR PIERS

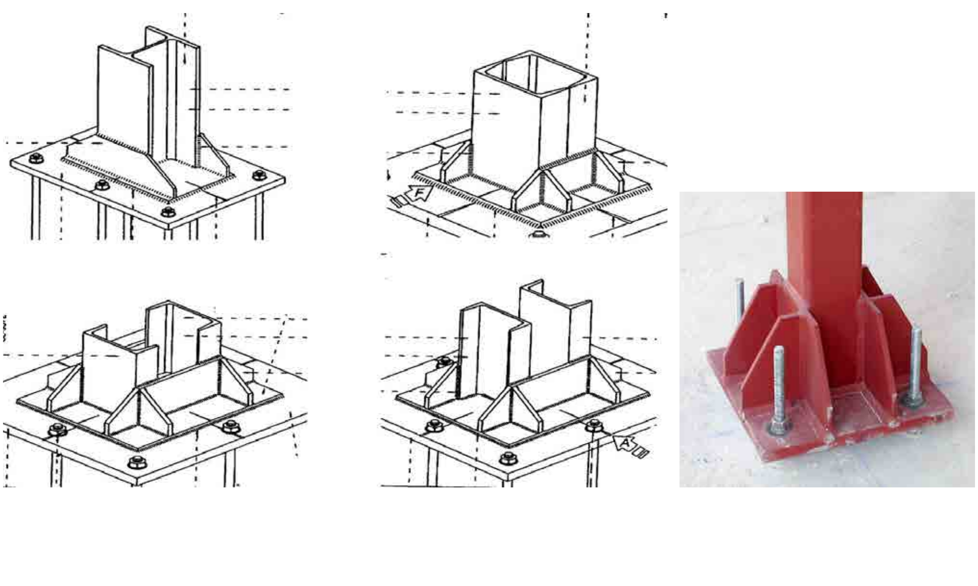


Fig. 66. Designs and photo by Fernando Ripollés.

PIERS CONNECTION

a. Continuos:

(6)

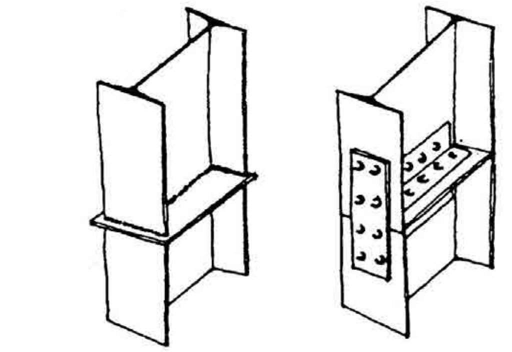


Fig. 67. Designs by Fernando Ripollés.

b. With change of section:

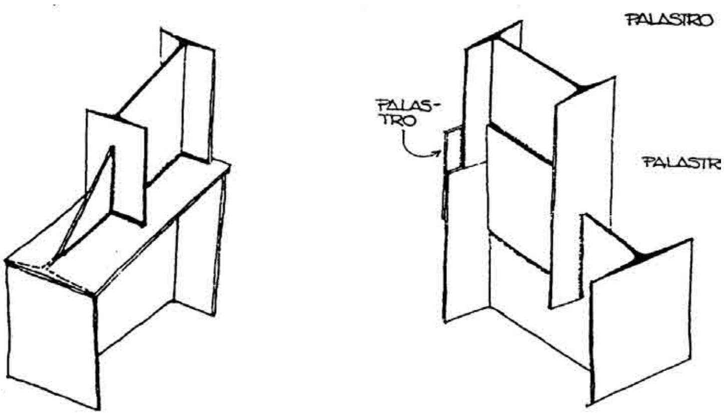


Fig. 68. Designs by Fernando Ripollés.

MAIN BEAMS

1. Simple profiles, continuous web
   I-H-U shapes

2. Compound profiles, thin walled beams
   Direct union
   Use of plates

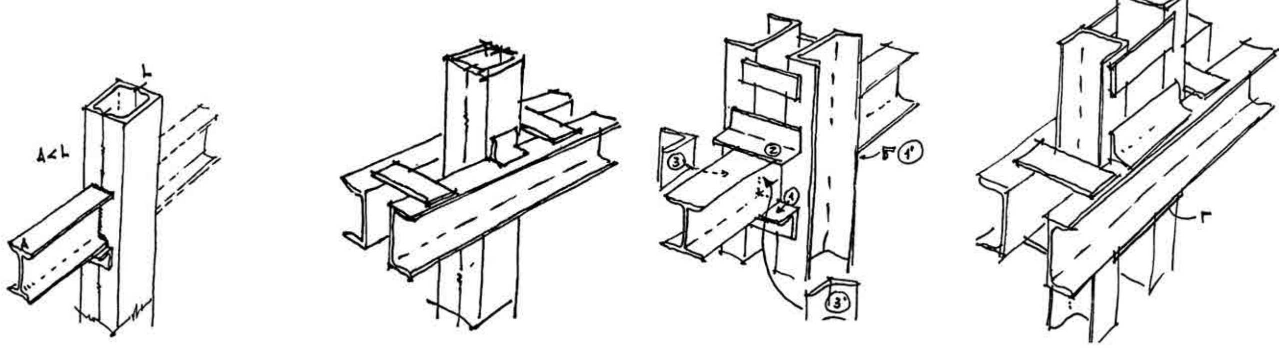


Fig. 69. Designs by Fernando Ripollés.

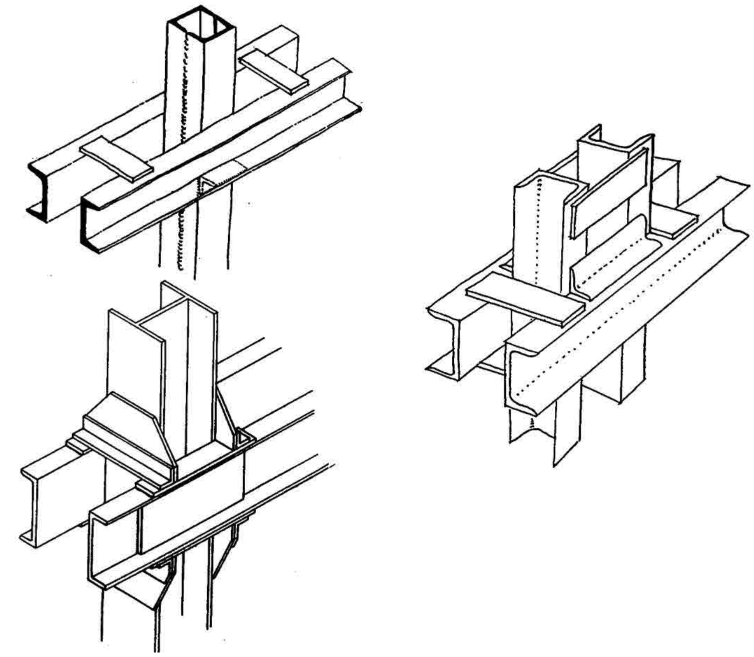


Fig. 70. Designs by Fernando Ripollés.

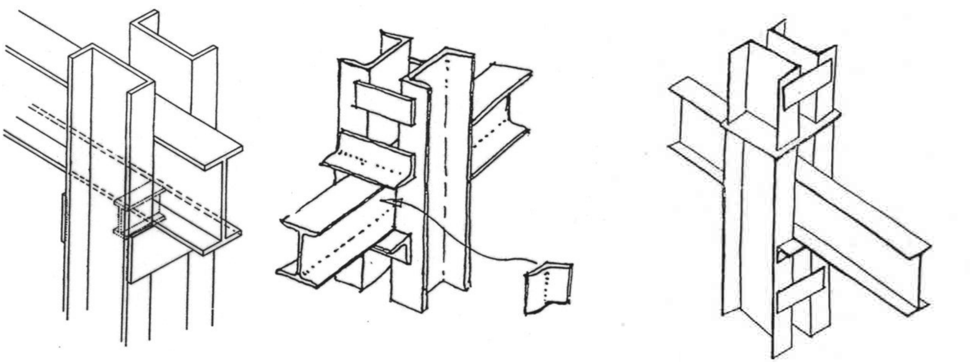


Fig. 71. Designs by Susana Mora.

STEEL STRUCTURES. BEAMS:

Pillar And Beam Unions

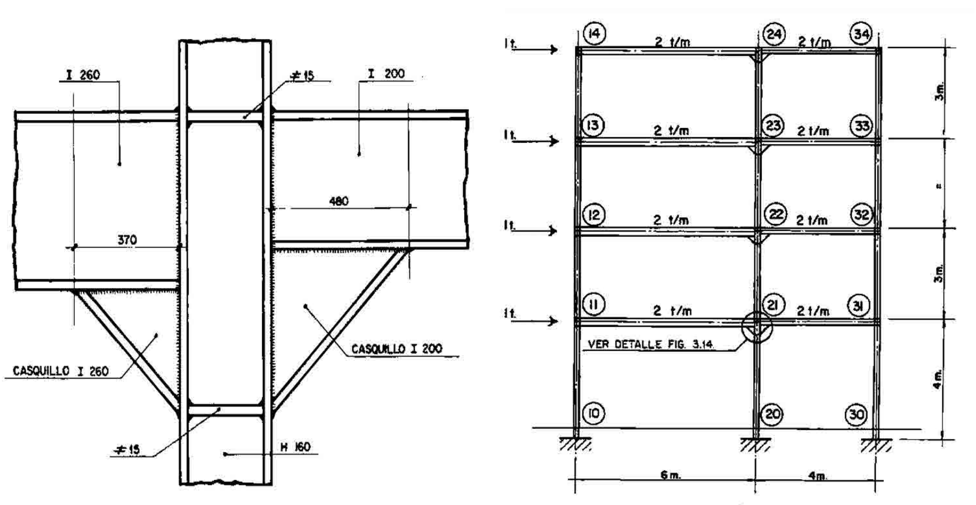


Fig. 72. In NTE ((Normas Tecnológicas de la Edificación).

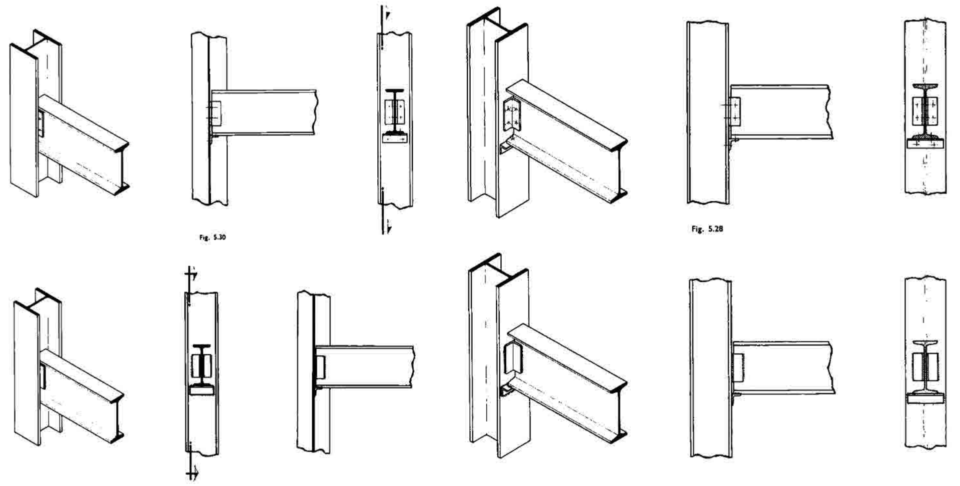


Fig. 73. In NTE (Normas Tecnológicas de la Edificación).

Continuous Beams

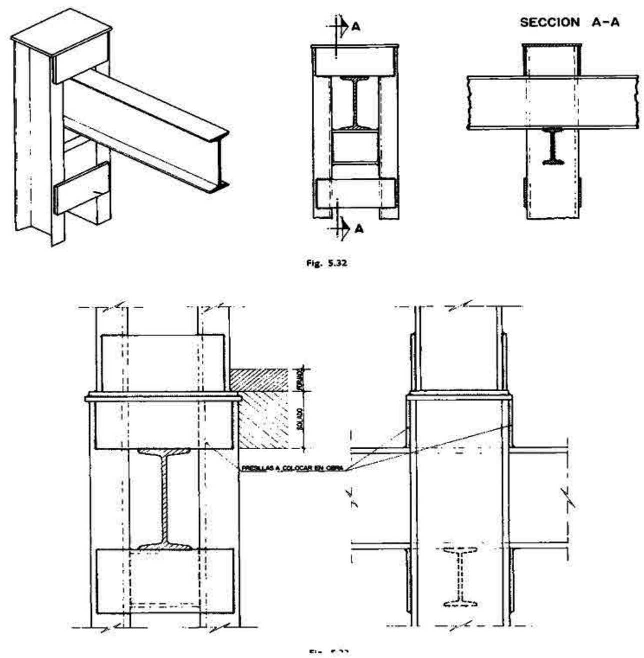


Fig. 74. Designs by Fernando Ripollés.

Hubs

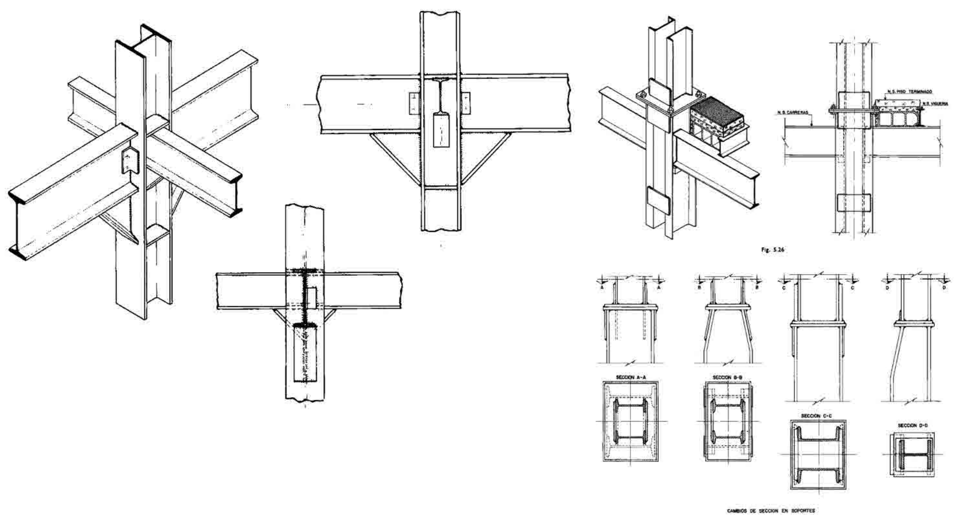


Fig. 75. Designs by Fernando Ripollés, from Prontuario Ensidesa.

Trimmer Joists

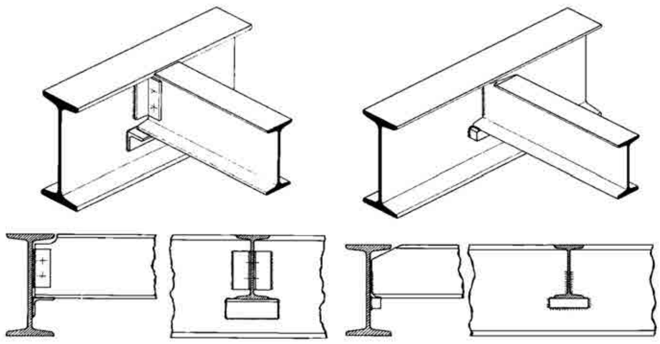
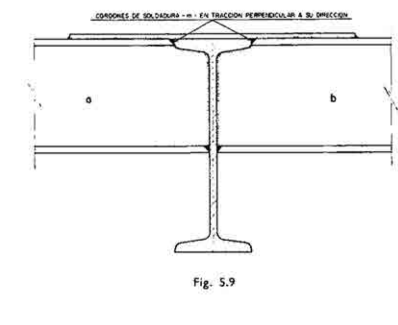


Fig. 76. Designs by Fernando Ripollés.

Fixed Union



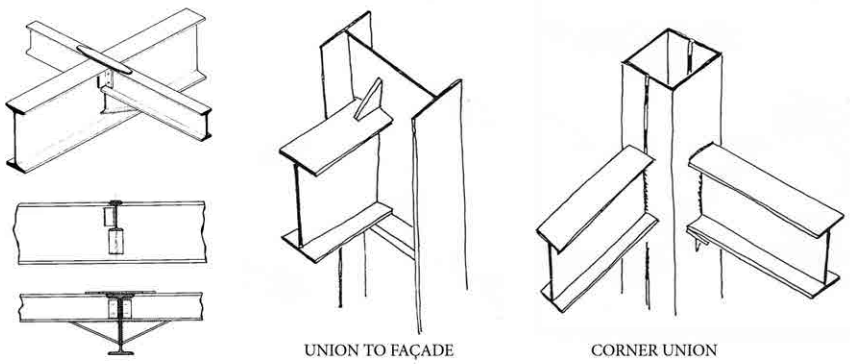


Fig. 77. Designs by Fernando Ripollés and Susana Mora.

Support:

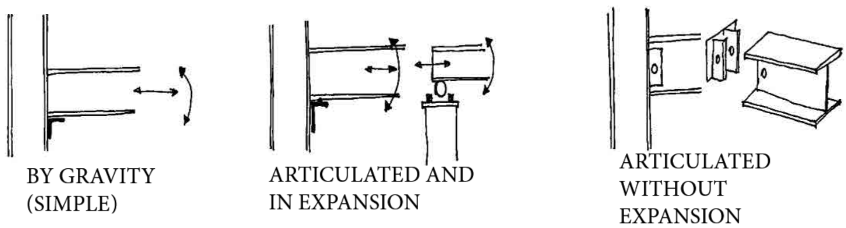


Fig. 78. Designs by Fernando Ripollés and Susana Mora.

Fixed Unions:

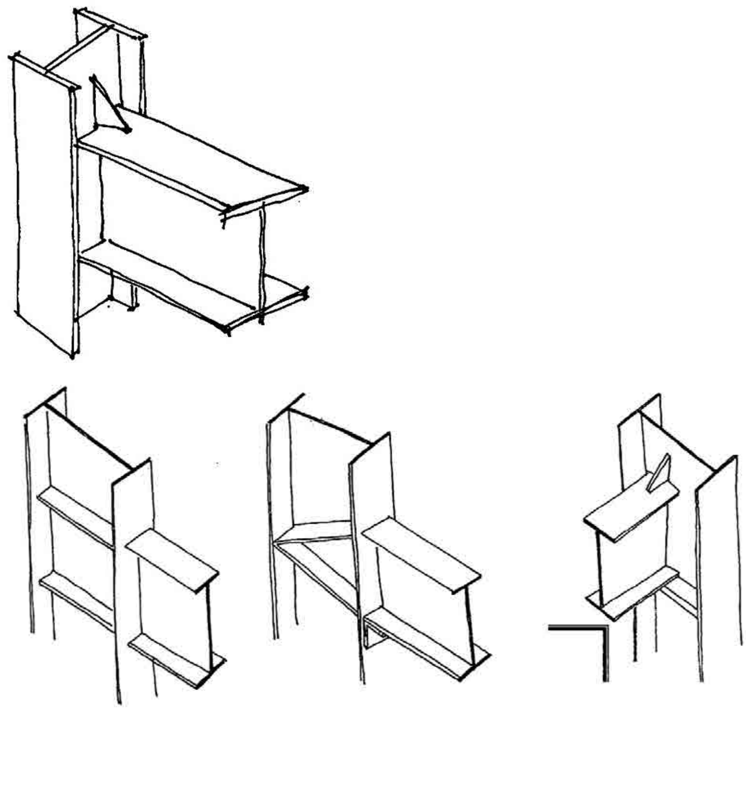


Fig. 79. Designs by Fernando Ripollés.

STEEL STRUCTURES. BEAMS. SUPPORTS

Support On Concrete:

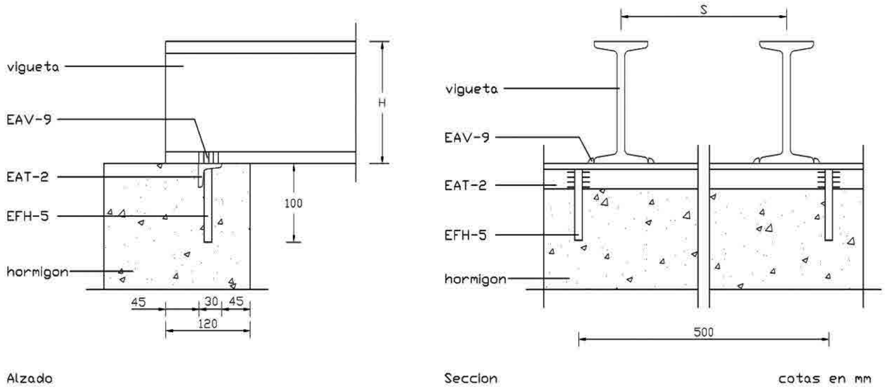


Fig. 80. In NTE (Normas Tecnológicas de la Edificación).

Support On Masonry Brickwork:

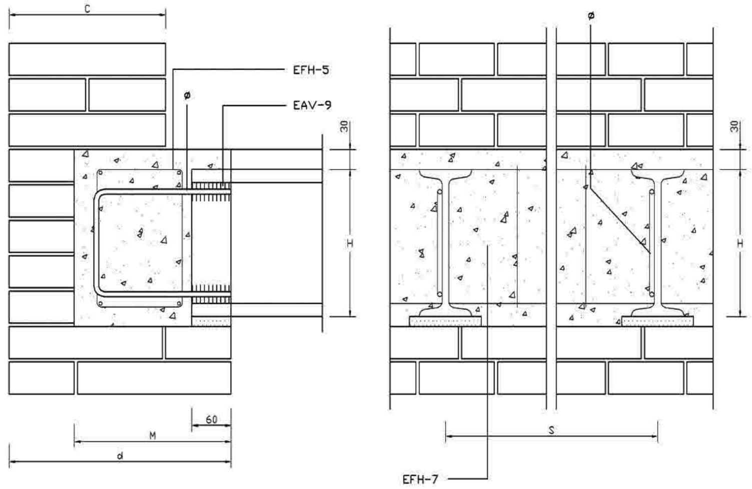


Fig. 81. In NTE (Normas Tecnológicas de la Edificación).

STEEL STRUCTURES. BRACING.

Bracing:

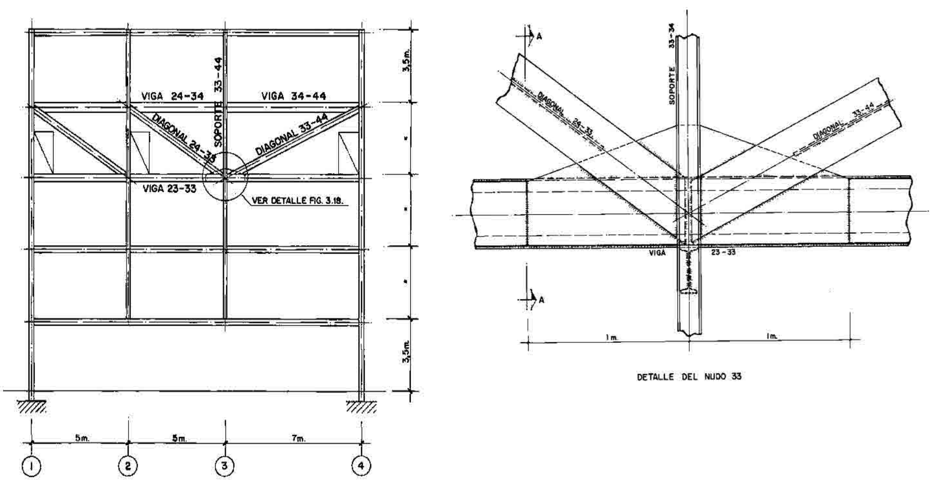


Fig. 82. In NTE (Normas Tecnológicas de la Edificación).

LIGHTWEIGHT STRUCTURAL SYSTEMS

Triangular Structure

Boyd Beams

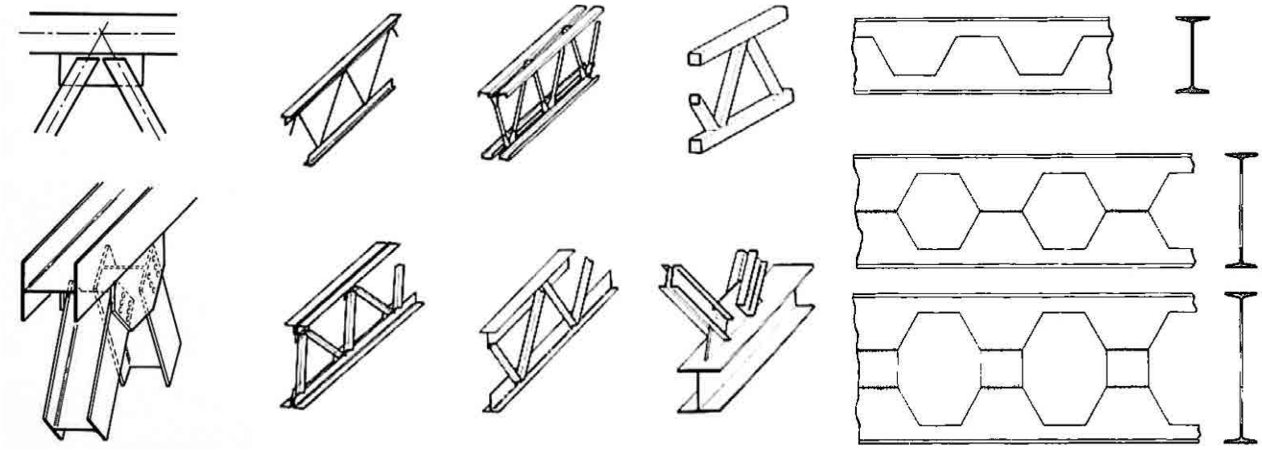


Fig. 83. Designs by Fernando Ripollés.

TUBULAR LIGHTWEIGHT STRUCTURAL SYSTEMS. SPACE FRAMES

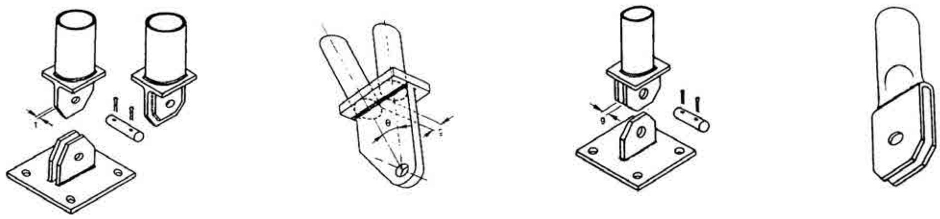


Fig. 84. Examples of screwed unions. Designs by Fernando Ripollés.

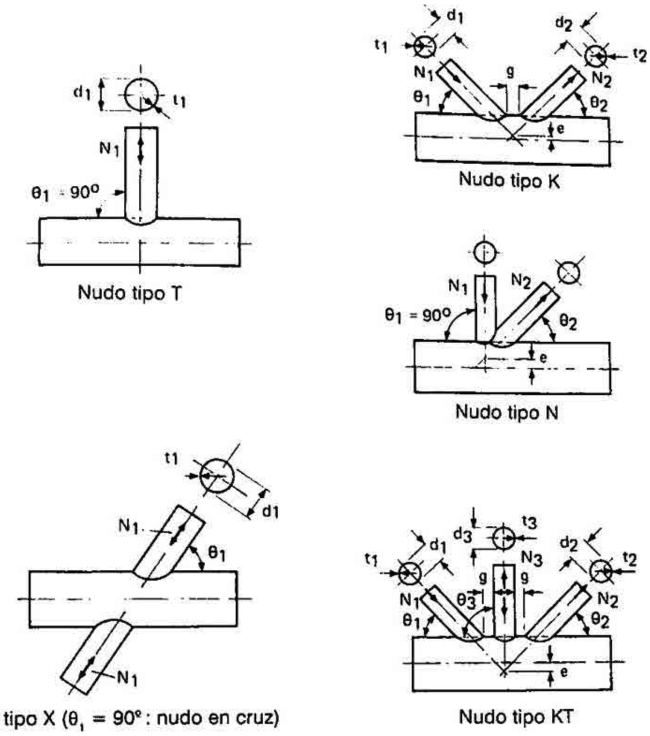


Fig. 85. In NTE (Normas Tecnológicas de la Edificación).

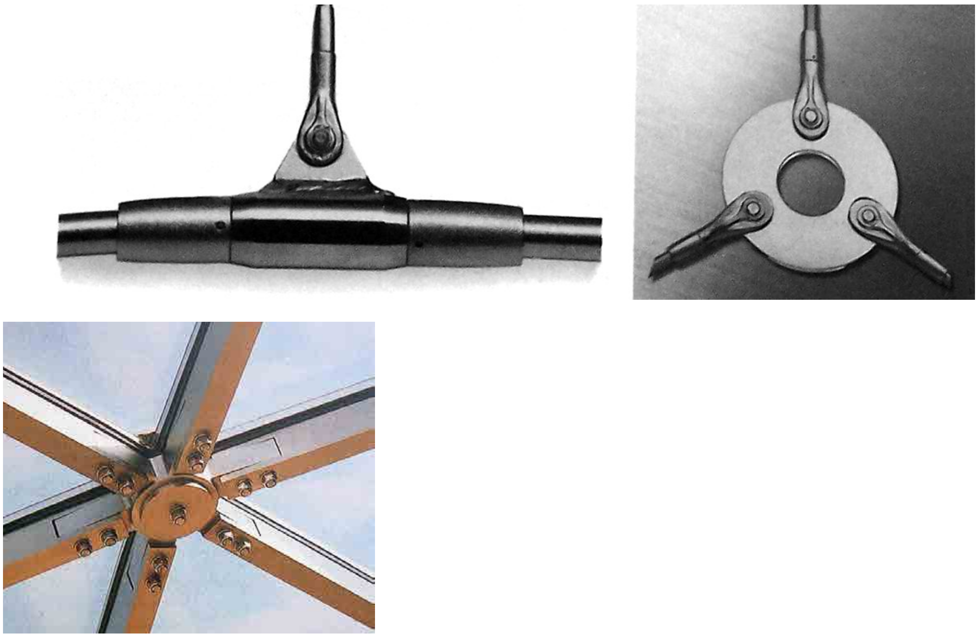


Fig. 86. Photos courtesy of Alfonso García Santos.

Tied Space Frames

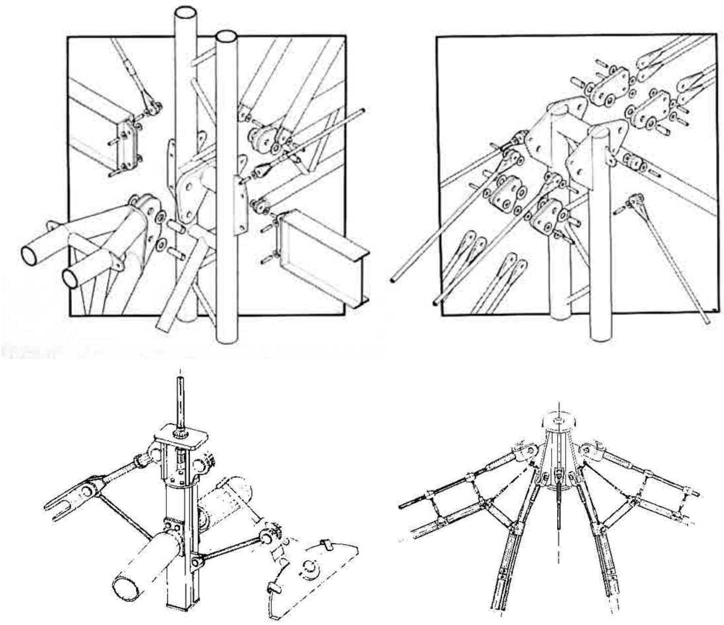


Fig. 87. Drawings courtesy of Alfonso García Santos.

Space Frames. Hubs

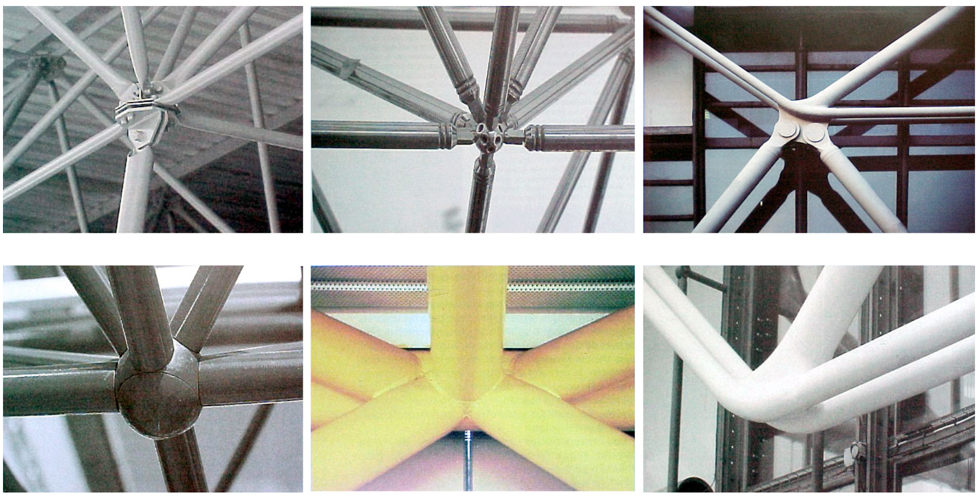


Fig. 88. Photos courtesy of Alfonso García Santos.

Space Frames. Hinges

Fig. 89. T-4 Terminal. Barajas Airport, Madrid (Spain). Photos by Alfonso García Santos.

NOTES

1) See GONZÁLEZ MORENO-NAVARRO J.L., *Claves para construir 1*, UPC, 1999; NTE-EFP (Normas Tecnológicas de la Edificación), *Estructuras de fábrica de piedra*, 1979;

2) See ADELL ARGILES J.M., *La fábrica de ladrillo*, G. G., 2000, p. 290; NBE FL-90 (Norma Básica de la Edificación), *Muros resistentes de fábrica de ladrillo*, 2021;

3) See NTE, MOPU, Madrid, 1979; NTE-CCM, *Cimentaciones, contenciones, muros*; NTE FFB, *Fachadas. Fábrica de bloques*, 1975;

4) See NTE EHV, *Estructuras de hormigón armado*; *Dirección General de la Vivienda y la Arquitectura. España*, 2001;

5) See NTE EAV, *Estructuras de acero - vigas*, p. 314;

6) ARAUJO ARMERO R., *Construir en altura*, ed. Reverté, Madrid 2019; and also from the same author, *Construir con acero*, Laboratorio I+D+I UPM, 2009.

ARAUJO ARMERO R., *La Arquitectura como técnica*, ATC ed., Madrid 2007.

BEHLING S. & S., *Sol Power: la evolución de la arquitectura sostenible*, Ed. G.G., Barcelona 2002.

CHING F., ADAMS C., *Guía de construcción ilustrada,* Limusa Wiley, Mexico 2004.

SCHLAICH J., BERGERMANN R., *Leicht Weit/Light Structures*, Prestel, München-Berlin 2003.

TORROJA E., *Razón y ser de los tipos estructurales,* Inst. Torroja, 4º ed., Madrid 1957.

CHAPTER 16. THE POROUS AND MIXED HORIZONTAL LOADBEARING SYSTEM. GRID SLABS

OBJECTIVE

To receive the loads of the building and transfer them to the vertical structural elements (walls or pillars). (1)

TYPES OF SLABS

CLASSIFICATION.

ACCORDING TO THE DIRECTION OF THE REINFORCEMENT

– One way spanning slab:
  · Self-resistant joist: Do not need horizontal props.
  · Semi-resistant joist: Horizontal props needed.
  · Half-joists: Horizontal props needed.
  · Thin walled joists: Continuous formwork needed.
  · "On-site" joists: Continuous formwork needed.
  · Hollowcore plates: Do not need horizontal props.

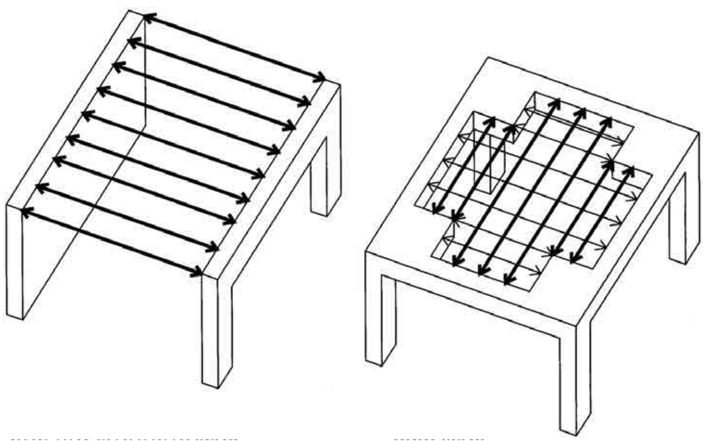


Fig. 1. Designs by Susana Mora.

– Grid slab:
  · Waffle slab: Continuous formwork is required.
    - Reusable coffers
    - Non reusable coffers (concrete, ceramic, EPS).
  · Massive slabs: Continuous formwork is required.

ACCORDING TO THE CAPACITY TO GAIN RESISTANCE

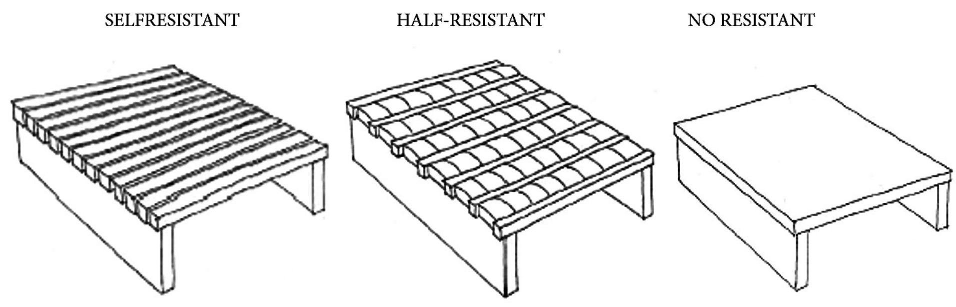


Fig. 2. Designs by Susana Mora.

– Type of slab election

· Load to be supported (death loads + life loads)
· Pillar span. Pillars layout.
· Economic cost
· Health and safety

MORE DECISIONS

– Economical Cost

When two types of slabs are technically appropriate, the choice criteria may be economic.

– Safe And Security

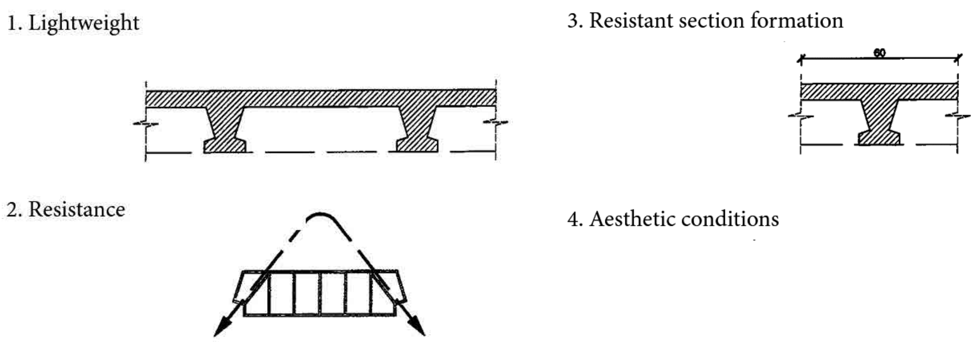
The safest slabs are those using continuous formwork.
The existence of collective protection measures for work is compulsory at heights of more than 2 m.

ONE WAY SPANNING SLABS

ELEMENTS:

1. Joists:
   · Resistant or self resistant.
   · Half-resistant or half-joists.
   · Reinforced concrete
   · Prestressed
   · Post-stressed
   · Steel joists
2. In-floor Blocks;
3. Slab Steel Reinforcement;
4. Slab Compression Layer.

Light-weighting Elements



(2)

Fig. 3. Designs by Susana Mora.

Posibilities for Beam Fill. Evolution.

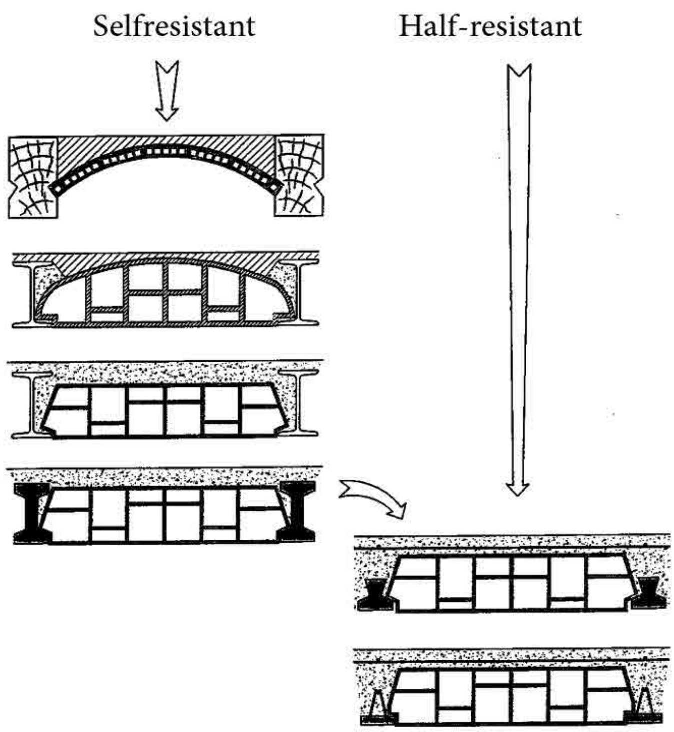


Fig. 4. Designs by Susana Mora.

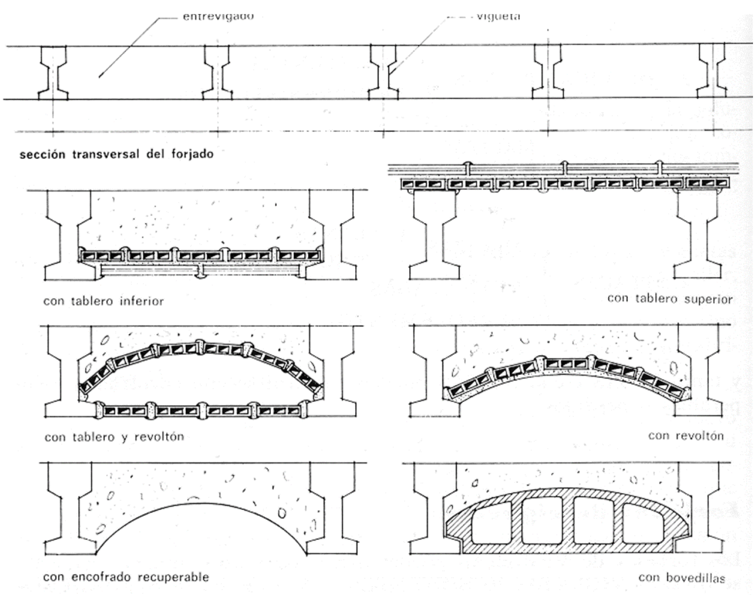


Fig. 5. Designs by Susana Mora.

CONCRETE BEAMS ONE WAY SPANNING SLABS

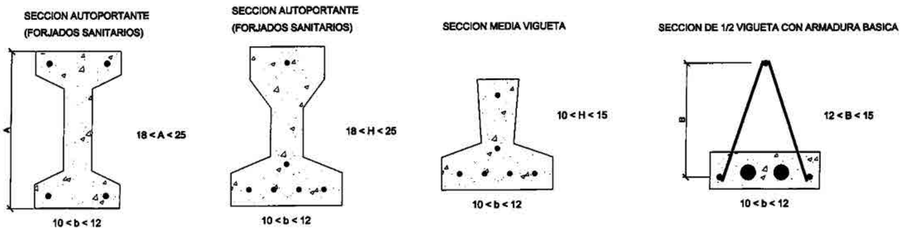


Fig. 6. Designs by Susana Mora.

Joists Supports:

– Loadbearing walls
  · Concrete loadbearing walls
  · Masonry brickwork (1 bat minimum thickness)
– Beams
  · Concrete beams
  · Hanging
  · Flat
  · Metallic beams

Beams And Joists Distribution

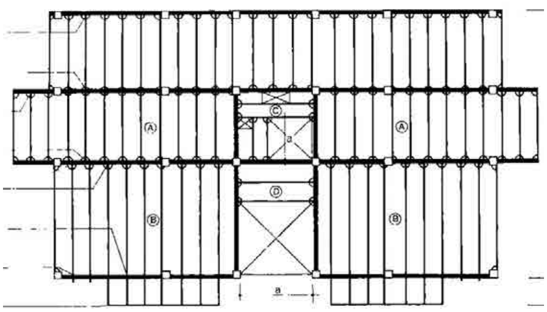


Fig. 7. Design by Susana Mora.

Solutions with one way spanning slab:

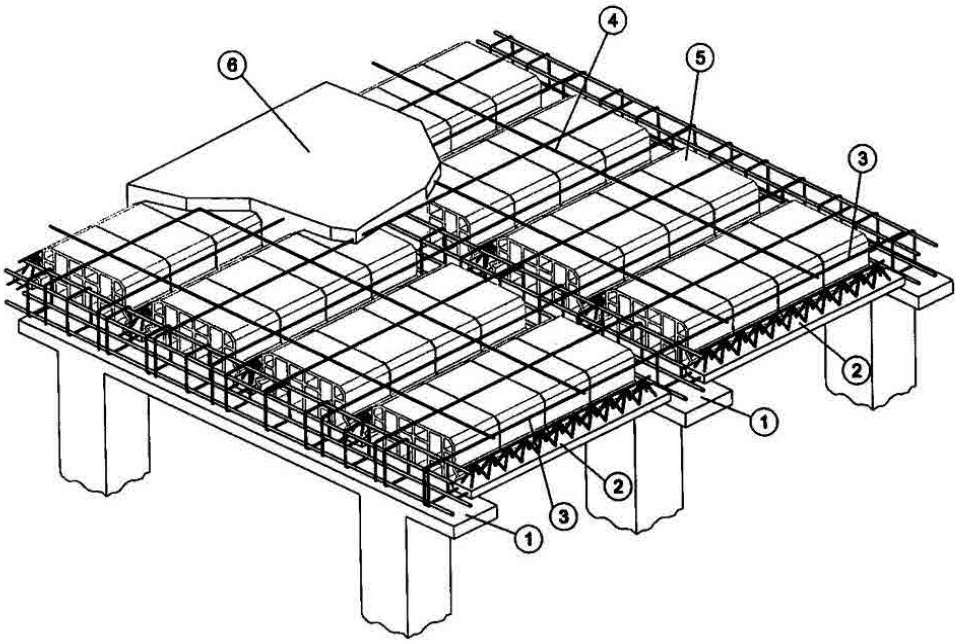


Fig. 8. Typical one way spanning slab – joists with basical reinforcement (grid layout). Design by Susana Mora.

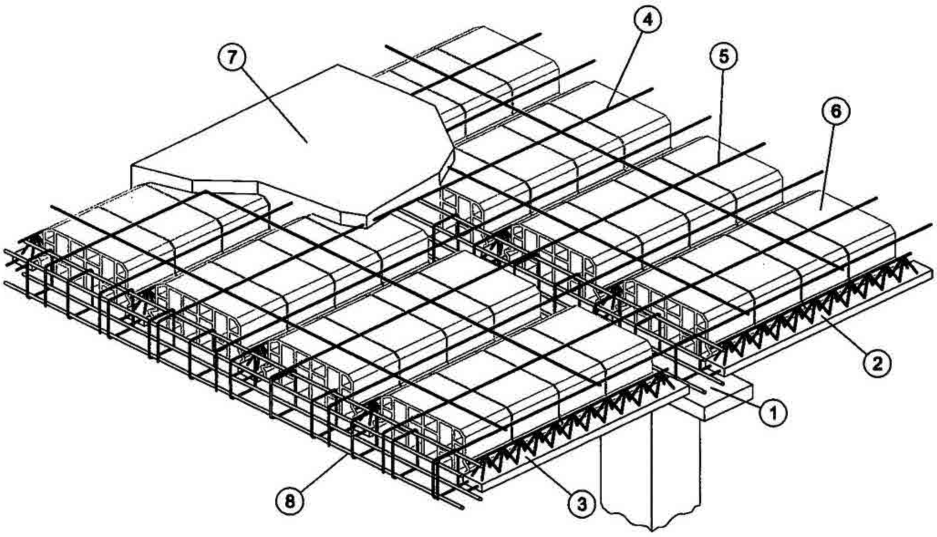


Fig. 9. One way spanning slab with cantilever– joists with basical reinforcement (grid layout). Design by Susana Mora.

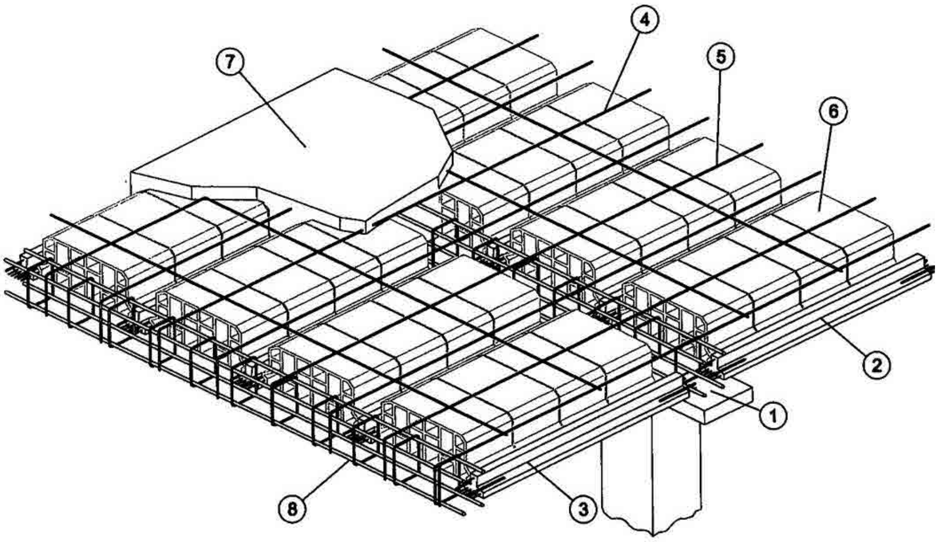


Fig. 10. One way spanning slab with cantilever – prestressed half-joists. Design by Susana Mora.

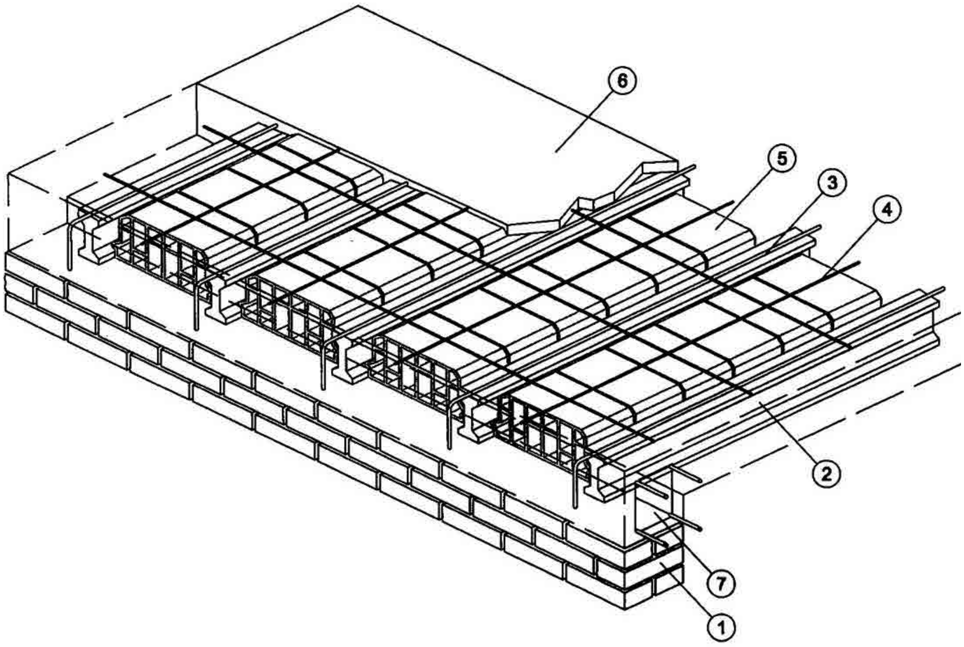
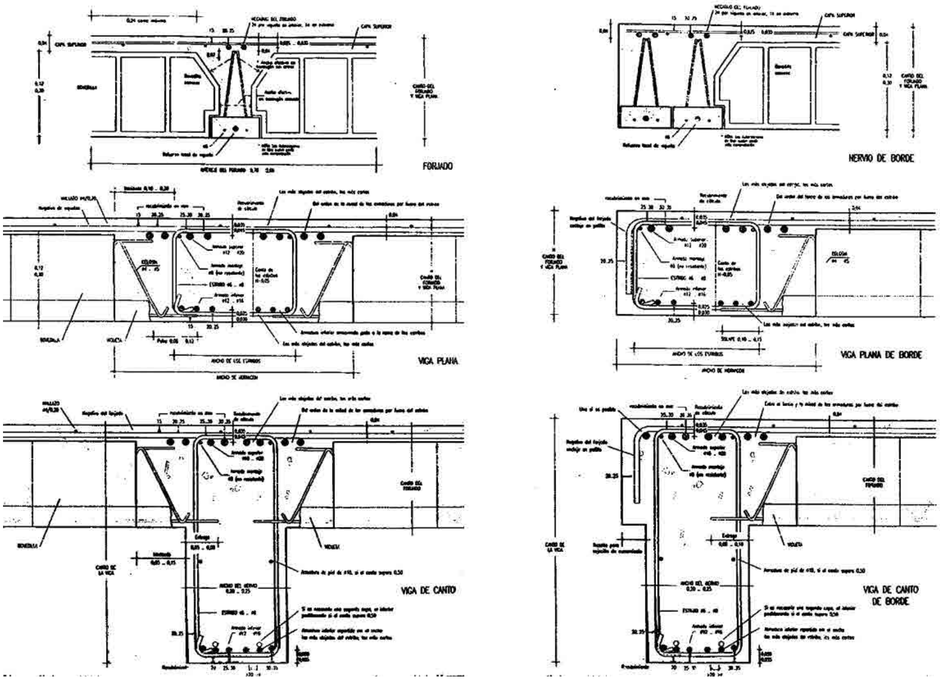


Fig. 11. Self-resistant one way spanning slab – ground sanitary slab. Design by Susana Mora.



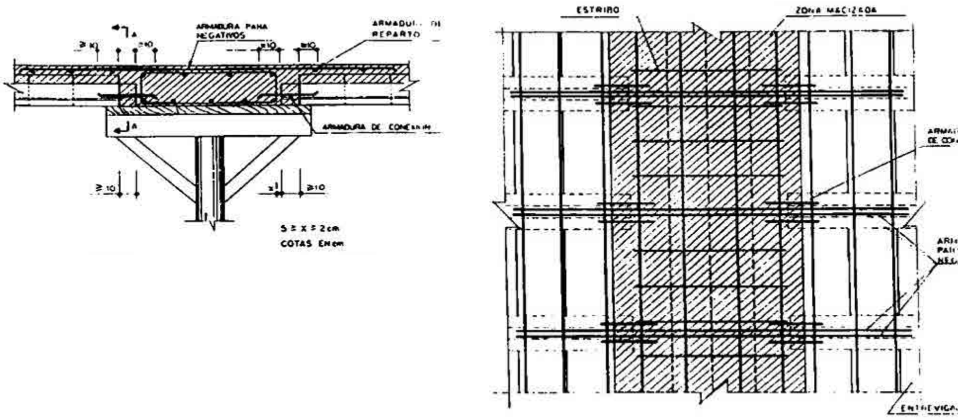


Fig. 12. Reinforced Concrete Half-joists On Reinforced Concrete Flat Beam. In NTE (Normas Tecnológicas de la Edificación).

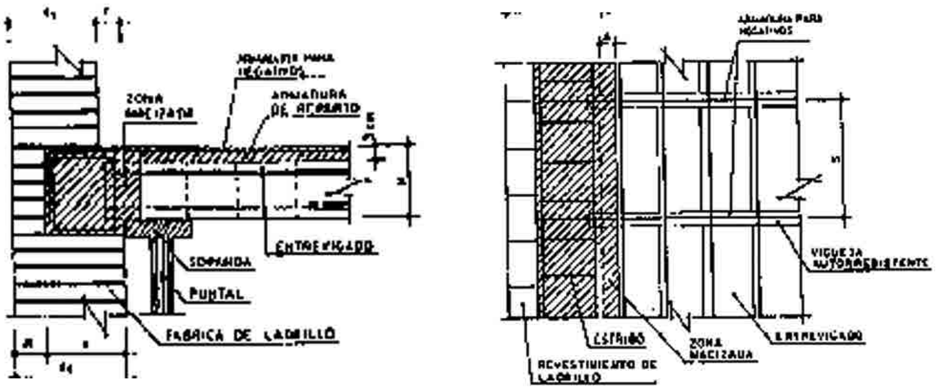


Fig. 13. Simple support on masonry work. In NTE (Normas Tecnológicas de la Edificación).

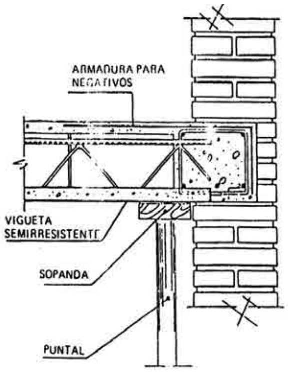


Fig. 14. Reinforced concrete half-joists on 1 bat masonry brickwork loadbearing wall. In NTE (Normas Tecnológicas de la Edificación).

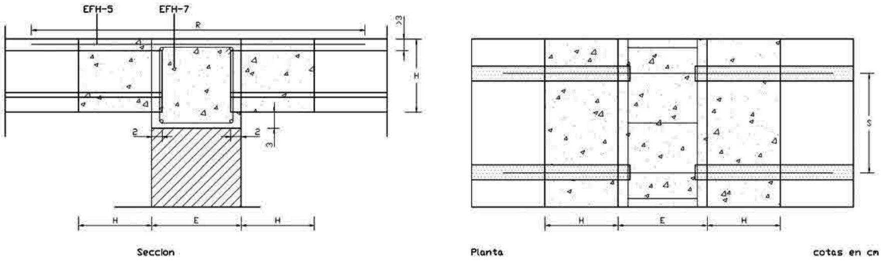
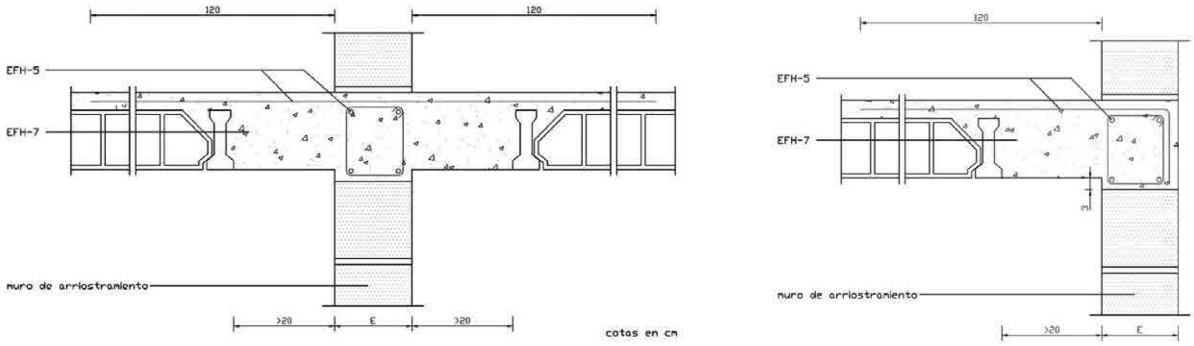


Fig. 15. Double support on masonry work In NTE (Normas Tecnológicas de la Edificación).

Concrete Joist One Way Spanning Slabs:



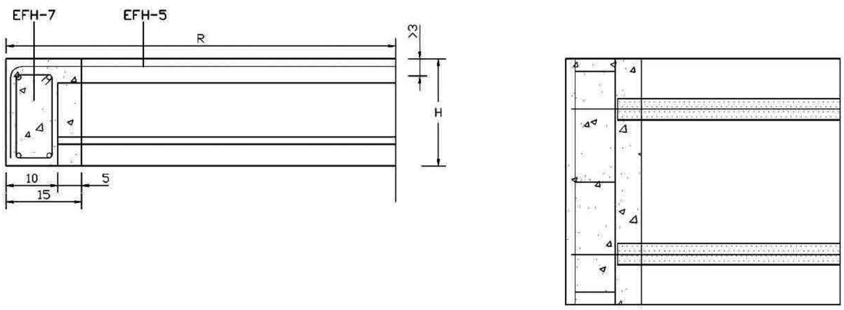


Fig. 16. Tie beam on wall. In NTE (Normas Tecnológicas de la Edificación).

Fig. 17. Continuous conection in cantilever edge. In NTE (Normas Tecnológicas de la Edificación).

SLOPING SLABS

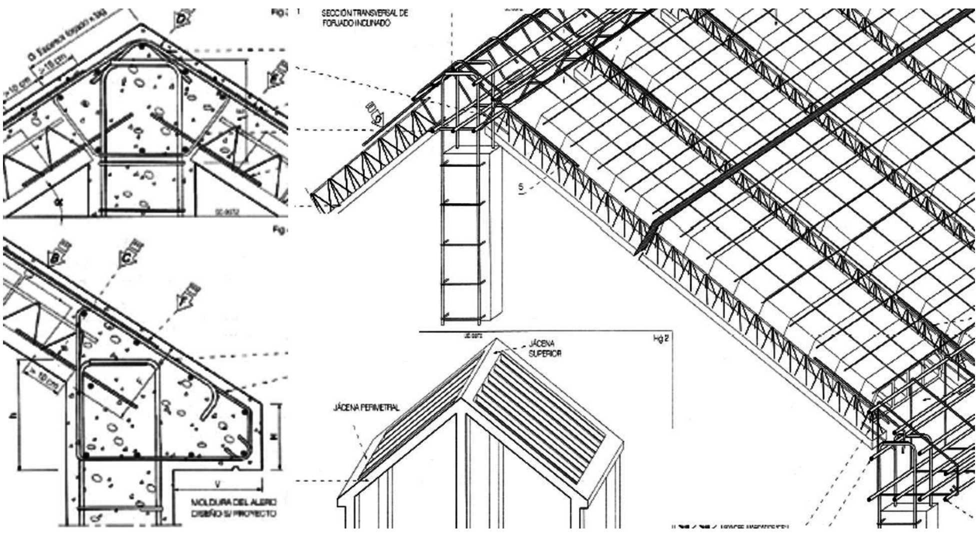


Fig. 18. In NTE (Normas Tecnológicas de la Edificación).

EXECUTION PROCESS

Fig. 19. Reinforcement for beams and half-joists. Photo by Fernando Ripollés and Celia Barahona.

Fig. 20. On the left: Placement of in-floor bricks and compression reinforcement of joists. On the right: Openings. Photos by Fernando Ripollés and Celia Barahona.

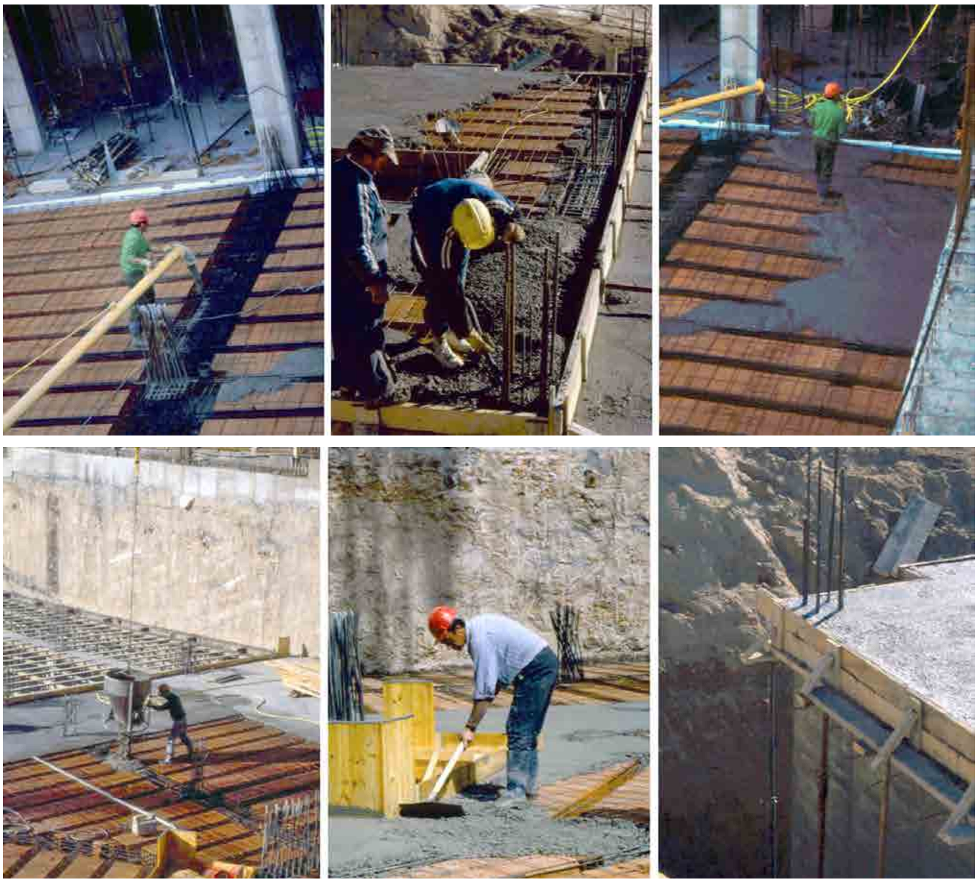
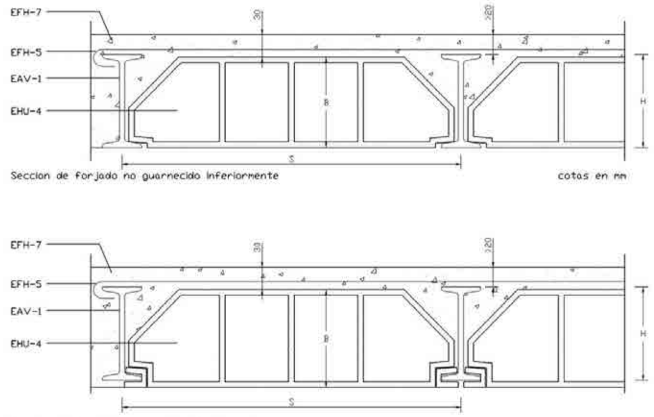
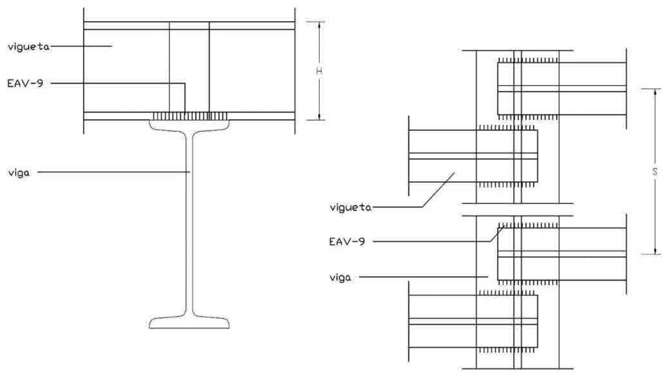
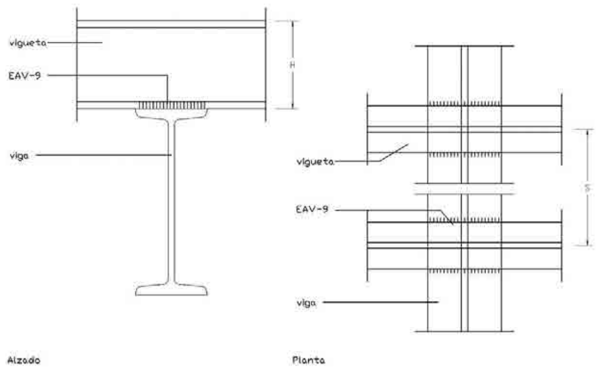


Fig. 21. Concreting. Photos by Fernando Ripollés and Celia Barahona.

STEEL BEAMS ONE WAY SPANNING SLABS







Simple support on steel beam.

Continuos support on steel beam.

Fig. 22. In NTE (Normas Tecnológicas de la Edificación).

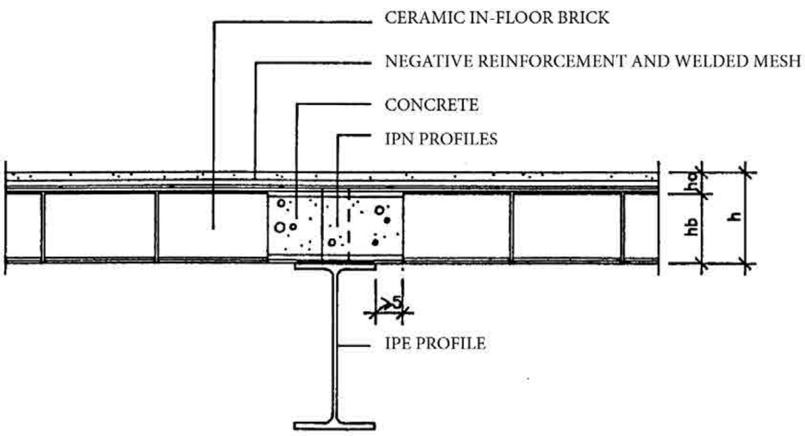


Fig. 23. Steel joists on steel beam. In NTE (Normas Tecnológicas de la Edificación).

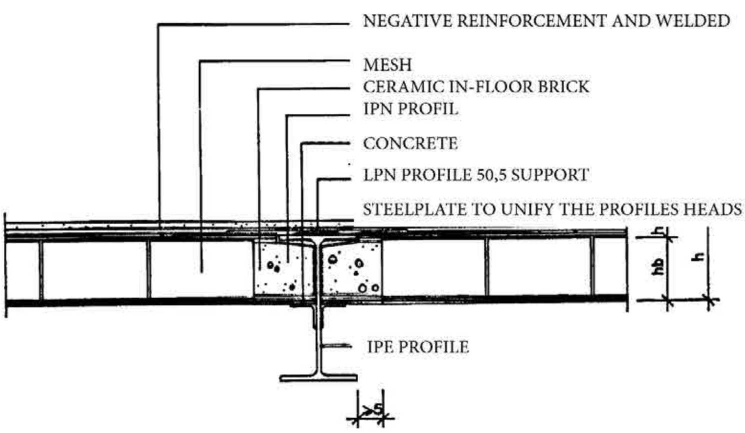


Fig. 24. Steel joist as trimmer joist to a steel beam. In NTE (Normas Tecnológicas de la Edificación).

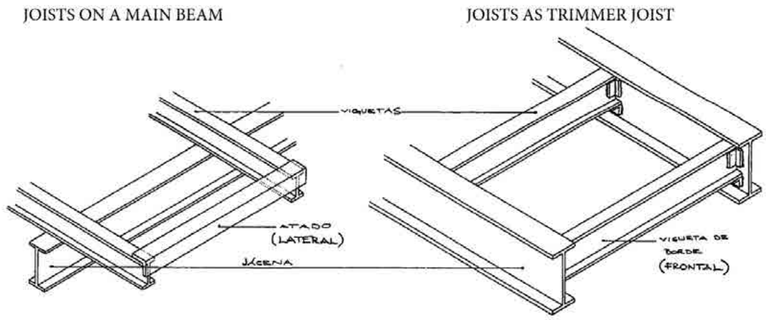


Fig. 25. Cantilevers. Designs by Susana Mora.

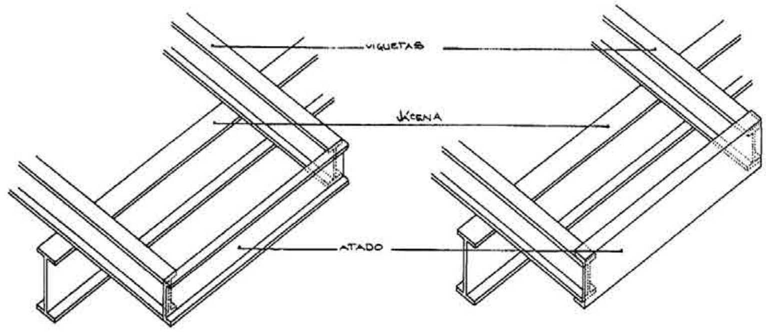


Fig. 26. Cantilever joists edges connection. Designs by Susana Mora.

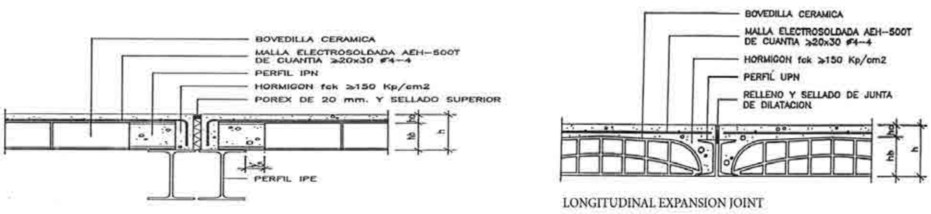


Fig. 27. Expansion joints. In NTE (Normas Tecnológicas de la Edificación).

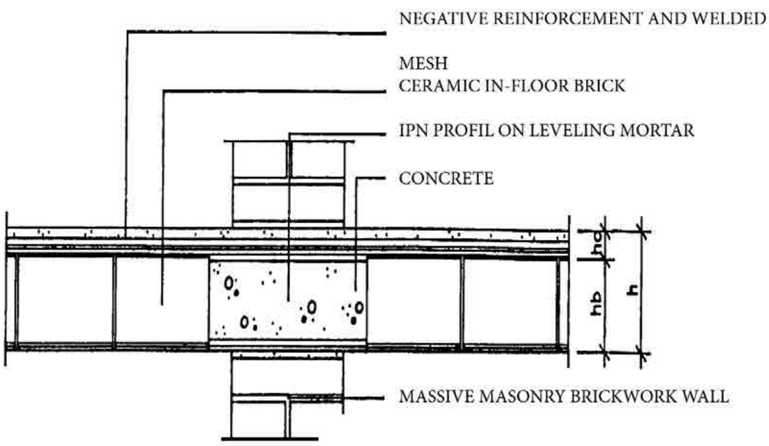


Fig. 28. Steel joists on internal loadbearing wall. In NTE (Normas Tecnológicas de la Edificación).

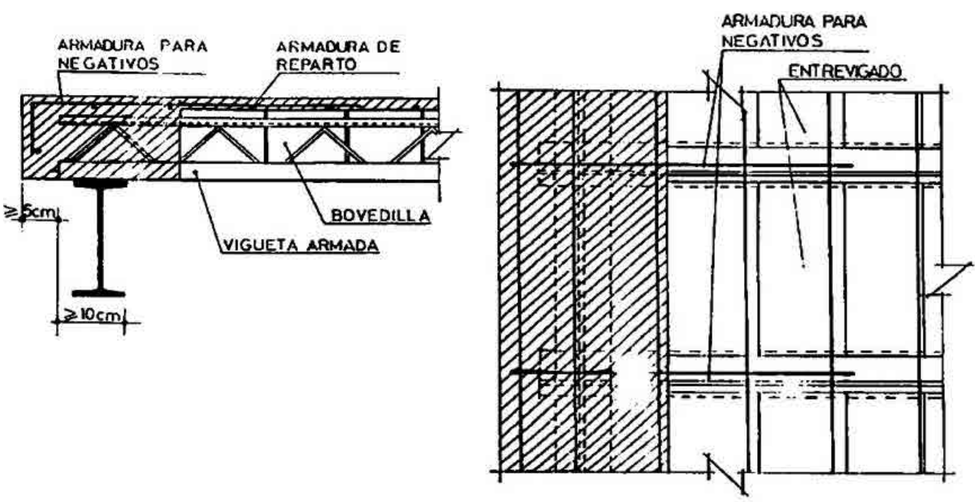


Fig. 29. Reinforced oncrete half-joists on steel beam. In NTE (Normas Tecnológicas de la Edificación).

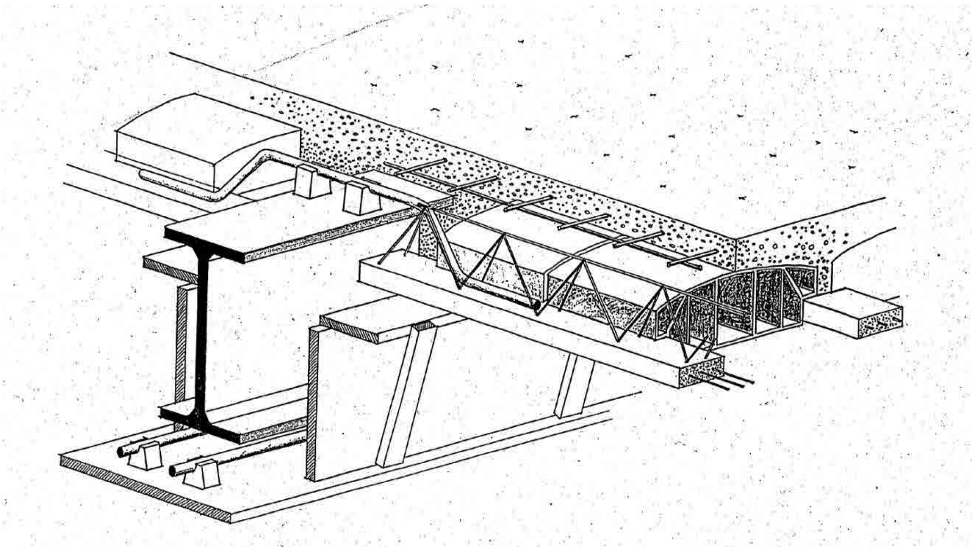


Fig. 30. In NTE (Normas Tecnológicas de la Edificación).

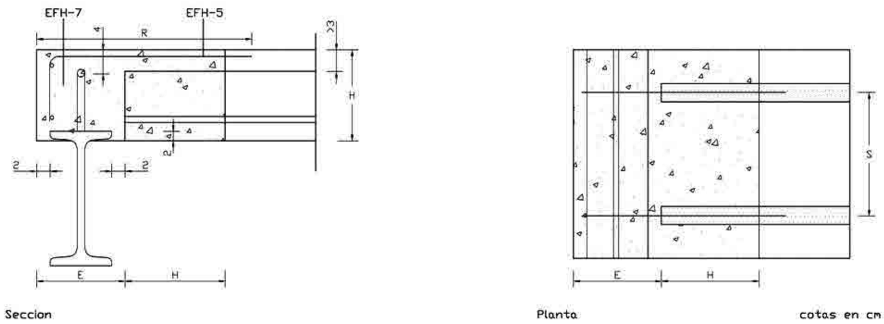


Fig. 31. Simple support on steel beam. In NTE (Normas Tecnológicas de la Edificación).

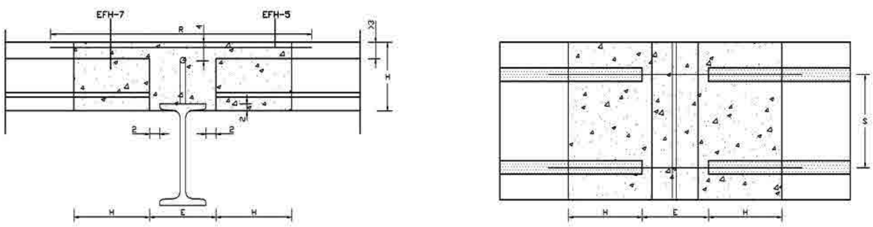


Fig. 32. Double support on steel beam. In NTE (Normas Tecnológicas de la Edificación).

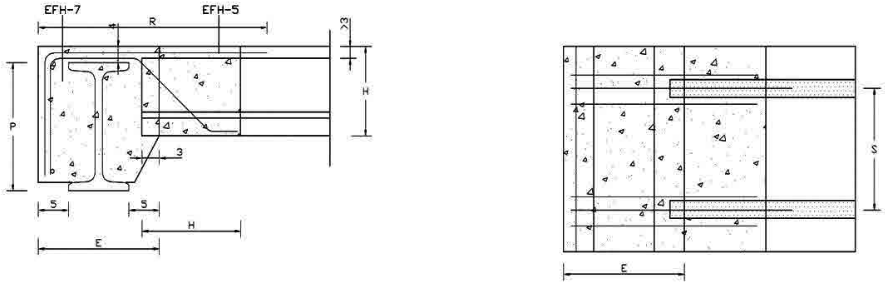


Fig. 33. Simple support on steel beam. In NTE (Normas Tecnológicas de la Edificación).

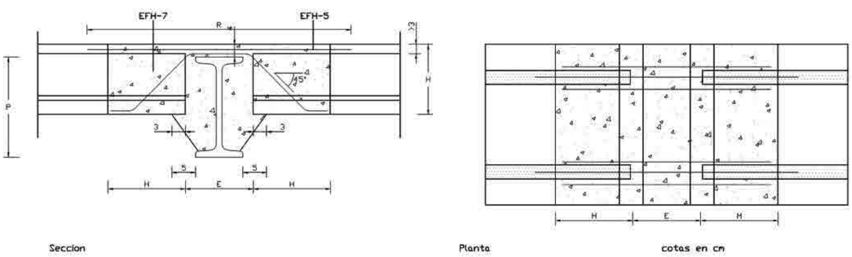


Fig. 34. Double support on steel beam. In NTE (Normas Tecnológicas de la Edificación).

GRID SLABS

MASSIVE AND LIGHTWEIGHT SLABS, PRECAST PANEL SLABS, MIXED CONCRETE DECKING SLABS

(3)

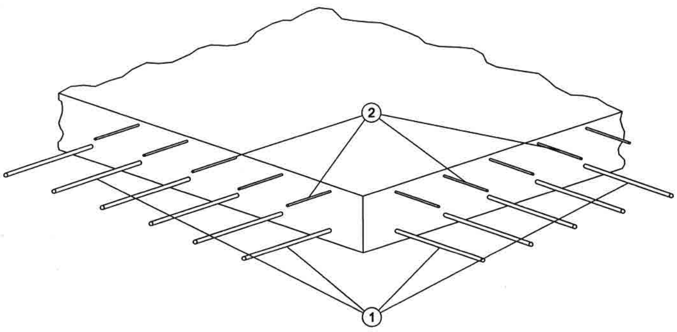


Fig. 35. Grid slab. Massive slab with two directions reinforcement. Design by Susana Mora.

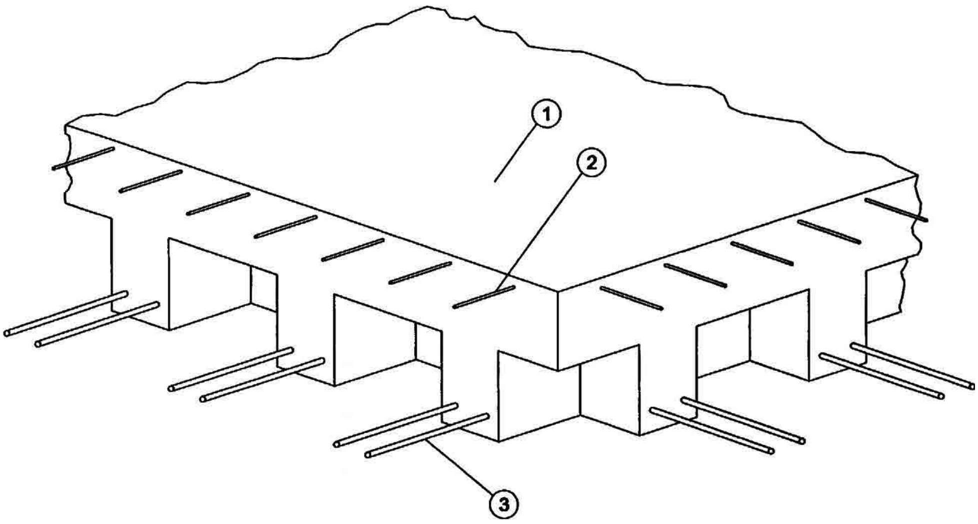


Fig. 36. Lightweight slab with reusable formwork. Design by Susana Mora.

LIGHTWEIGHT SLABS

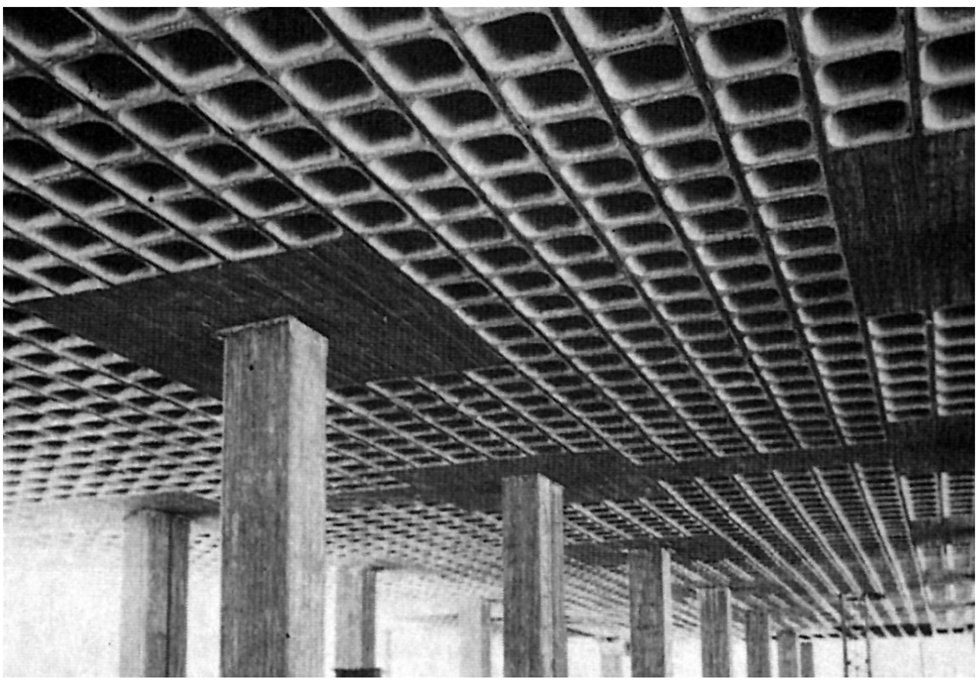


Fig. 37. Pillar and beams connection. From F. Casinello, *Hormigonería*, Reverte, 1996, Madrid.

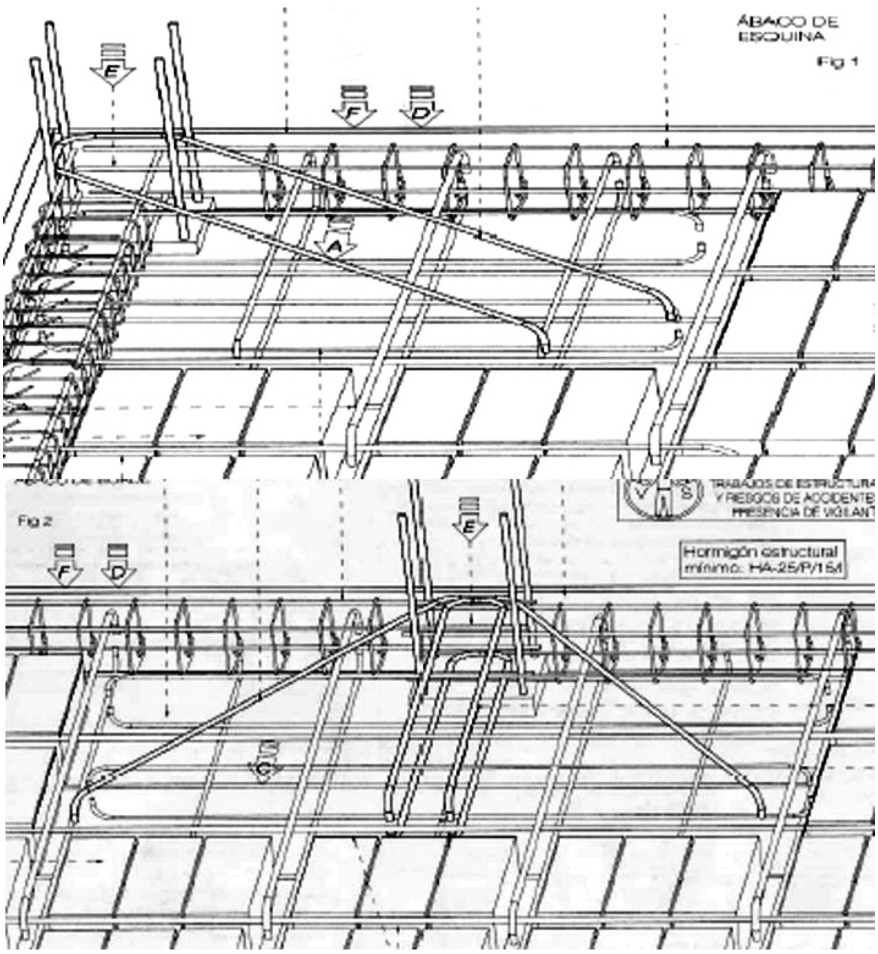


Fig. 38. Lightweight slab on reinforced concrete pillars. Design by Fernando Ripollés.

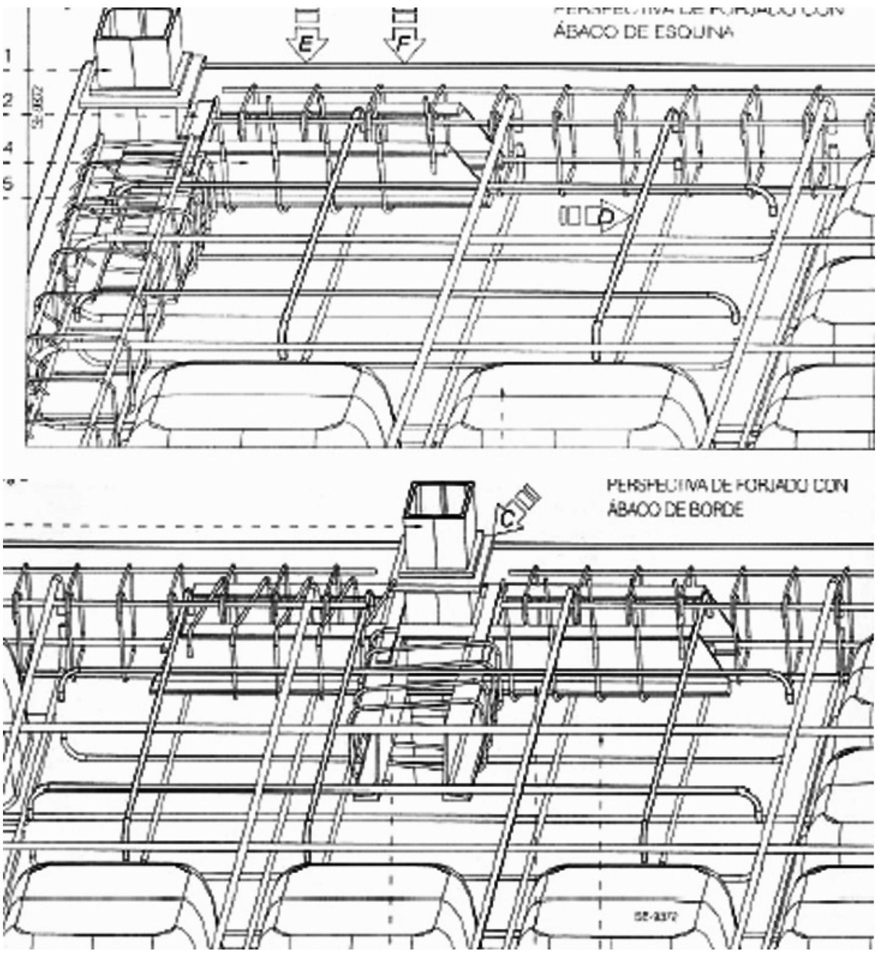


Fig. 39. Lightweight slab on steel pillars. Design by Fernando Ripollés.

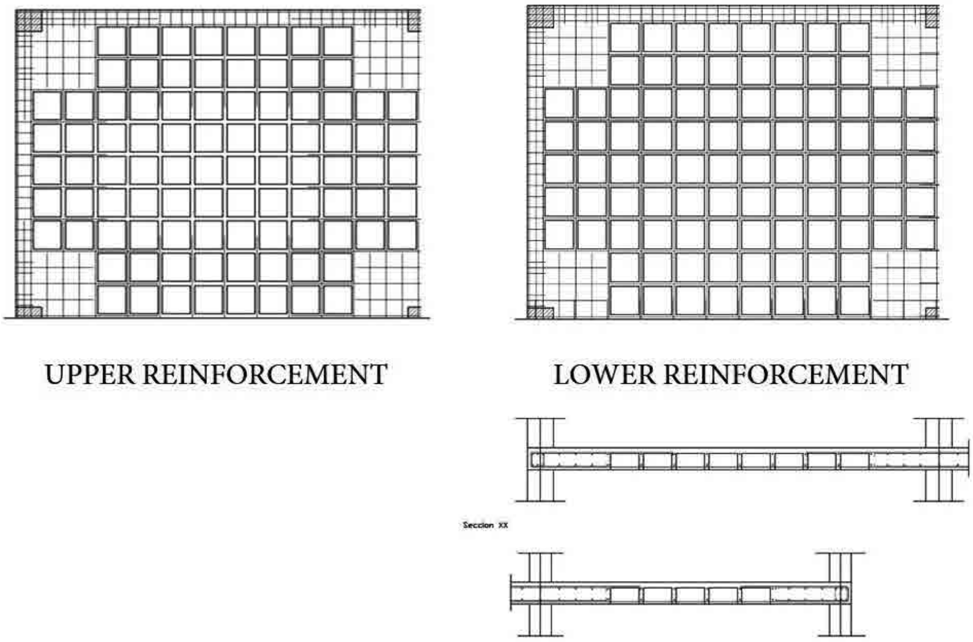


Fig. 40. Corner box. In NTE (Normas Tecnológicas de la Edificación).

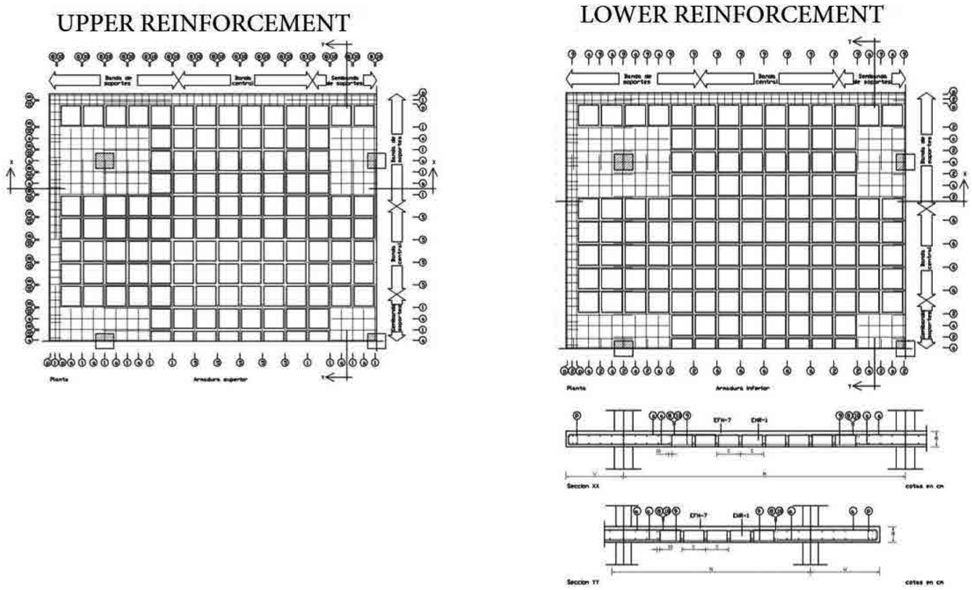


Fig. 41. Cantilever corner box. In NTE (Normas Tecnológicas de la Edificación).

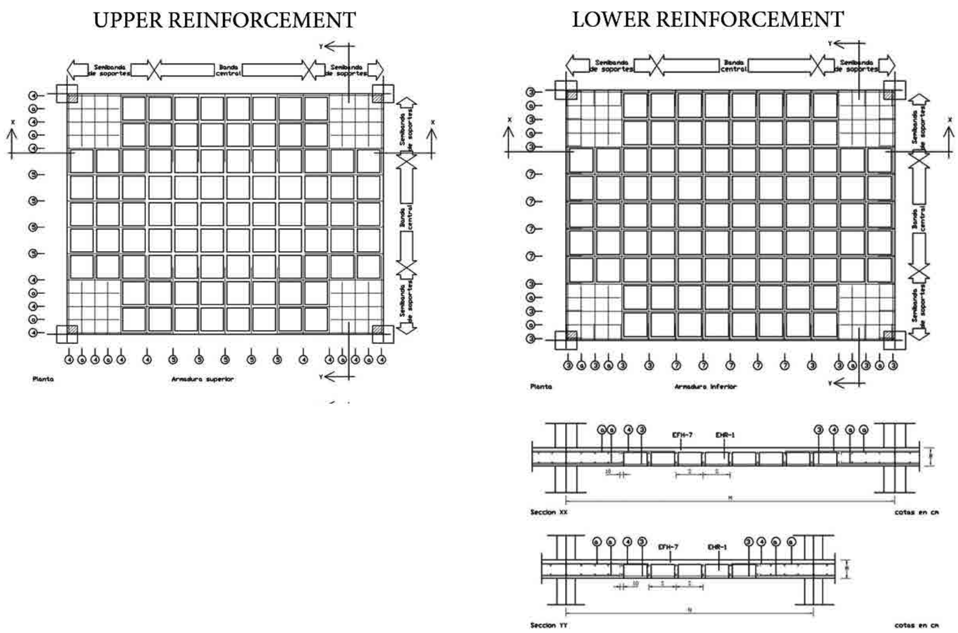


Fig. 42. Internal span box. In NTE (Normas Tecnológicas de la Edificación).

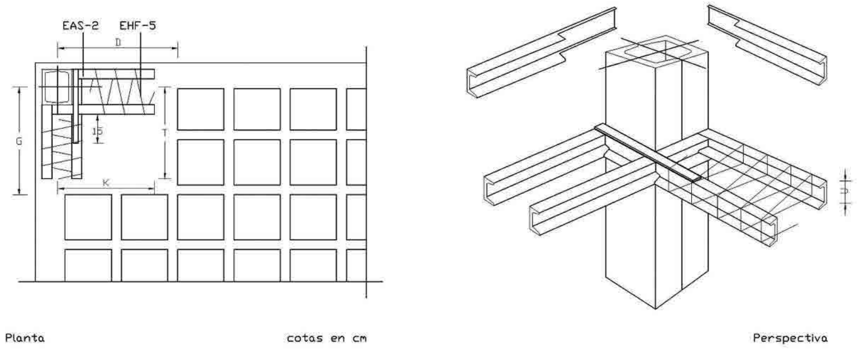


Fig. 43. Corner steel pieranchorage. In NTE (Normas Tecnológicas de la Edificación).

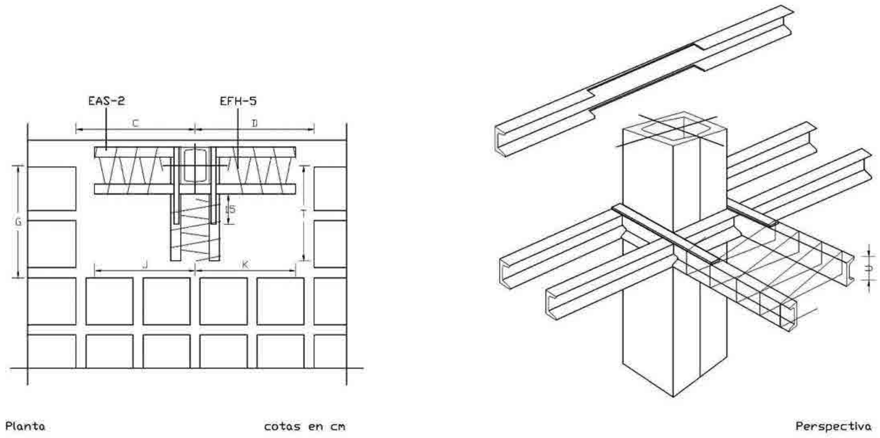


Fig. 44. Edge steel pillar anchorage. In NTE (Normas Tecnológicas de la Edificación).

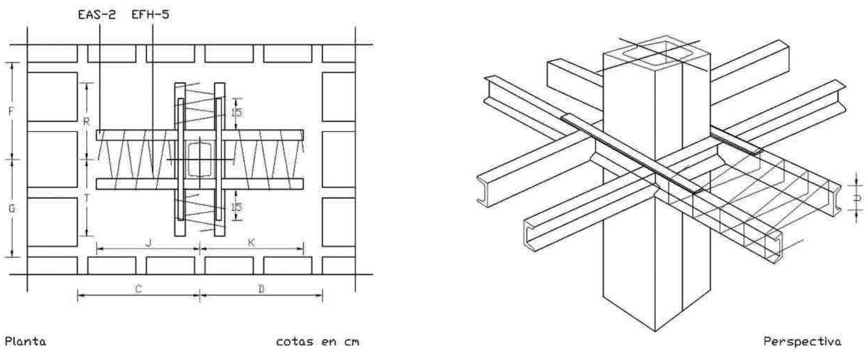


Fig. 45. Internal steel pier anchorage. In NTE (Normas Tecnológicas de la Edificación).

STEEL PILLARS GRID SLABS

Fig. 46. Photos by Fernando Ripollés and Celia Barahona.

CONCRETE PILLARS GRID SLABS

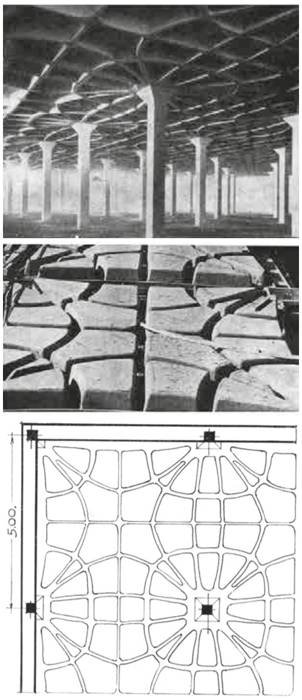


Fig. 47. Above: Gatti Factory. P.L. Nervi. Photos and designs from F. Casinello, *Hormigonería*, Reverte, 1996, Madrid.

Fig. 48. Above right: Photos by Fernando Ripollés and Celia Barahona.

MIXED CONCRETE DECKING SLABS

ORIGIN

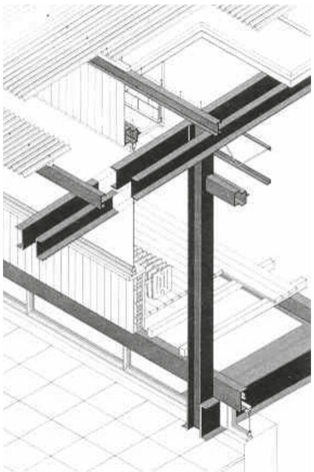


Fig. 49. Design courtesy of Fernando Ripollés.

PRECAST

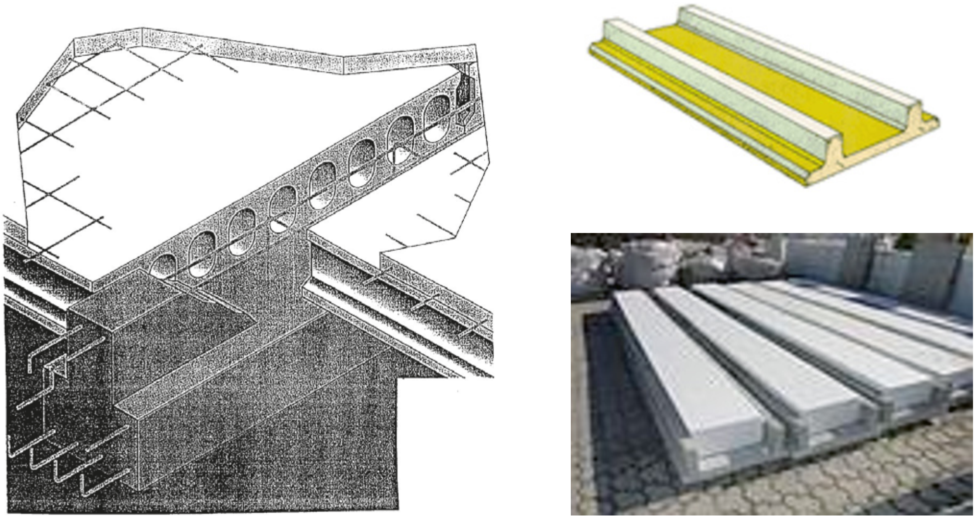


Fig. 50. Hollowcore plates. Designs courtesy of Fernando Ripollés.

NOTES

1) See *Instrucciones del Instituo Eduardo Torroja de la construcción y del cemento*, CSIC, 2011; GONZÁLEZ MORENO-NAVARRO J.L., *Clases para construir* 2, UPC; ARAUJO ARMERO R., *La Arquitectura como Ciencia: principios de proyecto y tipos de edificio*, ed. Reverté, Madrid 2019;

2) See NAVARRO J. V., *La evolución de los forjados de edificación hacia unas técnicas más competitivas económicamente*, 2009; *Los forjados unidireccionales*, Urbipedia, s.l. 2017;

3) See "Forjados estructurales", CYPE Ingenieros, 2002; "Forjado colaborante", INCOPERFIL S.A. Ingeniería y Construcción, 2016; and also "Sistemas", IRONLUZ, TECZONE, TZ60F, etc.

ARAUJO ARMERO R., *La Arquitectura como técnica*, ATC ed., Madrid 2007.

CHING F., ADAMS C., *Guía de construcción ilustrada,* Limusa Wiley, Mexico 2004.

GOLDSMITH M., *Building and Concept*, Rizzoli International Publications, New York 1987.

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CHAPTER 17. ROOFS: SLOPING AND FLAT ROOFS

SLOPING ROOFS: TYPES ANALYSIS

– Analysis by components of high slope and low slope roofs. (1)

– Types of plans.

– Formation of slope in roofs of high slope.

– Structural base.

FACTORS CONDITIONING THE FORMAL AND CONSTRUCTIVE SOLUTIONS FOR ROOFS:

– Design.

– Mechanical.

– Water and airtightness.

– Conditioning.

– Durability.

BASIC CONDITIONS

The roofs of buildings must meet certain basic conditions:

– Roofs must have enough mecanical resistance and stability in the face of:

· Mechanical actions.
· Thermal actions.
· Wind actions.

The deformability and movements of its components will be compatible between each other and with the rest of the building.

– Roofs must be water and airtight to provide:

· Waterproofing of the building (in any state and situation).
· Evacuation easiness.
· Wind protection.

– Their design and organization will prevent them from causing:

· Filtrations.
· Absorption.
· Condensation dampness.

– Roofs must possess a certain thermal insulation degree:

· That limits heat and cold transmisions.
· That impedes the loss of thermal energy.
· As a defensive factor against the appearance of condensation moisture.
· That defends the building against expansions or contractions.

– Roofs must possess an acoustic insulation degree and must fulfill the conditions of protection against fire.

DESIGN CRITERIA

The election of a roof type will impose some determining factors in the generality of the building due to:

· The general design.
· The relation of each component or element with the rest of the elements and with the totality.
· The relationship of the roof with the rest of the constructive elements and with the rest of the building.

Special care must be taken for:

– Connections or unions of the resistant base of the roof with the general structure of the building:

· Support on loadbearing wall.
· Support on loadbearing beam or main beam.
· Support on piers.
· Type of support
    - Fixed (embebbed).
    - Roller (articulated).
    - Pinned.

– The connection of the support of the roof sheathing with the resistant base.

– The connection of the roof sheathing with its vase on:

· Limits: Eaves, perimeter.
· Unions: Hips, valleys.

ROOF COMPONENTS

Commonly and in a very elementary way, roofs are formed by the following components:

– Resistant base.

– System of slopes.

– Support of the roof sheathing.

– Roof sheathing.

– Drainage system.

– Conditioning:
  · Thermal insulation
  · Vapour barrier
  · Waterproofing, …

CLASSIFICATION BY COMPONENTS:

RESISTANT BASE

It fulfills a resistant function.
It is responsible for maintaining the dimensional parameters.
It avoids the existence of deformations by excesses of rise that could make the water drainage difficult.

SLOPE STRUCTURE

Its function is to create a sloped surface that allows for the drainage of rainwater.
Depending on the system adopted, the roofs can be structured as follows:

– Aired or ventilated:

  · Built on a board, or with a system that allows air circulation.
  · These roofs are also known as:
    - Cold roofs.
    - Double layer roof.
    - Aired chamber roof.

– Not aired:

  · Built on lightweight concrete.
  · These roofs are also known as:
    - Warm roof.
    - Single layer roof.
    - Not aired roof.

HYGROTHERMAL PERFORMANCE:

AIRED OR COLD ROOFS

They consist of two elements separated by an air chamber connected with the outside environment under the roof sheathing.

– Organisational scheme:

· Upper layer.
· Intermediate layer. Ventilation with the outside.
· Lower layer. Thermal insulation.
· Base structure.

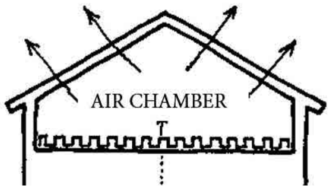


Fig. 1. Design by Fernando Ripollés.

VENTILATED OR COLD ROOFS

Types of cold roofs:

– Traditional:
· High slope.
· Air permeable.
· High and ventilated attic.

Waterproofing roof sheathing.

1. Ventilated attic with opening on the ridge.
2. Crossed ventilation. Warm air under the ridge.
3. Single slope ventilated roof.
4. Double layer flat roof.
   - If >12 m, intermediate ventilation is required.
5. Butterfly rood.
   - Deficient ventilation due to eddies.
6. Thin air chamber roof.
   - The steam condenses and slides down the bottom layer.

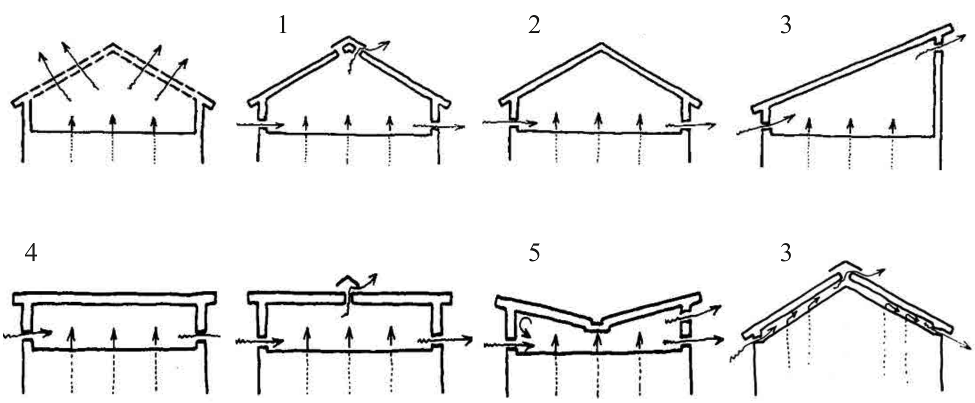


Fig. 2. Designs by Fernando Ripollés.

ROOF SHEATHING

Its function is to create a finishing plane. Therefore, it is the meeting zone between the roof and the external environment. This layer is responsible for the weather protection of the rest of the layers.

– According to the possible uses adopted, roofs can be classified as:

· Not accessible roofs:
  - Heavy waterproofing protection.
  - Lightweight waterproofing protection.

·Accessible roofs:
  - Heavy waterproofing protection.
  - No slope and flat roofing.
  - Green roofs.
  - Ecological roofs.
  - Sloped roofs.

THERMAL INSULATION

Acoording to the relative position of every element the roofs are described as:

· Traditional
  The thermal insulation function is to avoid thermal energy losses from the surrounding spaces.

· Reversed
  In addition to fulfilling the above function, it avoids thermal variations that the waterproofing membrane may suffer, reducing the material fatigue phenomena and increasing its durability.

WATERPROOFING

This membrane prevents water penetration into the lower layers of the roof. The position of this layer establishes two differentiated zones on the roof.

Acoording to the type of material user for waterproofing membranes, roofs are described as:

– Bituminous. Membranes.
  · Adhered system.
  · Non-adhered system, with ballast.
– Plastic. Membranes or coating (paint).
  · Polyethylene.
  · Polypropylene.
  · Polyester.
  · PVC.
  · Thermoplastic polyolefins of ethylene propylene.
– TPO
– Synthetic rubber. Membranes.
  · SBS (Styrene Butadiene Styrene).
  · EPDM (Ethylene propylene diene monomer).

SELECTION CRITERIA

Criteria for roofs selection are:

– General criteria: these lead us to establish the typological characteristics of the roof.

– Technical criteria: those that singularize and determine the detailed aspects established by the recognized typology.

GENERAL CRITERIA:

– The determination of the type of roof and the main factors to be taken into account in the choice are directly related to:
    · The characteristics of the covered space.
    · Dead load.
    · Thermal and acoustic insulation capacity.
    · Maximum spans between supports.
    · The expressive internal and external possibilities.

It should be borne in mind that roofs can play an important role in natural conditioning, obtaining a good level of natural lighting and ventilation through skylights, which will help in energy saving and in the quality of habitability of the space below.

TECHNICAL CRITERIA:

– The following technical criteria should be taken into account when deciding on the specific aspects of the type of roof chosen:
    · Compatibility of components.
    · Movements due to thermal effects.
    · Interaction of the structure with the roof sheathing.
    · Stability and mechanical resistance.
    · Fire safety.
    · Watertightness.
    · Safety of use.
    · Protection against noise.
    · Energy saving and thermal protection.

MORPHOLOGICAL CLASSIFICATION

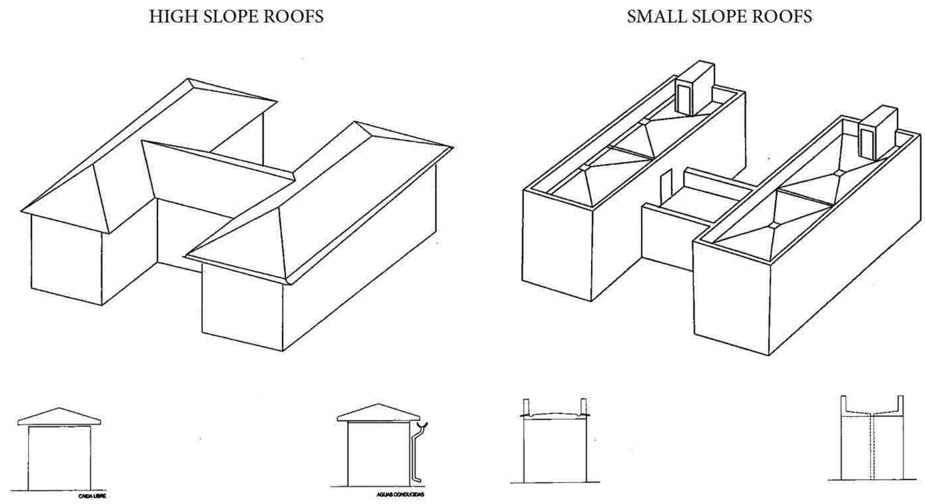
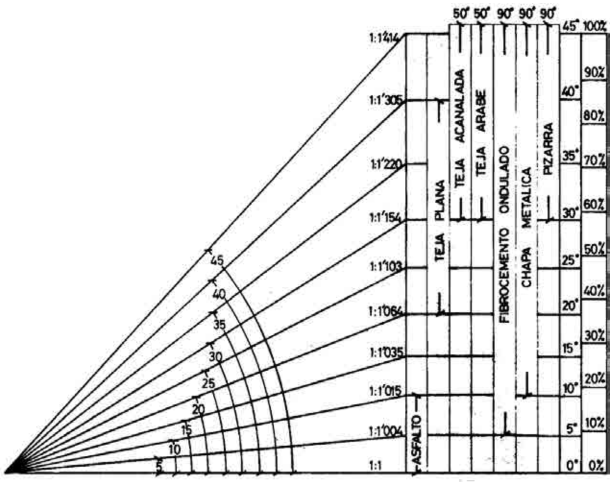


Fig. 3. Designs by Susana Mora.

HIGH SLOPE OR SLOPING:

- Slope > 15º
- They usually drain to the outside of the building.



SMALL SLOPE OR FLAT:

- Slope < 5º
- They usually drain to the inside of the building.
- Possibility of being recoverable for transit and use.

GENERAL CONSTRUCTIVE ORGANIZATION FOR A ROOF PLANE

SINGLE LAYER ROOF: Without insulation:
- Waterproofing.
- Resistant base.

SINGLE LAYER ROOF:With insulation:
- On the resistant base:
  - · Waterproofing.
  - · Thermal insulation.
  - · Vapour barrier.
  - · Resistant base
- Under the resistant base:
  - · Waterproofing.
  - · Resistant base
  - · Thermal insulation.
  - · Vapour barrier.

DOUBLE LAYER ROOF: With insulation:
- Waterproofing.
- Resistant base
- Thermal insulation.
- Vapour barrier.

TYPES OF ROOFS ACCORDING TO THEIR RESISTANT BASE

- Flat
  - · Slab:
    - - Horizontal.
    - - Sloping(obliquely).
- Straight bars bundles (with isolated bars):
  - · Traditional.
  - · Gable roofs portal frames.
  - · Sloped main beam.
  - · Contemporary solutions.
- Bars grid (triangled):
  - · Flat bars.
  - · Main beams.
  - · Trusses: with or without tie beam
  - · Space frames.
- Bent bars set:
  - · Traditional solutions.
  - · Ruled surfaces: surface of revolution, surface of no revolution.
  - · Not ruled surfaces: surface of revolution, surface of no revolution.
- Masonry work:
  - · With ribs.
  - · With plates.
- Tensioned sets:
  - · Cables.
  - · Suspension cable.
- Gas filled spaces with difference of pressure.

SLOPE FORMATION (plane)

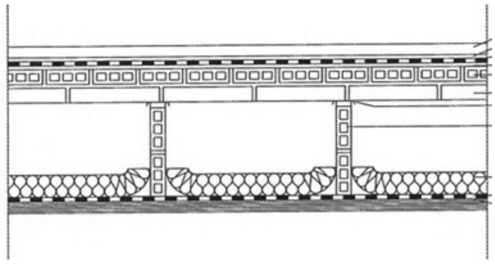


Fig. 4. Slopes system. Minipartitions. Designs by Susana Mora.

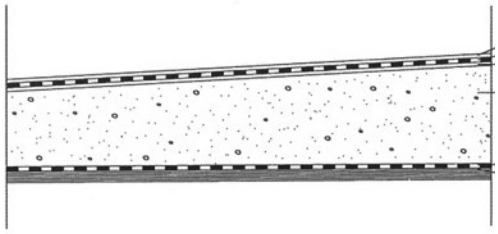


Fig. 5. Slopes system. Lightweight concrete. Designs by Susana Mora.

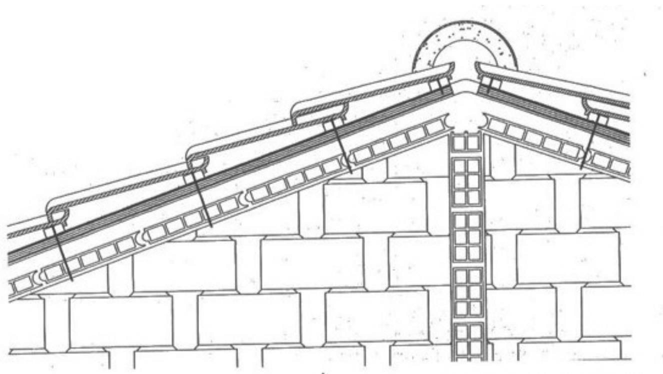


Fig. 6. Indirectly on the slope plane. Designs by Susana Mora.

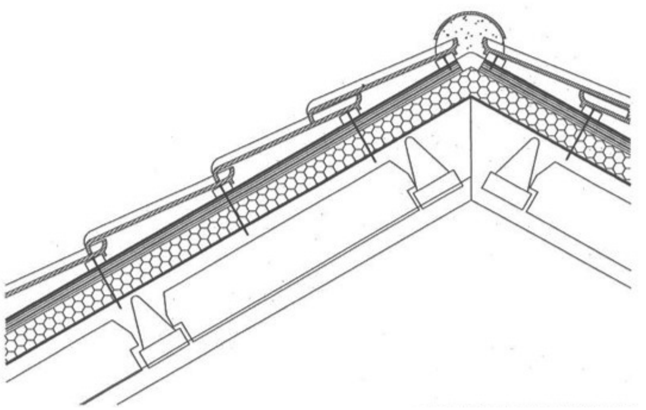
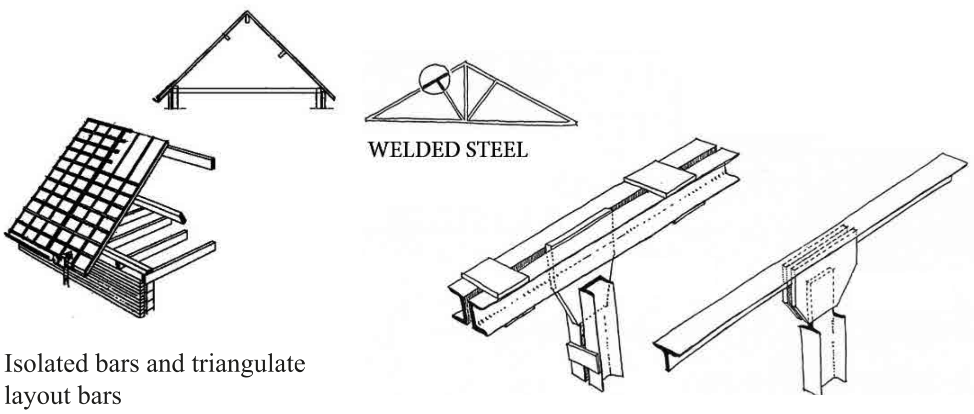


Fig. 7. Directly on the slope plane. Designs by Susana Mora.

SLOPE FORMATION (Bars)



Isolated bars and triangulate layout bars

Fig. 8. Designs by Susana Mora.

HIGH SLOPE ROOFS

- Basic types according to their organization:
  - · On an horizontal flat structure:
    - - Brickwork + Bottom shuttering:
      - · Heavy.
      - · Lightweight.
    - - Brickwork+bars:
      - · Wood.
      - · Steel.
  - · On a sloping flat structure:
    - - Masonrywork.
    - - Modular:
    - - Heavy.
    - - Lightweight.
  - · On a sloping bars structure:
    - - Bars disposed according to:
      - · Maximun slope: Rafters.
      - · Contour lines: Joists.
  - · On a complex bars structure:
    - - Trusses.
    - - Triangled beams.
    - - Portal frame.

- Basic types according to their form:
  - · Eave solutions:
    - - Rafter projection.
    - - Tie beam projection.
    - - Rafter + tie bem projection.
  - · Slopes:
    - - Uniform.
    - - Ashlar solution.
    - - Mansard solution.

- Water drainage:
  - · In lines free fall:
    - - Edges.
  - · In points free fall:
    - - Valleys.
    - - Gutters + Gargoyles.
  - · In lines collection:
    - - Valleys.
    - - Gutters.
  - · In points collection:
    - - Simple absorbers (gully heads).
    - - Syphon gullies + Downspouts.

- Expansion joints.

- Conditioning:
    - - Thermal and acoustic insulation.
    - - Water proofing.
    - - Vapour barrier.

COMMON STEEL PROFILE

OMEGA SHAPE PROFILE ALLOWING NAILING

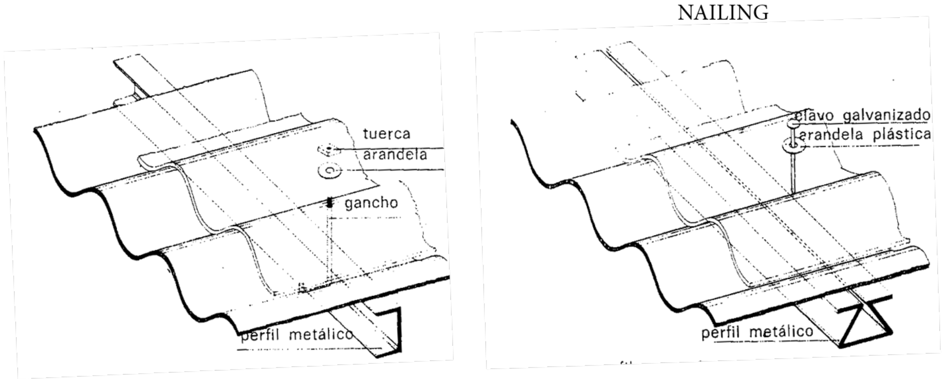
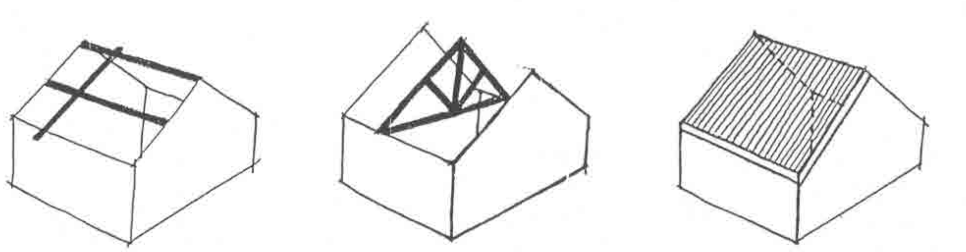


Fig. 9. Designs by Susana Mora.

STRUCTURAL BASE AND SLOPES SYSTEM



ISOLATED BARS IN DIFFERENT POSITIONS

TRIANGULATED BARS

CONTINUOUS PLANS: SLABS OR PRECAST PIECES

Fig. 10. Designs by Susana Mora.

TRADITIONAL STRUCTURAL SOLUTIONS:

– Bundle of rafters (+ joists):
  · Directly supported on the masonry brickwork.
  · Supported on sleepers: “A par y picadero”.

– Bundle of joists (+ small rafters):
  · Supported on the masonry brickwork: “A la molinera”.

– Bundle of rafters on gable roof:
  · Counteracting on the head:
    - Against a ridge bar: “A par e hilera” or close couple roof.
  · Counteracting on the foot:
    - Fixed masonry embebed.
    - With a tensined bar: “Rafter and tie beam”.

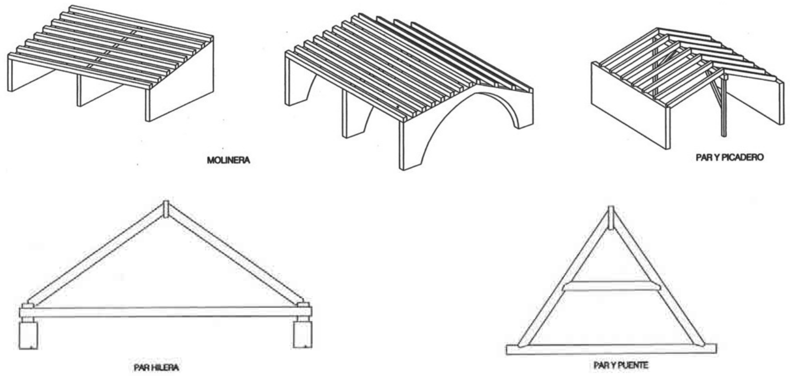


Fig. 11. Traditional solutions with isolated bars. Designs by Susana Mora.

A la molinera

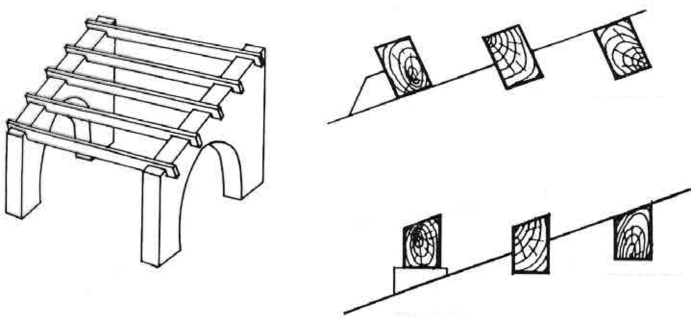


Fig. 12. Design on the left by Susana Mora. Designs on the right by A. Cámara in “*Madera*” for ETSAM.

Par y picadero
Close couple roof

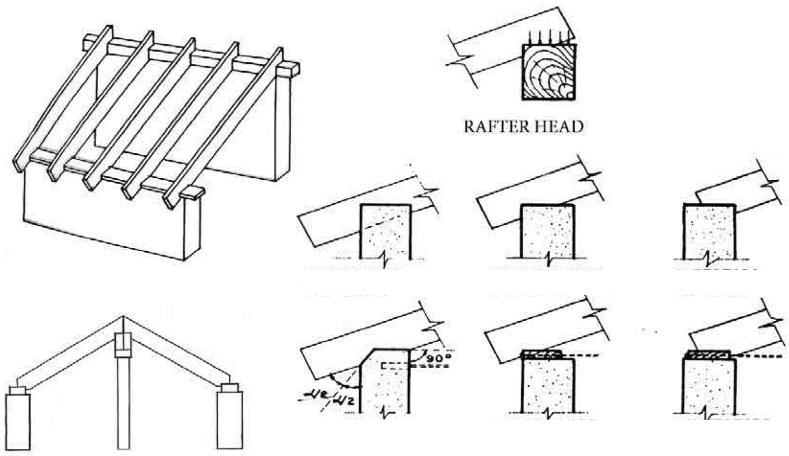


Fig. 13. Traditional solutions with isolated bars. Design on the left by Susana Mora. Designs on the right by A. Cámara in “*Madera*” for ETSAM.

Close couple roof

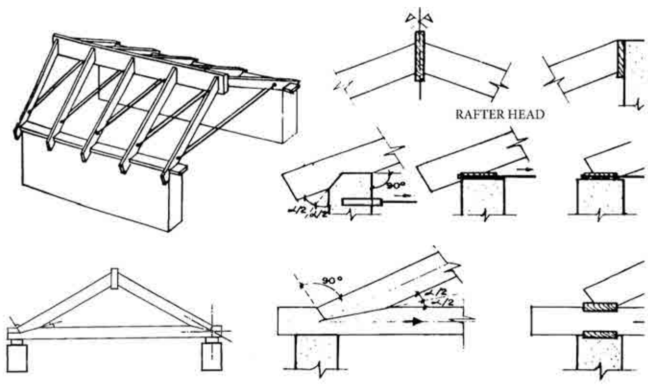


Fig. 14. Design on the left by Susana Mora. Designs on the right by A. Cámara in “*Madera*” for ETSAM.

CONTEMPORARY STRUCTURAL SOLUTIONS

– Contemporary interpretation of traditional solutions:
  · Bundle of rafters.
  · Bundle of joists.
  · Flat pieces or other kind of bars as a complement.
  · Complex structures made of bars.

– Directly on planar structure:
  · Slab.
  · Precast concrete stripes.
  · Light materials prefabricated stripes.

– Indirectly on planar structure:
  · Slab + Brick oper work roof support"+
    - Wooden strip.
    - Steel or concrete joists.
    - Heavy board.
    - Light board.

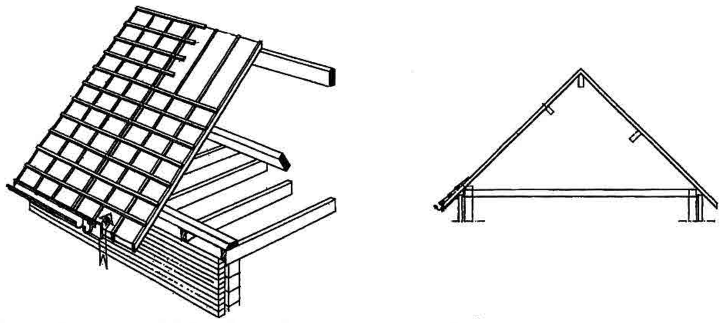


Fig. 15. Bundle of joists supported on masonry work. Designs by Susana Mora.

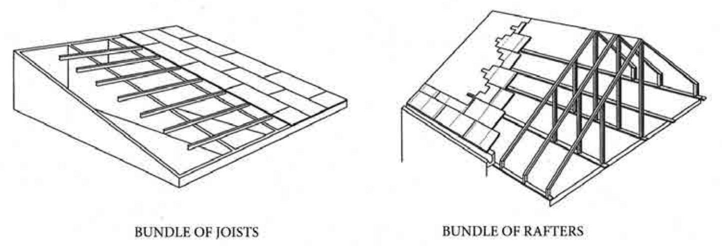


Fig. 16. Designs by Susana Mora.

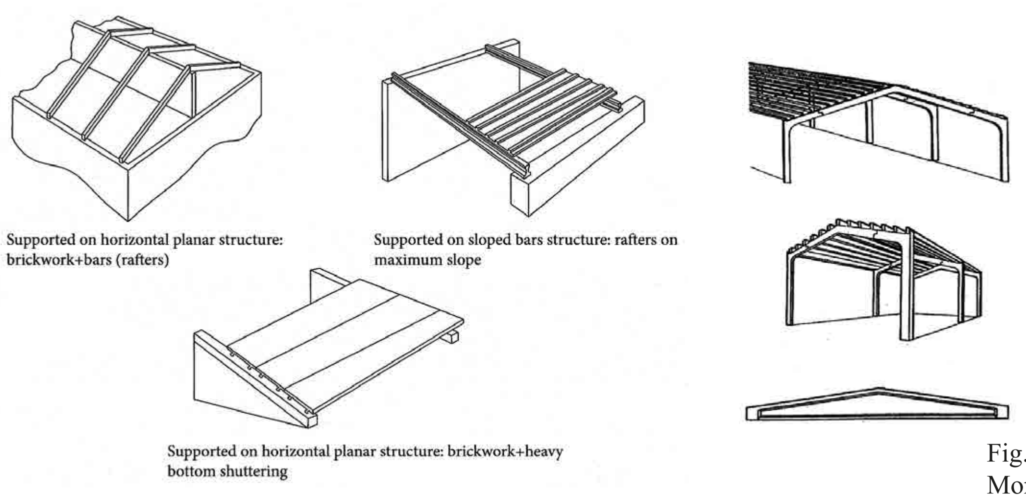


Fig. 17. Designs by Susana Mora.

TRUSSES

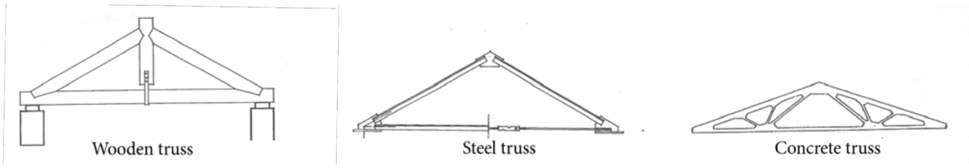
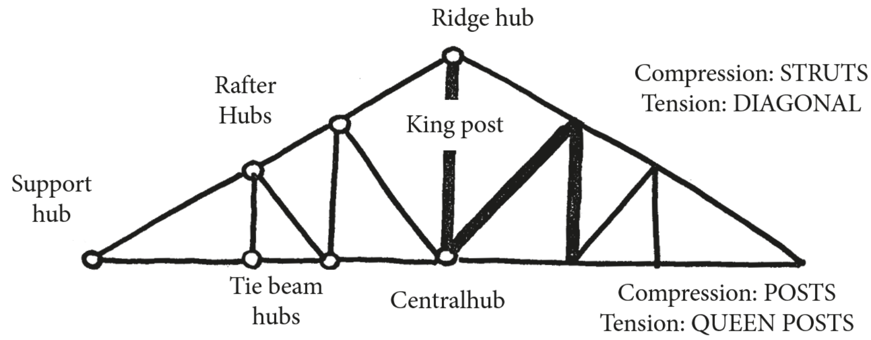


Fig. 18. Designs by Susana Mora.



– Types of truses

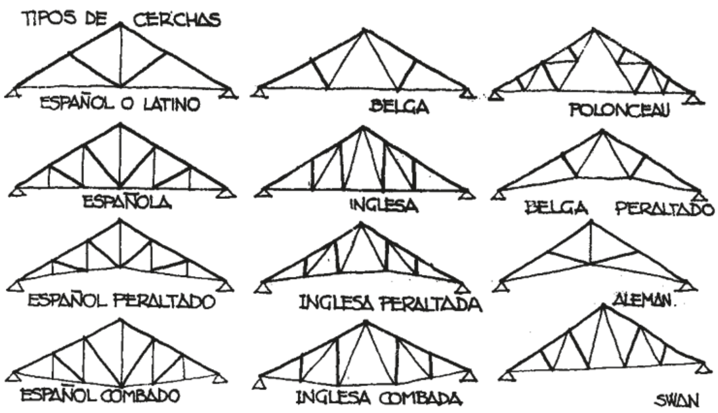


Fig. 19. Designs by Fernando Ripollés.

– Base Structure:

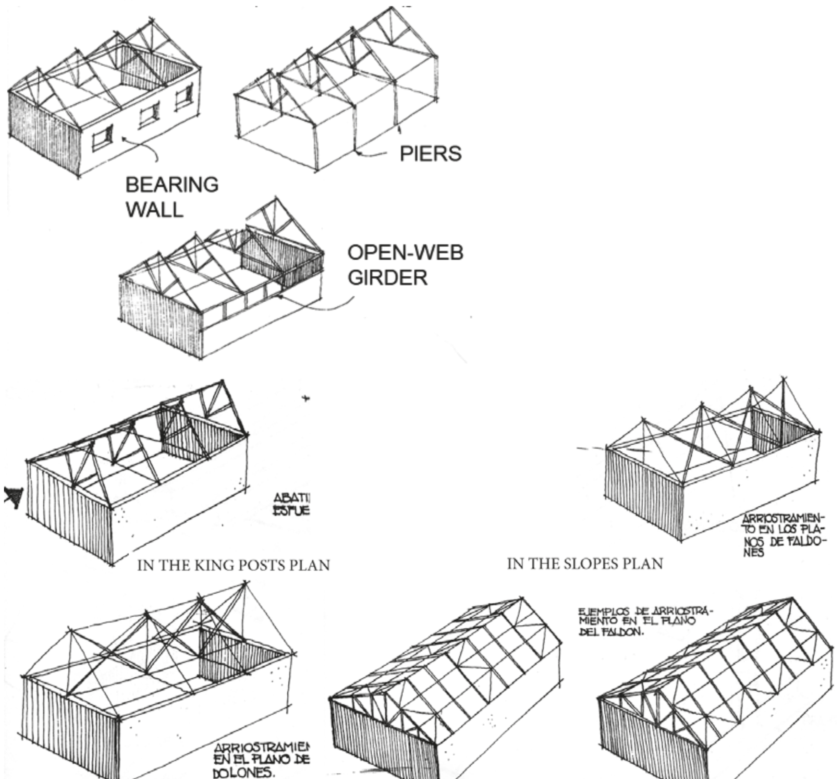


Fig. 20. Designs by Fernando Ripollés.

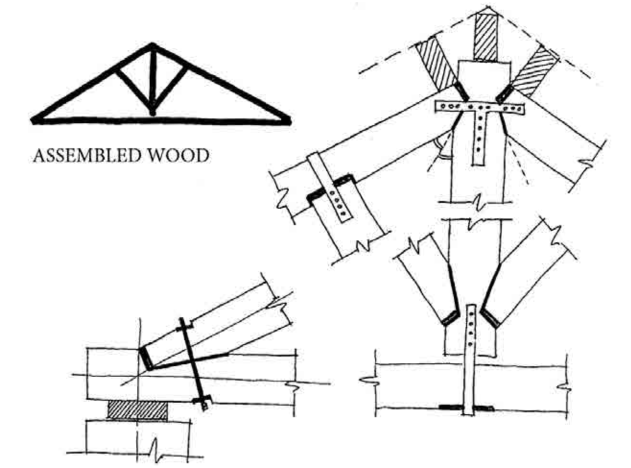


Fig. 21. Designs by Susana Mora.

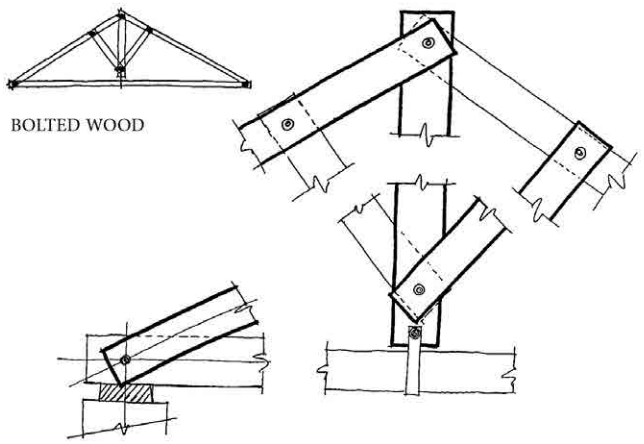


Fig. 22. Designs by Susana Mora.

LAMINATED WOOD

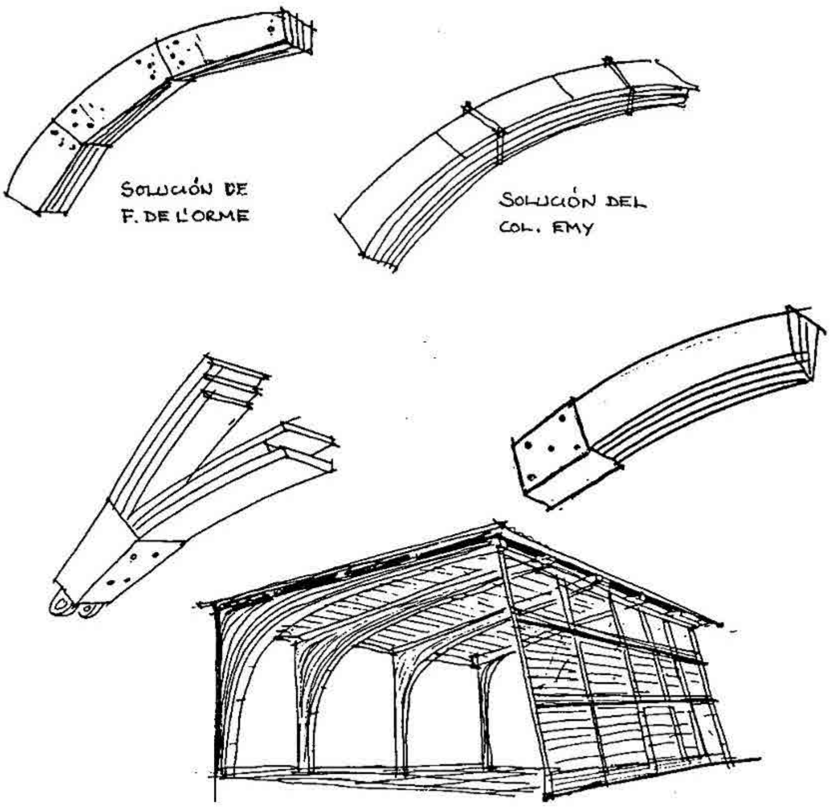


Fig. 23. Designs by Fernando Ripollés.

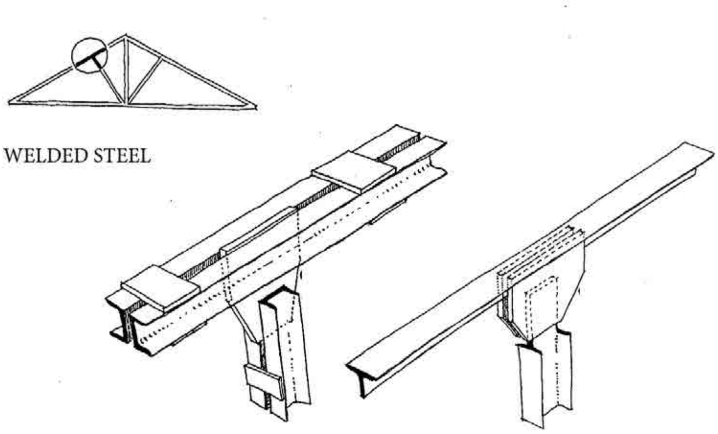


Fig. 24. Designs by Fernando Ripollés.

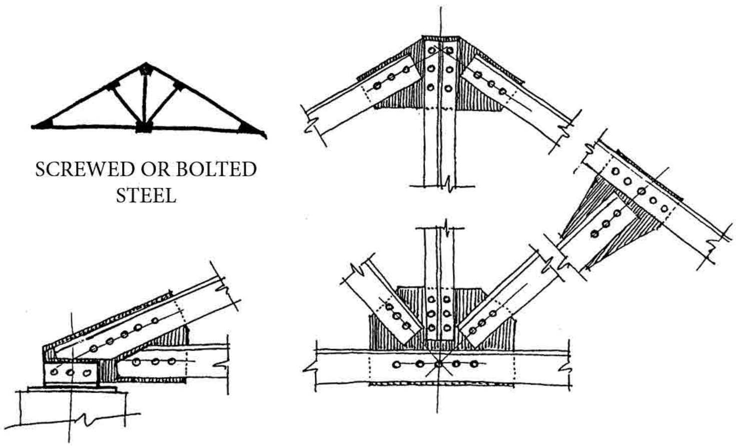


Fig. 25. Designs by Fernando Ripollés.

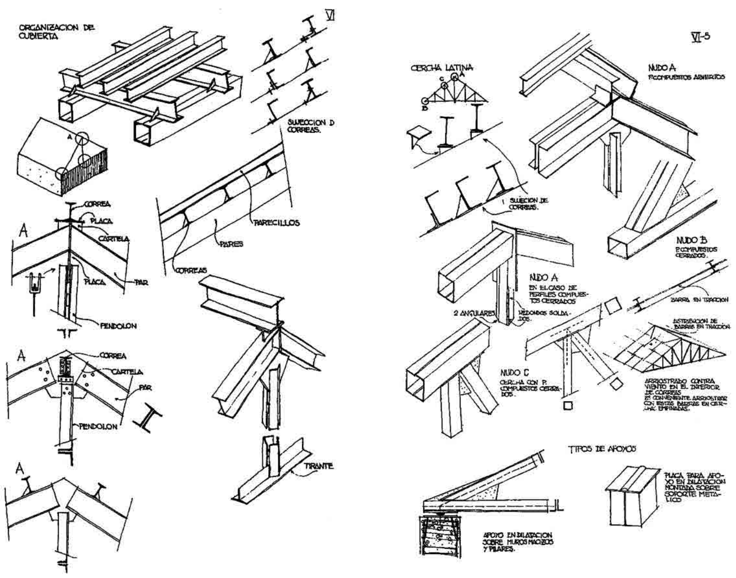


Fig. 26. Designs by Fernando Ripollés.

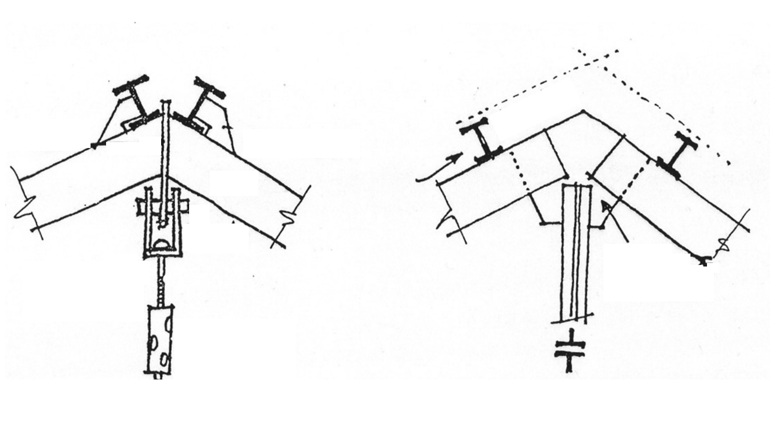


Fig. 27. Designs by Fernando Ripollés.

HIGH SLOPE ROOFS

BASE AND PLANE STRUCTURE

– It can be executed out by any of the following methods:
  · With shingle board, solution in disuse.
  · With big hollow bricks.
  · With prefabricated reinforced mortar ribbed plates.
  · With hydrofuged wood boards.
  · With rippled fibrocement board, when the sheathing is solved with curved tile that has the same curvature as the wave of the rippled board. Supported on steel beams.

HYDROFUGED TIMBER BOARDS

– Pressed wood
– Wood veneer.
– Phenolic pressed wood.

The roof panels are made up of several layers:
– External face: water-repellent agglomerate or phenolic plywood.
– Core: thermal insulation (extruded polystyrene XPS).
– Lower surface: fire-resistant water-repellent agglomerate, phenolic plywood or wood friezes.

RIPPLED BOARD

It leaves additional small air chambers under the waves.

WATERPROOFING

When the slope is < 25% and depending on the type of tile used for the roof cladding, to waterproof the board is necessary.
– Rippled board
  · Fiber cement.
  · Fiber bitumen.

– Waterproofing membrane
  · Bituminous.
  · PVC.
  · Chlorinated rubber.
  · Polymers.

INSULATION

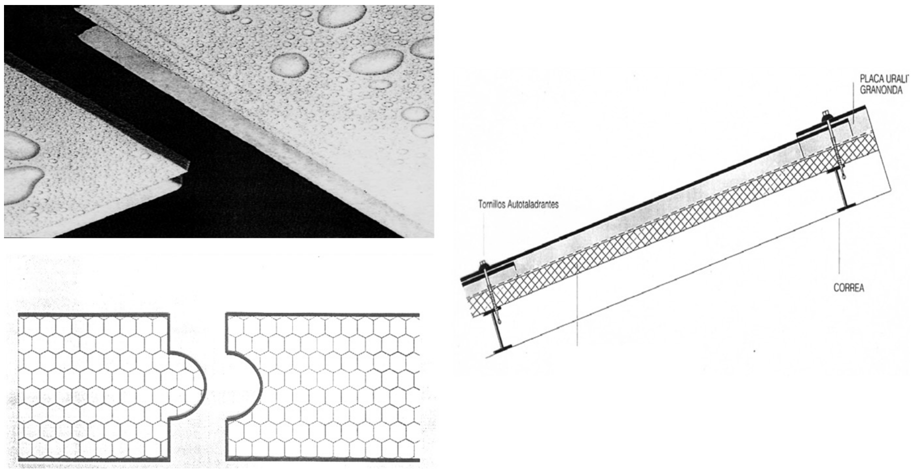
The insulation is achieved with two basic elements:

– The air chamber, which is generated between the structure and the slope plane. It can be more or less ventilated (cold roofs). It also allows dissipation of the water vapour that comes from the under spaces in winter, as well as the heat of the radiation in summer.

– An insulation blanket, laid on the supporting structure. No vapour barrier should be placed underneath them because it would hinder the water vapour from escaping into the chamber that is where it has to arrive to dissipate.

Extruded polystyrene (XPS)

Thermoplastic foam with a homogeneous and closed cellular structure.



Expanded polystyrene (EPS)

Rigid white thermoplastic foam

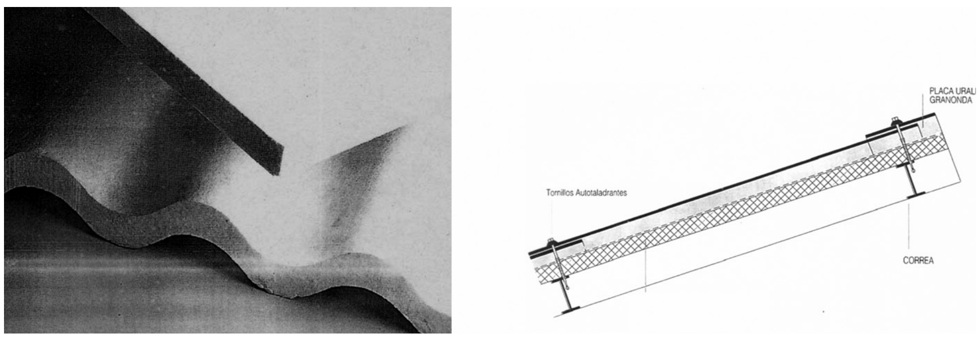


Fig. 28. Photo and designs courtesy of Fernando Ripollés.

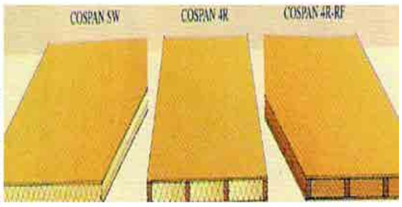


Fig. 29. Hydrofuged timber boards Photo and design courtesy of Fernando Ripollés.

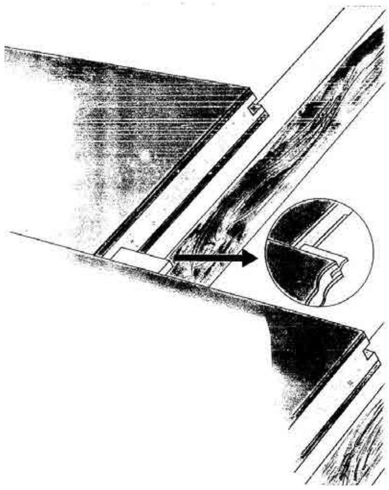
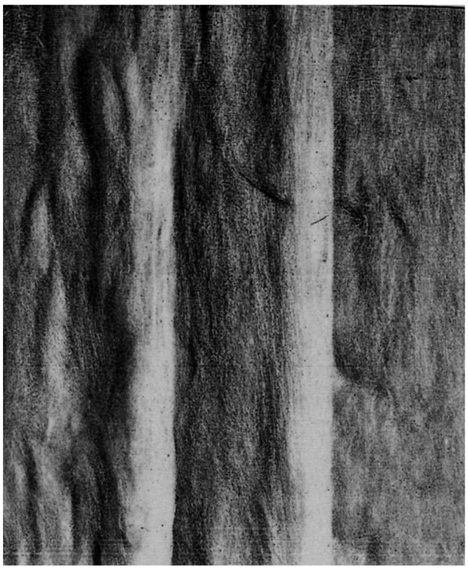


Fig. 30. Panels connection detail. Design courtesy of Fernando Ripollés.

Fiberglass wool:

Glass wool blanket and panel.

Consisting of glass wool agglomerated with thermosetting resins.



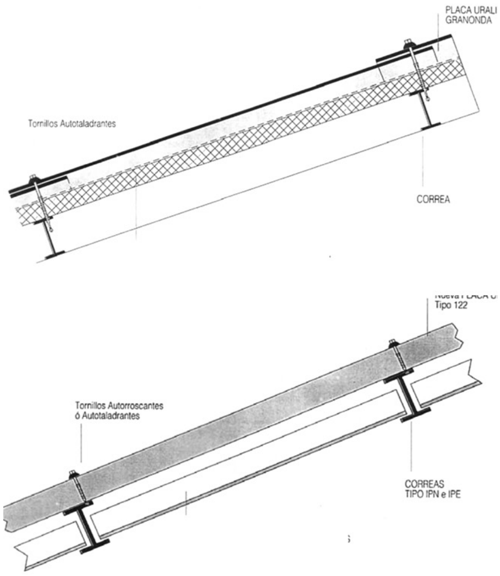


Fig. 31. Designs courtesy of Fernando Ripollés.

Rockwool:

Roof and façade insulation panels

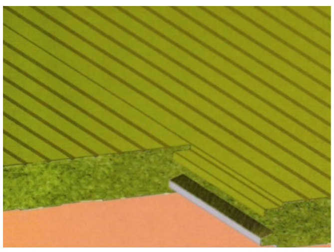
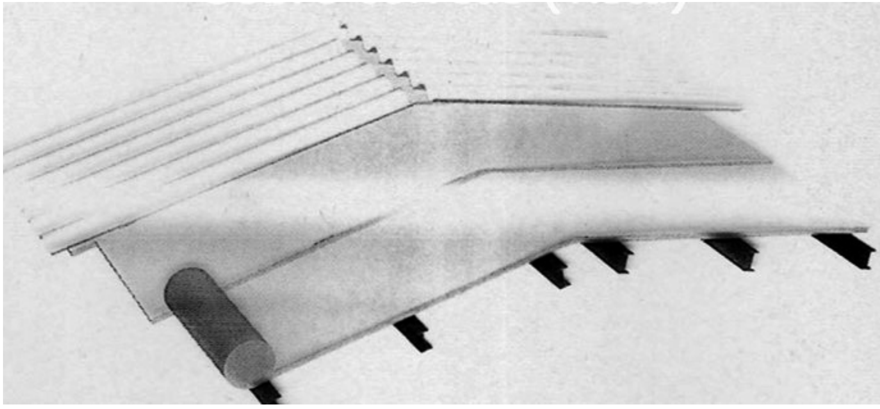


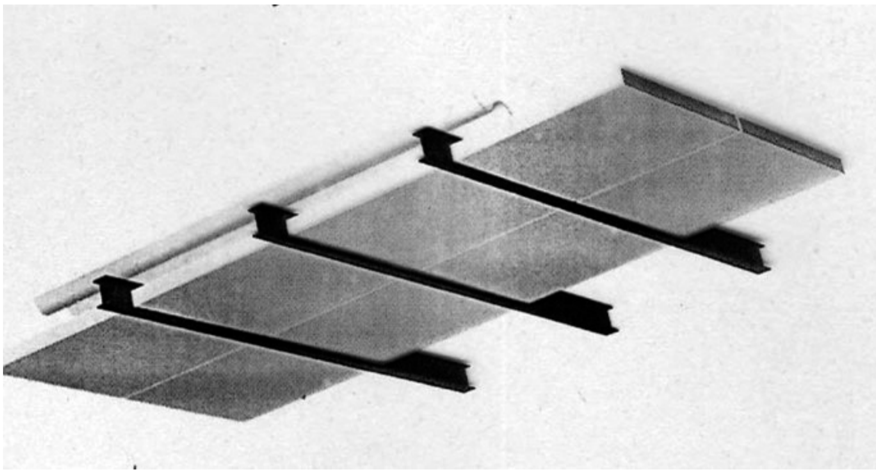
Fig. 32. Photo and design courtesy of Fernando Ripollés.

THE INSULATION POSITION

On top of the joists:



Between joists:



Figs. 33-34. Design courtesy of Fernando Ripollés.

ROOF CLADDING

– Ceramic or mortar roof tiles:
  · Spanish roof tiles, the oldest and most appreciated.
    - Single pattern. One is placed upward acting as a channel and another is placed downward acting as a cover.
  · Mixed roof tiles, S-shapes, with channel and cover in the same piece, some of them double.
    - Flat or French roof tiles, with overlaps hooked on all fronts.
    - Plates, made of different materials, mainly slate, ceramic and fiber cement.

– Fiber cement rippled boards.

– Fiber cement or metal corrugated sheets.

– Metal sheets made of zinc, lead or copper.

FLAT ROOFS: TYPES ANALYSIS

– Analysis by components of high slope and low slope roofs.

– Types of plans.

– Formation of slope in roofs of high slope.

– Structural base.

General considerations of factors conditioning the formal and constructive solutions for roofs, the design criteria, components and classifications have already been described in the previous chapter.

Therefore, the following discourse will be focussed on the particularities of flat roofs.

LOW SLOPE OR FLAT ROOFS

The flat roof is currently in a process of reviewing its function and, therefore, its design. It is not just a question of conceiving it as a plane whose only function is waterproofing.

Thanks to the new technologies existing on the market, the flat roof can fulfill new functions as:

· capture of solar energy.
· water storage.
· green soil area.
· paving.

It makes possible the proposal of modern movement architects about conceiving roofs as the fifth façade of the building.

Fig. 35. *Revista Tectónica*, Tejados, Escuela Técnica Superior de La Coruña.

GENERAL COMPOSITIVE CRITERIA

- General layout:
  - · Floor plan analysis.
    - - Existing downpipes.
    - - Pipes influence divisions.
    - - Points.

- Types according to use:
  - · Non trafficable.
  - · Trafficable.
  - · Special type: garden roofs.

- Types according to organization:
  - · Single layer.
  - · Double layer.
  - · Insulation placement: direct or inverted.
  - · Water drainage:
  - · Free falling.
  - · Water collection:
    - - Linear.
    - - Punctual.

- Conditioning strategies:
  - · Waterproofing.
  - · Thermal insulation.
  - · Acoustic insulation.
  - · Vapour barrier correct placement.

- Elements on the roof plan:
  - · Slope formation layer.
  - · Insulation.
  - · Waterproofing.
  - · External finishing.

- Characteristic features.

WATERPROOFING ELEMENTS AND INSULATORS

TYPES ACCORDING TO MATERIALS

- Sheets and foils (elastic and not elactic):
  - · Butyl Rubber.
  - · Oxyasphalt.
    - - Not protected.
    - - Selfprotected.
    - - Coated.
    - - Reinforced.
    - - Sandwich type.

- Anchors / Stabilizations:
  - · Gravity.
  - · Weight.
  - · Mecanical.
  - · Adhesion.
  - · Hung.

- Covering material:
  - · Plants.
  - · Wood.
  - · Stone.
  - · Ceramic.
  - · Hydraulic.
  - · Metal.
  - · Plastic.
  - · Glass.
  - · Flexible continuous sheets.

- Usual thermal insulation materials:
  - · Rigid.
  - · Flexible.
  - · Granular.
  - · Foam.

- Anchors:
  - · Wood.
  - · Metal.
  - · Mortars.
  - · Nails and staples.
  - · Adhesives.

FLAT ROOFS CLASSIFICATION

According to thermal performance:

– Compact roofs, single layer.
– Ventilated roofs, double layer.

According to placement order for their components:

– Direct roofs.
– Inverted roofs.

COMPACT FLAT ROOFS

There is no air chamber and it is necessary to install a vapour barrier in order to avoid internal condensation.

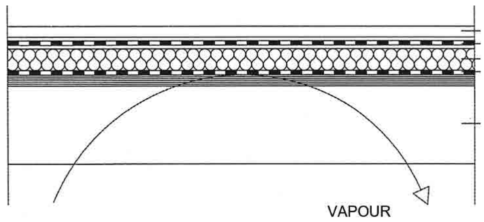


Fig. 36. Designs by Susana Mora.

VENTILATED ROOFS

In order to avoid condensation air or any other material that constantly ventilates it is used as a means of evacuation.
The vapour barrier does not exist and it is replaced by an air cushion that is constantly renewed by openings on the roof pane.

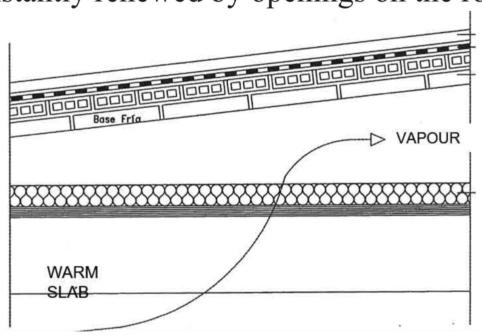


Fig. 37. Designs by Susana Mora.

DIRECT ROOF (dry insulation)

Traditional position of waterproofing elements and insulation.

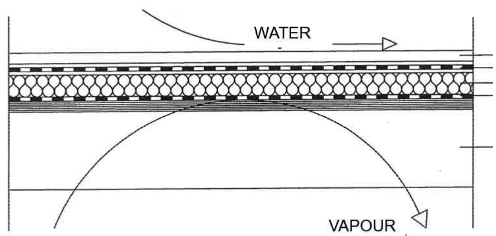


Fig. 38. Designs by Susana Mora.

Finishing options:

– Insulation under slope plane:

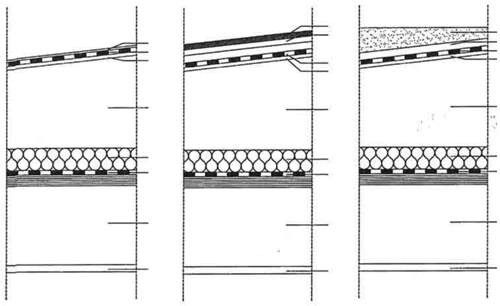


Fig. 39. Designs by Susana Mora.

– Insulation on slope plane:

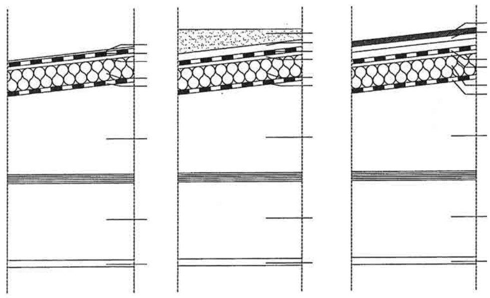


Fig. 40. Designs by Susana Mora.

INVERTED ROOF (hydrophile insulation)

The position of the insulation is reversed and the insulation could be wetted.

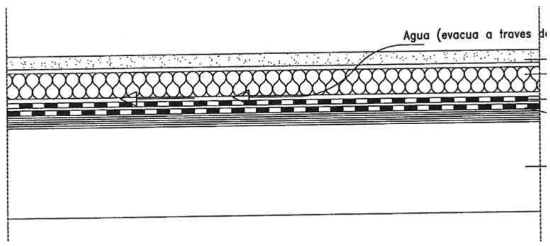


Fig. 41. Designs by Susana Mora.

Finishing options:

– Single layer roof

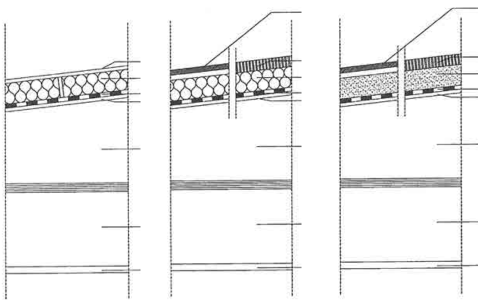


Fig. 42. Designs by Susana Mora.

– Two-layer roof:

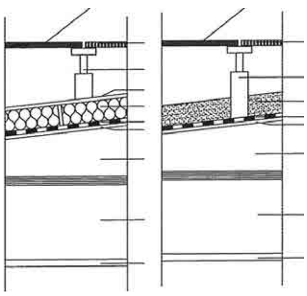


Fig. 43. Designs by Susana Mora.

Details:

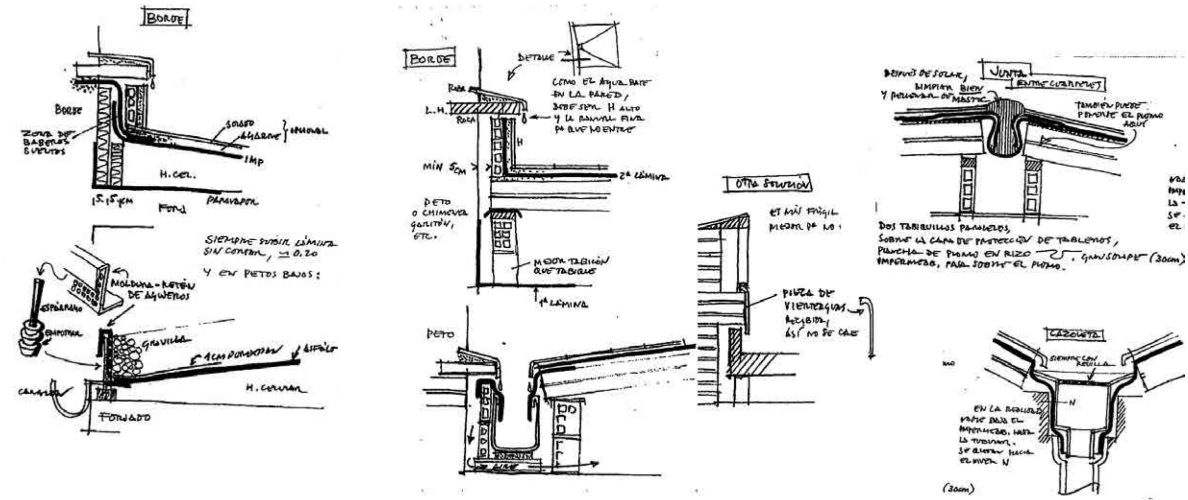


Fig. 44. Designs by Fernando Ripollés.

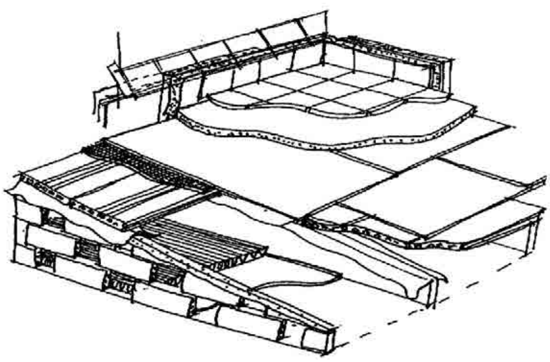


Fig. 45. Design by Fernando Ripollés.

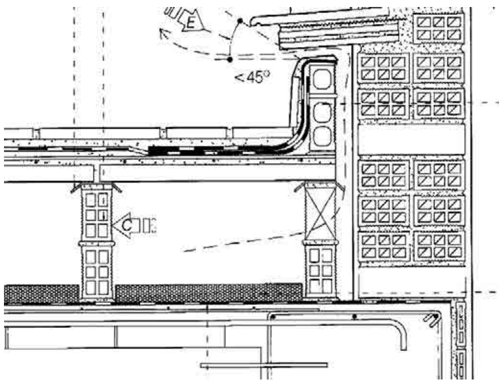
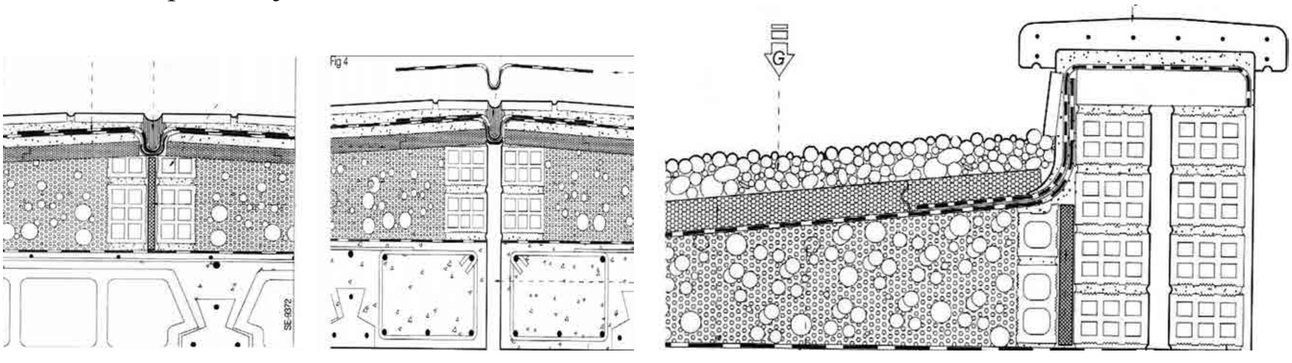
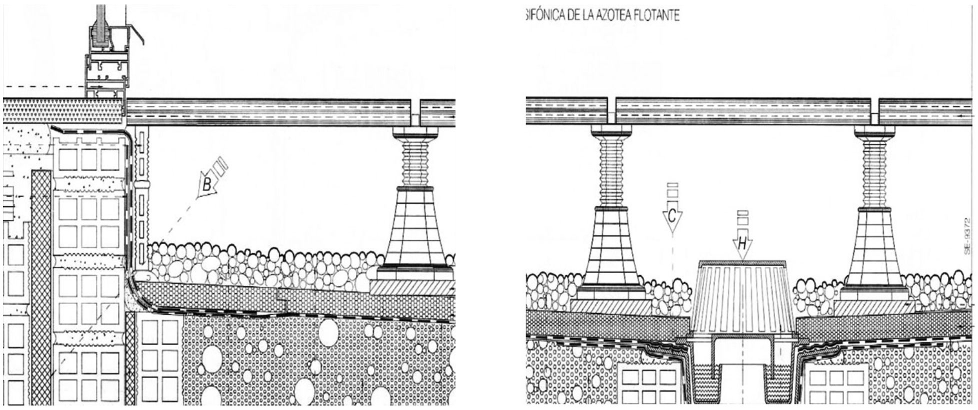


Fig. 46. Design courtesy of Fernando Ripollés.

HIPS

Structural expansion joint:





Figs. 47-48. Inverted. Copied Detail. Designs courtesy of Fernando Ripollés.

Fig. 49. Two-layer inverted. Trafficable. Designs courtesy of Fernando Ripollés.

SELECTION CRITERIA. TYPES.

- Traditional.
  - A. - Not trafficable with heavy protection.
  - B. - Trafficable.
  - C. - Not trafficable with selfprotected membrane.
- Inverted.
  - D. - Not trafficable with heavy protection.
  - E. - Trafficable.
- Green Roof.
  - F. - Garden roofs.
  - G. - Eco-friendly. Water storage systems.
- Metal Plate Base.
  - H. - Deck:
    - · Not trafficable.
    - · Gravel ballast.
    - · Heavy protection.
- SPECIAL USE.
  - I. - Deck system for road traffic.

TRADITIONAL LOW SLOPE ROOF

On the roof deck, a slope formation layer with a minimum slope of 2% and a minimum thickness of 3 cm is disposed. A vapour barrier compatible with the material of the waterproof membrane sheet is placed on top of it.

Above these, thermal insulation panels are placed and an auxiliary geotextile layer is placed on top of them to guarantee that the waterproof sheet does not adhere to the thermal insulation material.

The waterproofing sheet is placed on top, over the rest of the system components and on top of it, an anti-puncture and non-stick geotextile sheet that improves the puncture resistance of the whole, and prevents the transmission of stresses from the pavement to the rest of the system.

The roof finishing is made with a heavy protection, which prevents the waterproofing sheet from being lifted up by the actions of the wind.

TRADITIONAL LOW SLOPE ROOF WITH HEAVY PROTECTION

Characteristics:

This type of thermally insulated roof is the most widespread solution of the group of warm or non-ventilated, flat roofs.

It is useful in cold climates, with moderate summer temperatures.

It can therefore be used as long as there are no significant thermal gradients.

It is solved as compactly as possible.

In case of adapting the floating solution between the different elements of the system, possible harmful interactions between elements for the stability of the whole can be avoided.

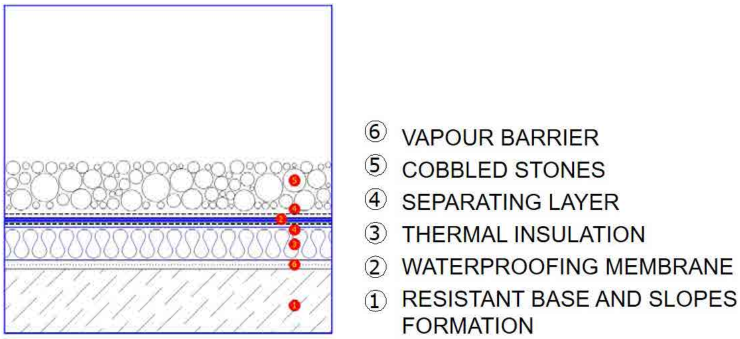


Fig. 50. Design courtesy of Fernando Ripollés.

Execution process:

The roof finishing is a heavy protection, which prevents the waterproofing sheet from being lifted up by the actions of the wind. The minimum thickness of gravel in ballasted systems is 5 cm.

In this solution, the geotextile sheet placed on top of the waterproofing sheet must have a greater thickness, since it must be able to protect the waterproofing membrane from the punching action that the gravel may exert on it due to the eventual use of the roof for maintenance work.

Special care must be taken in the solving of the drains, so that smaller aggregates cannot cross them, falling down the drain pipes and breaking the pipes connections.

TRADITIONAL LOW SLOPE ROOF TRAFFICABLE WITH CERAMIC TILES PROTECTION

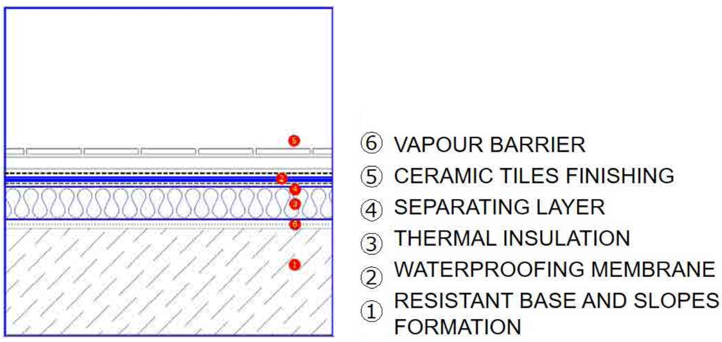


Fig. 51. Design courtesy of Fernando Ripollés.

TRADITIONAL LOW SLOPE ROOF TRAFFICABLE WITH RAISED FLOOR.

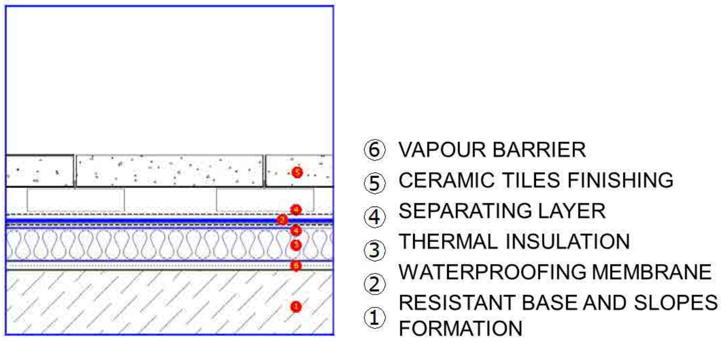


Fig. 52. Design courtesy of Fernando Ripollés.

LOW SLOPING INVERTED ROOF

It is a type of thermally insulated roof.

It is suitable for climates with high thermal gradients.

If it is used for trafficable roofs, the thermal insulation material must have mechanical resistance that allows it to absorb the loads received.

The thermal insulation material is subjected to the action of water. If the waterproofing material has a high accessible porosity from the outside, it will be wetted and the insulation properties will disappear.

As it is thermally protected, the waterproofing sheet is subjected to less dilatation-retraction stresses and, therefore, its durability will be increased.

Due to their low density, the buoyancy of the insulation panels makes dangerous any water retention on the deck if they are not properly ballasted. The auxiliary layer that is placed on top of the panels contributes to their stability.

As with all flat roofs, a more careful solution of the singular points is required.

The minimum thickness of gravel in this kind of ballasted systems is 5 cm.

The thermal insulation must have a water absorption under 0.5% by volume so that, its insulating conditions are not altered as a result of the moisture absorbed. Even so, in this type of roof, the calculation conductivity must be increased by 10% to compensate not only the 0.3% possible absorption but also any losses due to joints or singular points.

INVERTED LIGHT SLOPE FLAT ROOF NOT ACCESSIBLE. WITH HEAVY PROTECTION.

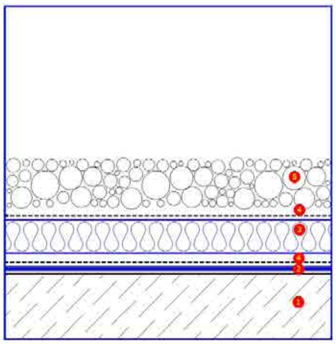


Fig. 53. Design courtesy of Fernando Ripollés.

LOW SLOPING INVERTED ROOF NOT TRAFFICABLE. WITH HEAVY PROTECTION.

As the roof is not trafficable, the thermal insulation does not necessary need special mechanical requirements.

If the thermal insulation is protected with gravel, there must be a separating layer that distributes the punctual tensions that the gravel may produce during maintenance work.

If the thermal insulation material is not protected, there is a danger of wind suction due to the light weight of these materials.

LOW SLOPING INVERTED ROOF TRAFFICABLE.

The gravel is replaced by a trafficable pavement.

The difficulty of evaporation of the water that filters between the joints of the pavement, and that can be stored in the existing layers above the waterproofing sheet, makes it advisable to use some complementary drainage system.

In the case of using floating pavements, the possibility of storing water is minimised, as the water that penetrates can easily evaporate.

This system allows for the use of any type of paving material.

The thermal insulation material must have mechanical resistance properties that are directly related to the type of use envisaged.

INVERTED LIGHT SLOPE FLAT ROOF TRAFFICABLE. WITH CERAMIC PROTECTION.

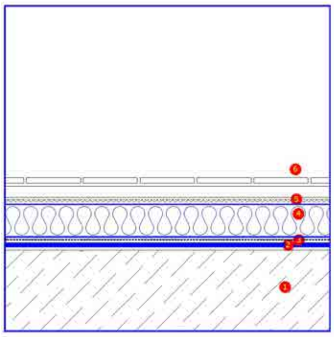


Fig. 54. Design courtesy of Fernando Ripollés.

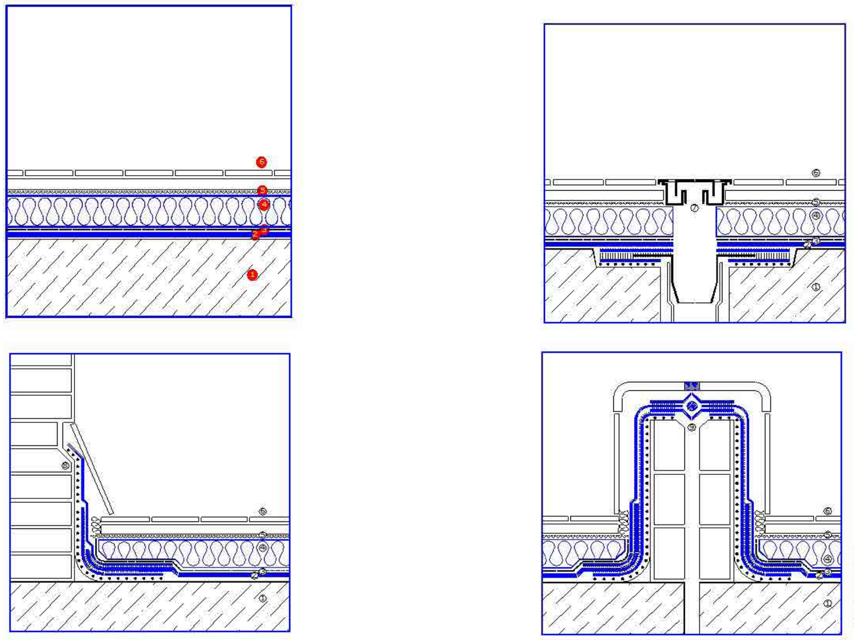


Fig. 55. Design courtesy of Fernando Ripollés.

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1) See BROTRÜCK T., *Construcción de cubiertas*, ed. G.G., Barcelona 2021;

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CHAPTER 18. FAÇADES: POROUS SYSTEM, VENTILATED FAÇADES, COMPACT SYSTEM AND CURTAIN WALLS

GENERAL OVERVIEW

– Panels system with open joints. The performance of the ventilated façade. (1)

– Stone cladding and anchorages. Lightweight ceramic façades. The execution of the openings. The corners. The upper and lower finishes. The delimitation of the openings.

FUNCTIONS

– Protection.
– Relationships.

LIVABILITY

– Comfort:
  · Humidity.
  · Temperature.
  · Brightness.
  · Noise.

– Security in the face of:
  · Mecanical actions:
    - Wind.
    - Rain.
    - Blows.
  · Physical actions:
    - Water.
    - Hygrothermal Changes.
    - Chemical actions:
      · Living organisms.
      · Pollution.
      · Fire.

EXTERNAL AGENTS RELATED TO FAÇADES

– Water (liquid, solid, gas).

– The sun:
  · Day light.
  · Heat (infrared radiation).
  · Dilatation.
  · Desiccation.

- Chemical Effects (ultraviolet radiation).
- Wind (direction, speed, duration):
    - · Dynamic pressure.
    - · Temperature variation.
    - · Inner ventilation.
    - · Physical effects.
- Animals and plants.
- People (noise, pollution).
- Fire.

FAÇADES TYPOLOGIES

1. Simple walls.
2. Double walls:
    - With inserted outer leaf.
    - With through outer leaf.
    - With hanging outer leaf.
3. Heavy façades. Porous:
    - Simple walls.
    - Double walls.
    - Double walls with inserted outer leaf.
    - Double walls with through outer leaf.
    - Double walls with hanging outer leaf.
4. Lightweight façades.
    - Ventilated façade
        - A. - Open joint panels system.
            - Porous:
                - · Stone cladding.
                - · Ceramic cladding.
                - · Wooden lightweight cladding.
                - · Concrete.
            - Compact:
                - · Metallic panels.
    - Curtain walls. Compact system:
        - B. - Studs and transoms system.
        - C. - Modular façade system.
        - D. - Structural glass system.
    - Complementary elements:
        - Framing.
        - Glass.

HEAVY FAÇADES

DOUBLE WALLS

- The Anglo-Saxon solution of the CAVITY WALL, with interior load-bearing wall and self-supporting exterior leaf starting from below, with anchorage keys to the internal wall. It is limited to a maximum of 4 floors.

- The Spanish solution of the capuchin wall, with ceramic or metallic keys.

The solutions of non-structural walls differ according to how the support of the outer leaf of the façade on the edge of the slab is solved:

- *INSERTED LEAF:* Both leaves are inserted between two successive slabs.

- *THROUGH OUTER LEAF -HEAVY-:* The exterior leaf is supported by cantilever brackets projecting in front of the edge of the floor slab.

- *HANGING OUTER LEAF -LIGHT-:* the support system on the slabs is replaced by a system of anchors (hanging and retention).

Fig. 1. Photo by Alfonso García Santos.

DOUBLE WALLS WITH INSERTED OUTER LEAF

Both layers are inserted between the successive slabs.

This is the current conventional façade: heavy outer layer sheet of facing + air chamber + inner partition wall.

The outer sheet is plastered inside with cement mortar to improve the watertightness, since the humidity can reach its full thickness and reach the chamber.

The outer sheet rests directly on the edge of the slab, with a small overhang to cover the front of the slab with the same appearance as the rest of the façade. In this solution, the support always interrupts the continuity of the outer layer, the insulation and the air chamber.

It is necessary to check that in the calculation of the floor slab is limited to the deformation of the edge (either beam or strap) so that it is compatible with the rigidity of the brick wall.

DOUBLE WALLS WITH THROUGH OUTER LEAF

The outer sheet is supported by cantilever brackets in front of the slab edge. The bracket can be a L-shape metal profile, a concrete heel protruding from the slab itself or a sturdy and resistant ceramic bracket.

These brackets reduce the thermal bridging.

In this solution, only the outer layer or the insulation can pass through. The air chamber is interrupted by the supports on each slab level. In rainy climates, a solution for the bottom of the chamber must be provided (waterproof flanching and water outlet).

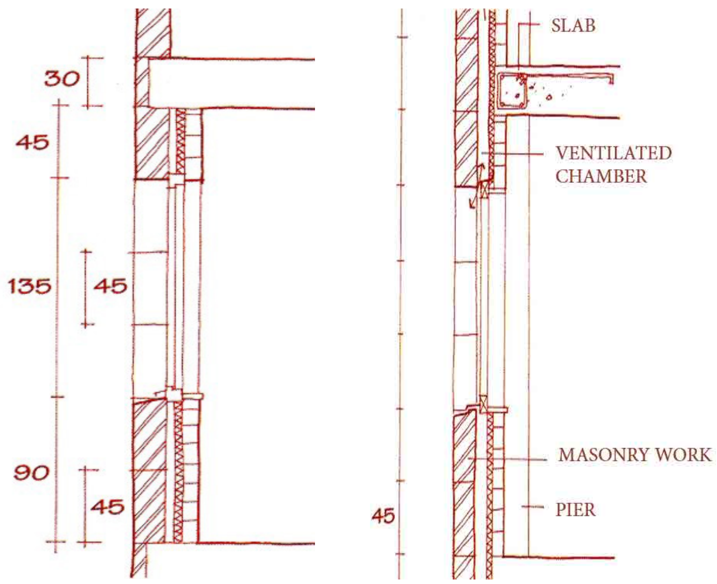


Fig. 2. Designs by Alfonso García Santos.

DOUBLE WALLS WITH HANGING OUTER LEAF

The system of support on slabs is replaced by a system of anchors (hanging and retention) that supports the weight of the outer layer and transfers that weight (together with the action of wind) to the inner support leaf.

The outer layer can be made of stone cladding pieces, hydrofuged wood board, metal cladding, ceramic cladding.

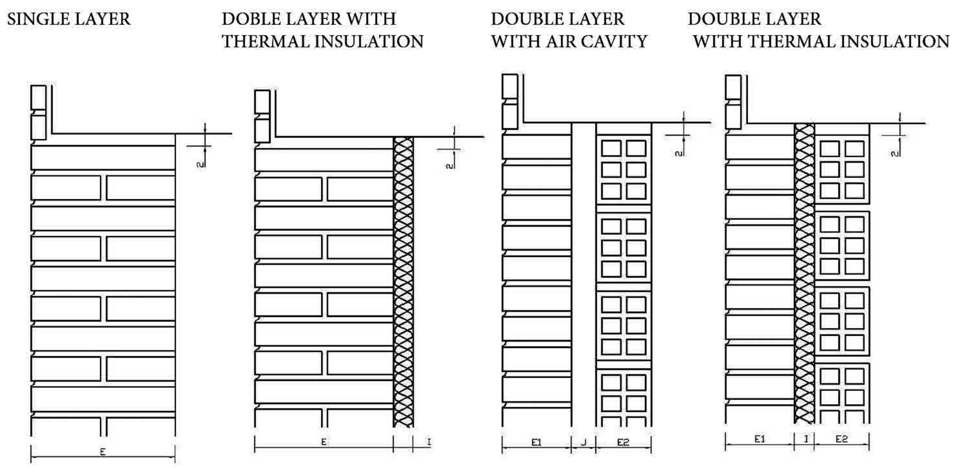
The outer layer is not adhered to the support but hung at a certain distance in order to create the necessary space for the air chamber and the layer of thermal insulation. The thermal insulation can pass in front of the slab and completely eliminate the thermal bridges of the conventional solution.

DOUBLE WALLS WITH HANGING OUTER LEAF

Solutions for outer leaf hanging from the interior support:
- Concrete panels.
- Ventilated stone façade: Façade tiles with open joints, anchored to direct fixings on the internal supporting wall.
- Same, with indirect anchors to a grid studs framework that is fixed at various points to the internal supporting wall.
- Same, with a substructure of profiles fixed to the slabs edges or pier lines.

CERAMIC FAÇADES

ENCLOSURE TYPES



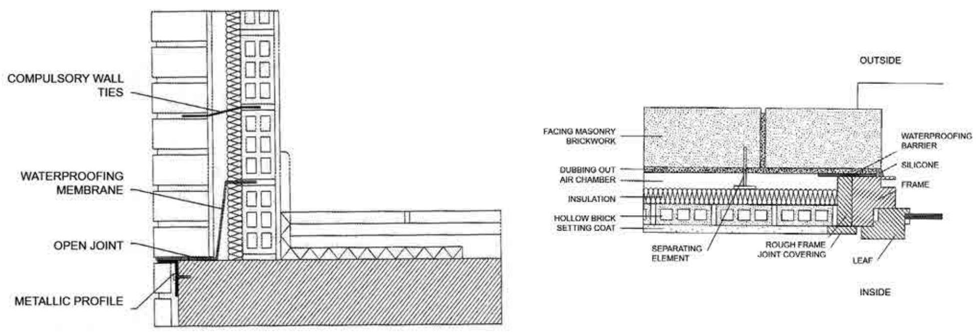


Fig. 3. Ceramic façades. Connections. Designs by Alfonso García Santos.

VENTILATED FAÇADE PERFORMANCE

– Ventilated façade (rain screen) ADVANTAGES:
    · Semi-permeable outer leaf, reducing the water entering the chamber.
    · Opened air chamber from below, which allows the evacuation of water.
    · The chamber must be open on top and/or laterally to allow the ventilation and evaporation of water.
    · The thermal insulation covers the entire enclosure and eliminates thermal bridges.
    · The inner leaf and the structure have little thermal load and therefore few expansions.
    · The outer sheet has a ventilated chamber at the back that cools it and reduces its expansions.
    · Both inner and outer leaves are unlinked and can move independently.

– Ventilated façade (rain screen) DISADVANTAGES:
    · Façades exposed to wind pressure:
        - Risk of water entering through any crack or open joint. The interior of the building will have less pressure than the vented façade.
    · The uniformity of the pressure inside the chamber can produce water inlets, because the external pressure changes in this same façade: higher pressure on top of the façade, or, at the same height, pressure has different intensity and sign depending on the orientation facing to the wind (leeward or windward) or also because of the situation with respect to the changes of plane (external corners, internal corners, eaves, etc.).
    · The only option is to confine the chamber, giving rise to a new type of façade with confined chamber (or sectorized).

EXECUTION OF A FAÇADE WITH SECTORED CHAMBER

The confinement or sectorization of the chamber:
– It must be effective (without cracks that allow the air to escape and modify the internal pressure).
– It will allow the water that has entered through the joints to escape.
– It will leave a chamber between the support and the cladding to facilitate fast drying.
– Be careful when the chamber meets the openings: avoid infiltrations.

Vertical sectoring:
– Anchorages using stainless steel or extruded-aluminium T-shaped profiles can be used.

Horizontal sectoring:
– Z-shaped profiles can be used.

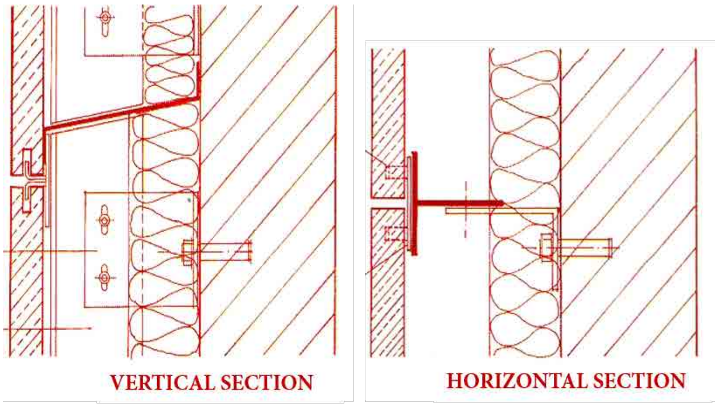


Fig. 4. Designs by Alfonso García Santos.

OPEN JOINT PANELS EXTERNAL CLADDING SYSTEM

LIGHTWEIGHT FAÇADES: FUNCTIONAL ANALYSIS

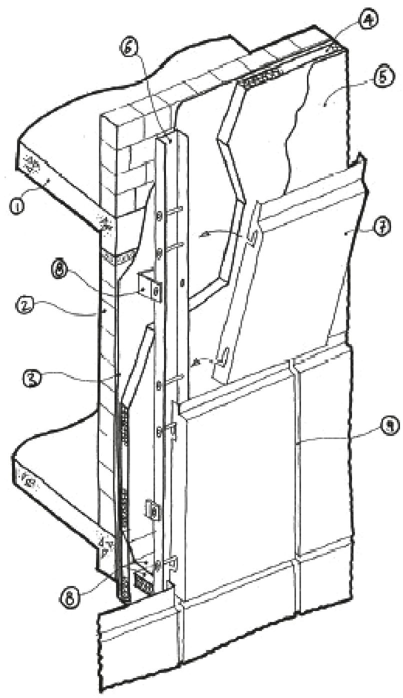
- Sealing: Secured by the finishing material (metal sheet, composites). Joints multiplication problem: closed (sealed) or open (ventilated) joint systems.
- Thermal insulation: incorporated in the panel (sandwich panels) or in the chamber between insulation and interior support. Condensation: if the façade material is a vapour barrier, it must necessarily be ventilated from behind.
- Acoustic insulation: Special care must be taken to ensure that the joints between the panels are airtight.
- Thermal expansion: Always provide very thin material. Façade orientation, colour and size of the pieces.
- In the sandwich panel there must be no contact between the exterior and interior sheet (tºC are very different, with differential expansion, which can produce convex curvature towards the outside).
- Joints: Substructure to structure. Panel to substructure. Panel to panel (horizontal joint, vertical joint).

LIGHTWEIGHT FAÇADE

- Self-supporting.
- Light (little thickness, little weight).
- Multi-layer.
- Dry-assembled.
- Based on large panels or pieces.

ELEMENTS

· Support.
- Anchorage system.
- Joint.
- Panel.



Components:

1. Main structure.
2. Structure supporting the enclosure.
3. Vapour barrier.
4. Insulation.
5. Vapour membrane (optional).
6. Auxiliary structure for pannels.
7. Open joint pannels.
8. Infiltered water evacuation flashing.
9. Joint between pannels: open.

Fig. 5. Design by Ramón Araujo.

LIGHTWEIGHT FAÇADES: THE FAÇADE SUPPORT

– Lightweight (linear) substructure made of aluminium, stainless steel or galvanised steel.
– Thick wall (surface) which supports the load of the anchors (load weight + wind pressure) and guarantees airtightness in ventilated façade solutions.
– Mixed, with auxiliary framing as anchorage support.
– The façade support has to make up for the lack of coordination between the cladding panels and the other components.

LIGHTWEIGHT FAÇADES: ANCHORAGES

– Direct: on substrate wall or at the back of it.
– Indirect: on framing structure.

MATERIALS

· Aluminium.
· Galvanized steel.
· Stainless steel.

ASSEMBLY

· 3D position regulation:
· Line-up, plumbing vertical alignment or leveling.

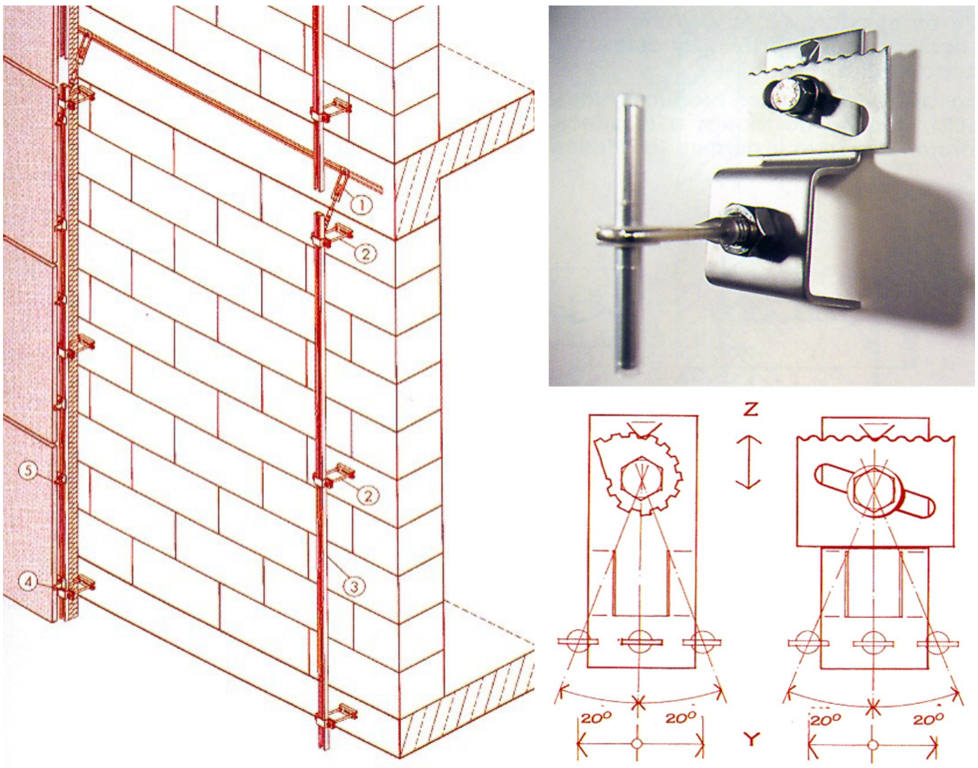


Fig. 6. Designs by Ramón Araujo.

LIGHTWEIGHT FAÇADES: JOINTS

- The panel may have the same or different design for of vertical and horizontal joints.
- Joint problems:
  - · Geometry.
  - · Sealing.
  - · Airtightness.
  - · Watertightness.
  - · Mounting tolerance and expansion clearance:

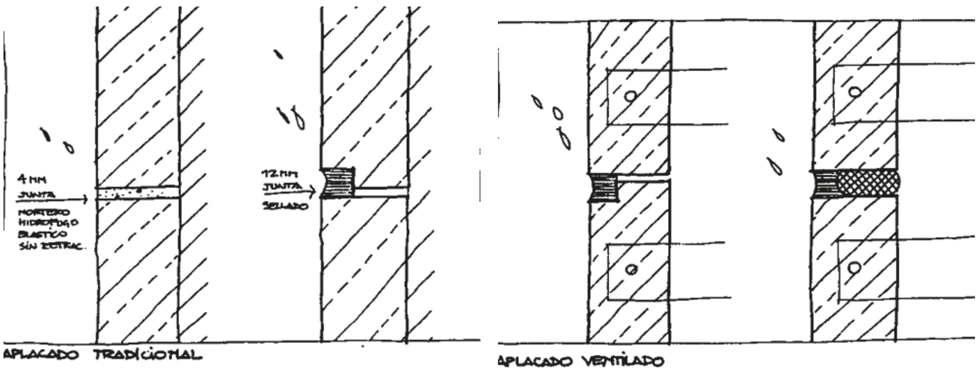


Fig. 7. Designs by Alfonso García Santos.

LIGHTWEIGHT FAÇADES: TYPES OF JOINTS (gaskets)

- Closed waterproof joint: double sealing gasket and an intermediate closed chamber.
- Open waterproof joint: closure by simple sealing, with open chamber to the outside for equalization of pressures and evacuation of the water that can enter.
- Permeable joint:
  - · This is the open joint for ventilated façades. It makes it possible to equalize the pressure between the ventilated chamber and the exterior, reducing the entry of water. It is essential to compartimentalise in corners and cornices to avoid air suction from the side façades or from the roof.
  - · Being very wide, the permeable joint increases water ingress.
  - · Being very narrow produces water entry by capillarity and can limit the expansion of the panel. Recommend between 5 and 10 mm wide.
  - · Not suitable for sandwich panels.
  - · Suitable for façade renovation working from outside (continuity of use of the building), adding insulation to façades that did not have it and renewing the envelope appearance without any demolition work.

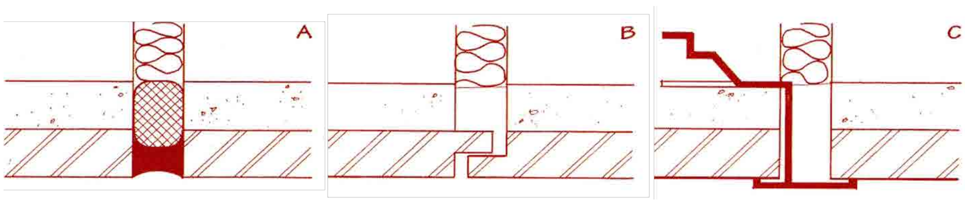


Fig. 8. Designs by Ramón Araujo.

STONE CLADDING FAÇADES

- Traditional cladding.
- Ventilated cladding.

STONE CLADDING TYPES AND THEIR RESPONSE TO WATER

– 2 types of cladding:
  · Traditional cladding façades.
  · Ventilated cladding façades.

– 3 types of water action on stone façades and walls:
  · Rain: Downward and horizontal penetration of rainwater.
  · Water vapour: Condensation and/or hygroscopic absorption by wetting the stone.
  · Soil moisture: Upward penetration by capillarity (stone / mortar / filler). The phenomenon especially affects masonry stonework walls.

TRADITIONAL CLADDING FAÇADES

– Description:
  · Lower quality masonry brickwork.
  · Natural stone plates external cladding. Thickness = 20 / 25 / 30 mm
  · Anchored to the support with 5 mm thick annealed brass or stainless steel rods, and glued at the back of the plate with 1:3 cement mortar proportions of CEM I-32.5 and sand.
  · Joints between plates are executed with PVC spacers of 1.5 mm thick and externally grouted with CEM I-32.5 or BL-32.5 cement grout.
  · The lack of expansion joints can produce great stresses in the cladding (4 mm in 10 metres of façade for a thermal jump of 50 ºC), leading to breakage of the anchorage and dislocation of the cladding or movements out of its plane.

– Performance:
  · These façades present different problems due to rainwater:
    - Water absorption in the joints (microcracks, detachment, horizontal capillarity).
    - Soaking of the cladding and the mortar at the back of the plates.
    - Water abundance in the masonry work which supports the cladding and the need to drain the chamber.
    - Water entering by lintels of openings with windows aligned to the external surface.
    - Stains due to differential drying of the plates, with recalcitrant wet areas.
    - If the quality of the anchors has not been controlled, rust stains may appear on the metal rods (galvanised steel) and, eventually, detachments of some plates.

–

– Good practices:
  · To prevent water entering through the joints:
    5 mm joint thickness is recommended, sealed with ready-mixed joint mortar: water-repellent, slightly elastic and without shrinkage.

  · To avoid the entry of water through the plates:
    Water-repellent treatment on the external surface. To improve the result, extend the water-repellent treatment to the inner face, ensuring that ultraviolet rays will never degrade the product.

  · To minimize the entry of water.
    Risks of interior humidity and the shaving of dispersed and recalcitrant stains on the outside are avoided.

VENTILATED FAÇADES. STONE CLADDING FAÇADES

– Description:
  · Stone plates outer leaf. Plates thickness > = 3 cm, with open joints > = 5 mm.
  · Open air chamber 4 or 5 cm thick.
  · Thermal insulation of extruded polystyrene plates / rock wool / projected polyurethane foam, density 40 kg/m^3, 3 cm thick.
  · Masonry brickwork / concrete blockwork enclosure.
  · Stainless steel anchors that transfer the loads from the cladding to the enclosure.

– Performance:
  · The cladding absorbs water and drains it in an easy and uniform way due to the ventilation of the chamber.
  · The water that penetrates into the chamber can be drained to the outside by the lower part.
  · Any additional element (windows flushing to the outside, etc.) that supposes a brake to the vertical drainage of the water from the chamber must be adequately designed.

– Problems:
  · Mechanical.
    - Reinforced concrete support. Thickness = 15 cm.
    - Problems with the concrete block.
    - Anchoring. Better vertical than lateral.
  · Breakage of plates by shock, suction or pressure.
    Plates thickness is obtained by test admitting 1/3 of the average of breakage.
  · Fire.
    Rock wool with water-repellent coating on the outside.
  · Wind.
    Confining and sectoring of the chamber.

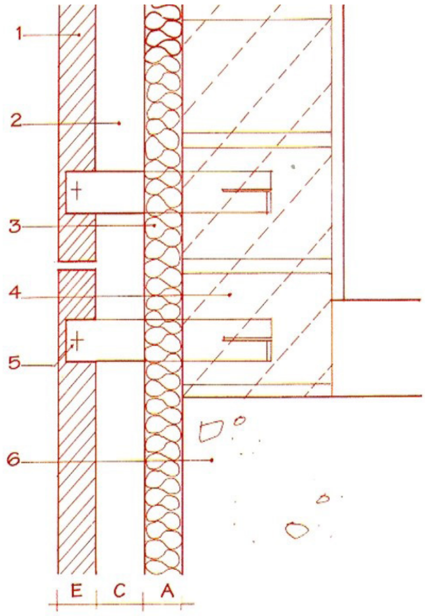


Fig. 9. Designs by Ramón Araujo.

– Types or anchorages and fixing:
  · With open joint, anchored to direct fixings on the inner supporting wall. The air chamber is created by the anchorage itself by regulating its depth. The chamber ventilates by a grid of open joints.
  · With indirect anchors to a studs and transoms framework fixed to the internal supporting wall. It facilitates the anchors fixing and makes the installation process more precise and faster.
  · With a substructure of profiles fixed to the slab edges or pier lines. The support layer has been replaced by the profile framework and the internal finish is solved with any lightweight backing solution. (This solution is acoustically weak and may require acoustic absorption material in a second non-ventilated chamber).

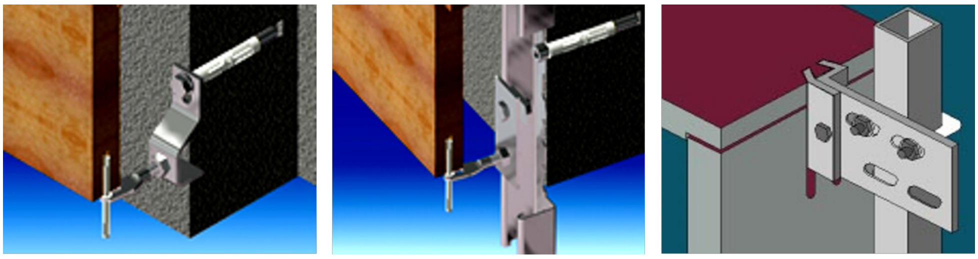


Fig. 10. Designs courtesy of Alfonso García Santos.

LIGHTWEIGHT CERAMIC FAÇADES

– MODULAR FAÇADES.
  · Single track.
  · Double track.
– VENTILATED FAÇADES.
– WATER AND AIRTIGHT FAÇADES
– ACOUSTIC FAÇADES.

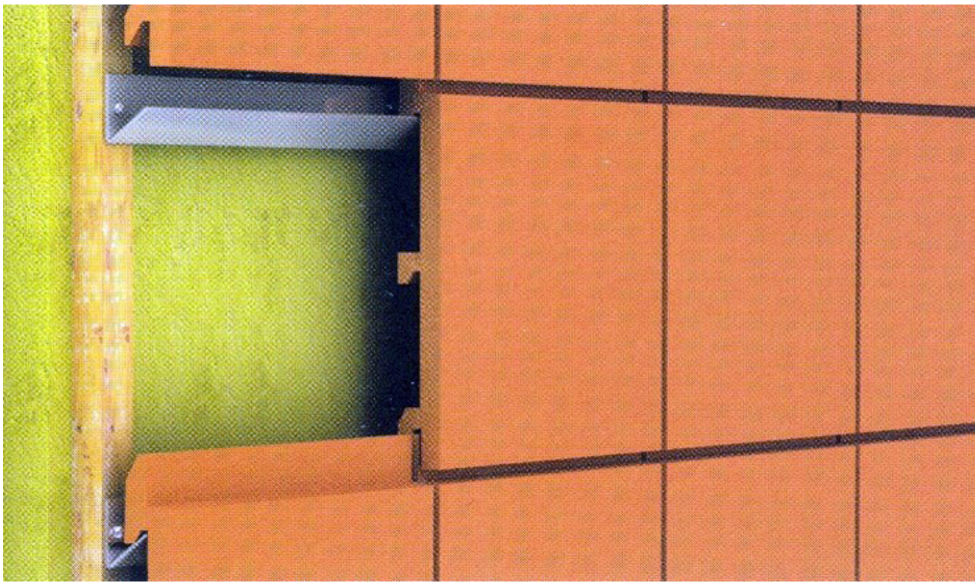
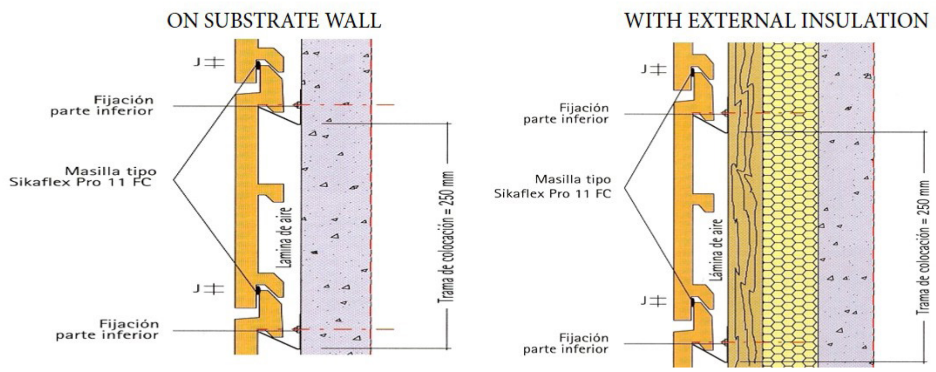


Fig. 11. Single track. Designs courtesy of Alfonso García Santos.



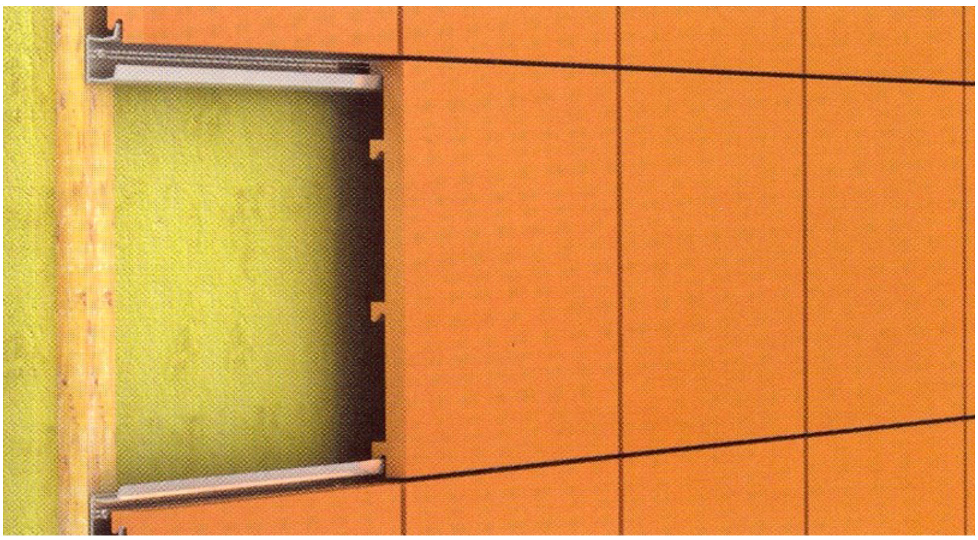


Fig. 12. Double track. Designs courtesy of Alfonso García Santos.

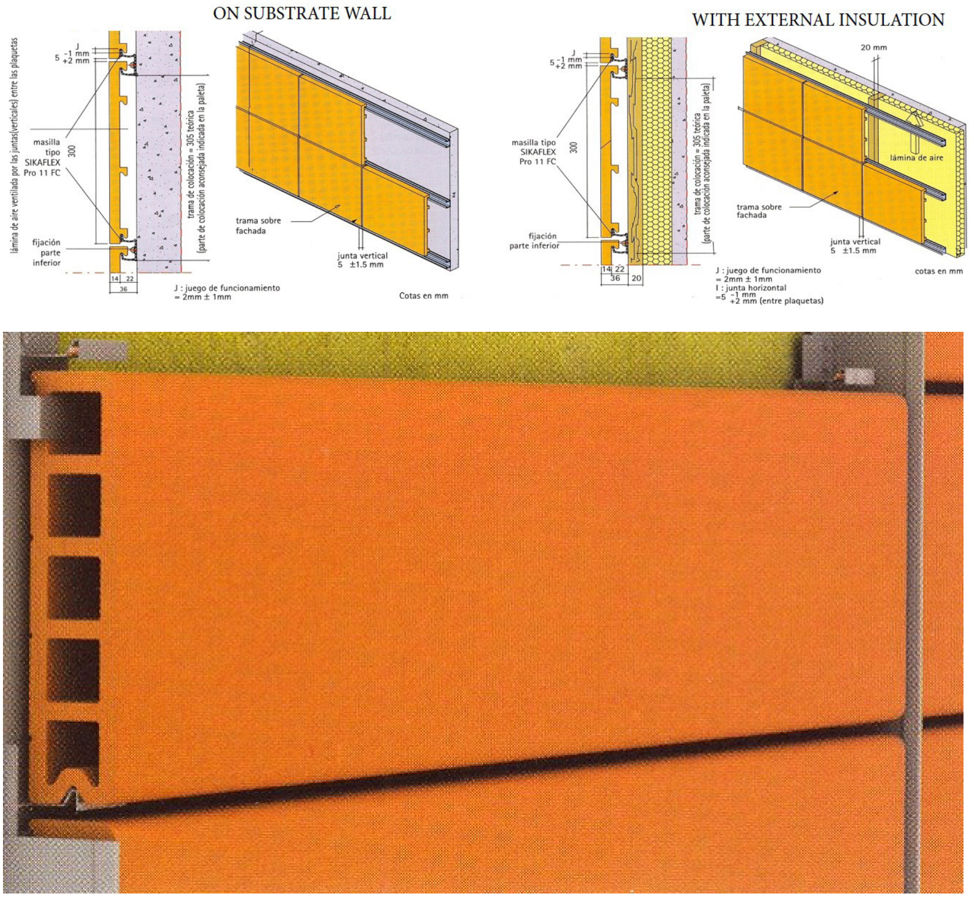


Fig. 13. Lightweight ceramic façades. Designs courtesy of Alfonso García Santos.

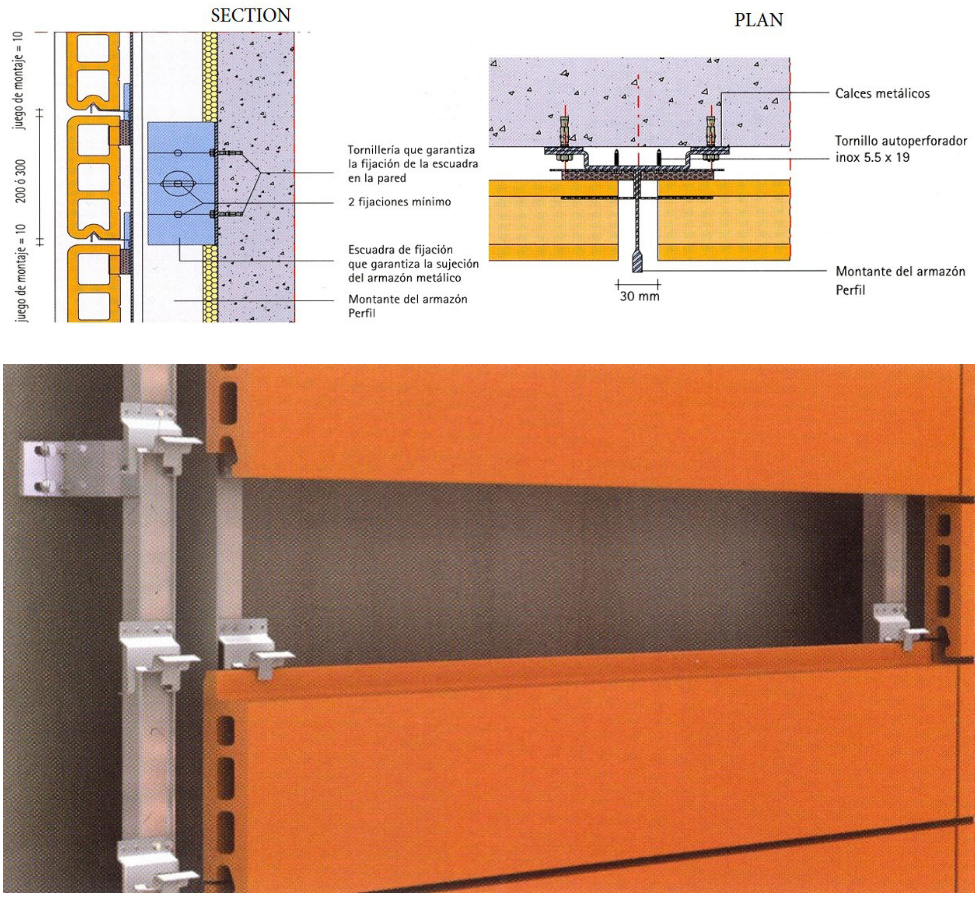
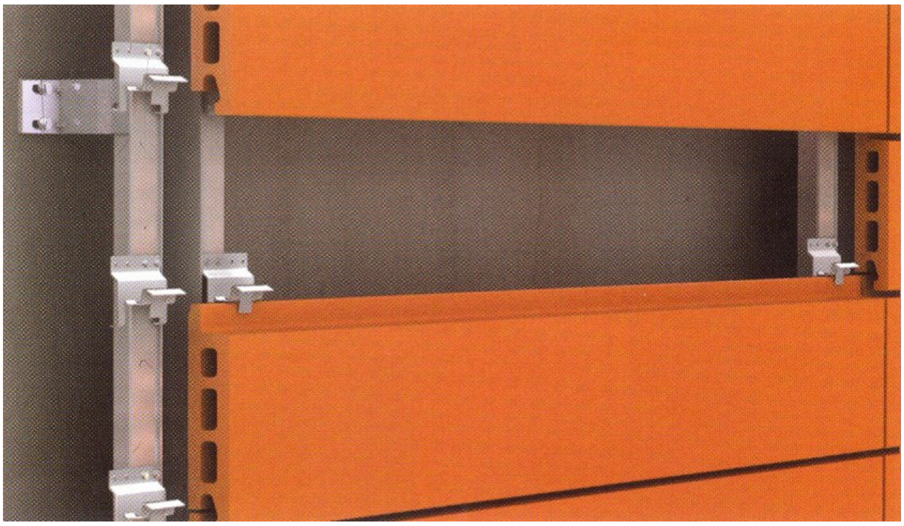
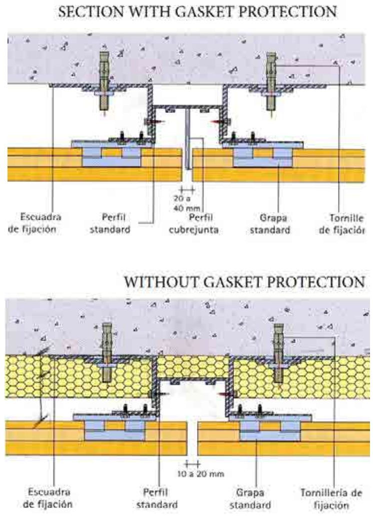
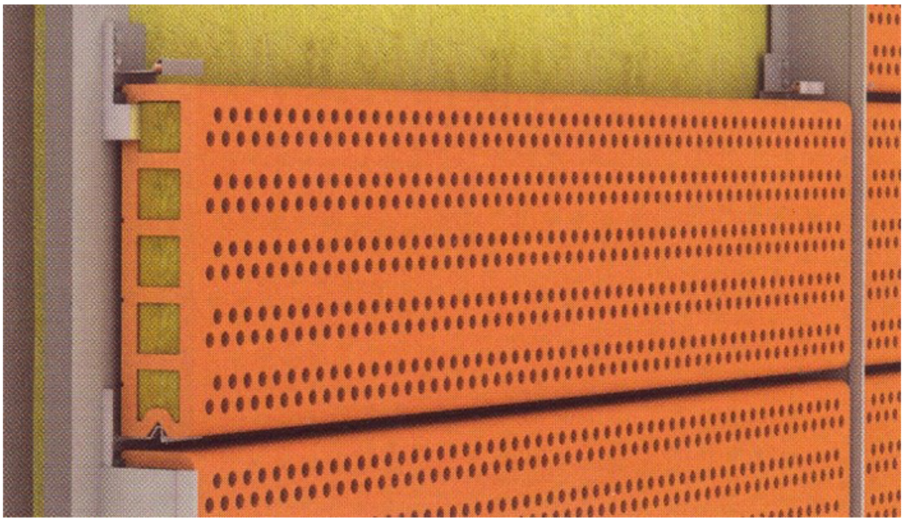


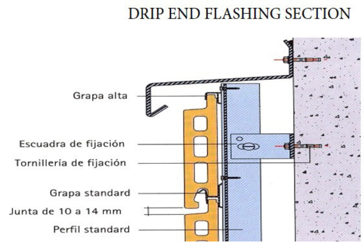
Fig. 14. Sealed ventilated façades. Designs courtesy of Alfonso García Santos.

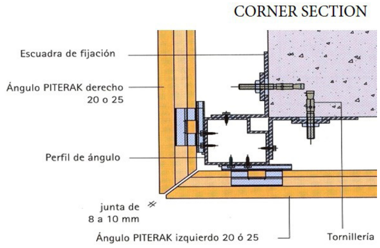




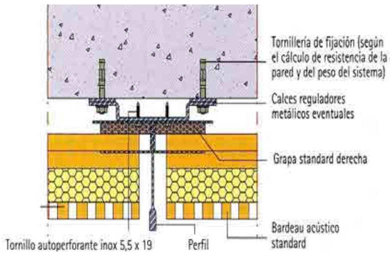
Sealed ventilated façades.







Acoustic façades.



Ceramic latticework.

Prefabricated rough frames for window openings. They act as a pre-frame than can be incorporated into any type of construction and wall dimension, fixed by anchor pins. They are used to finish off the perimeter of the openings.

Fig. 15. Designs courtesy of Alfonso García Santos.

LIGHTWEIGHT WOODEN FAÇADES

The present concept of the wooden façade appears in the nineteenth century connected to to the evolution of the saw and industrial nailing.

TYPES OF LIGHTWEIGHT WOODEN FAÇADES

- Structure made up of props and sleepers finished with boards joined together in solidarity.
- Cladding with wood on a different type of support.

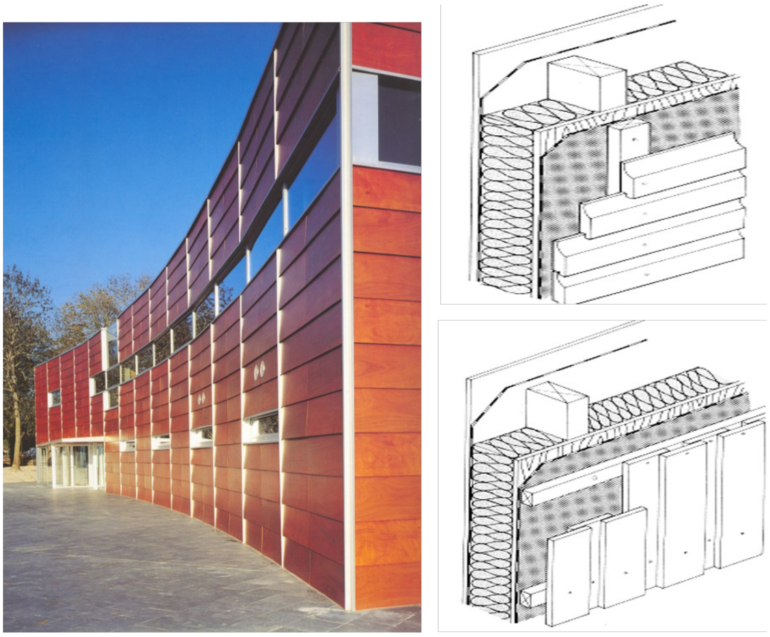


Fig. 16. Photo and designs by Ramón Araujo.

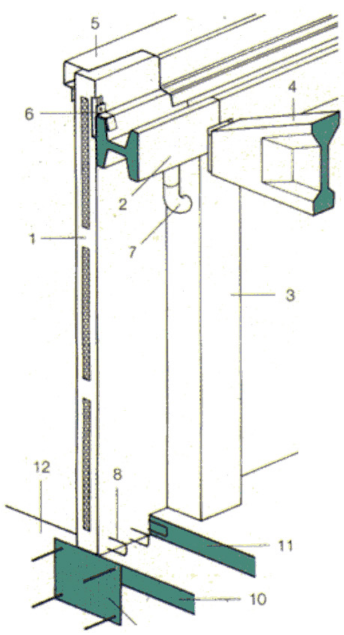
MATERIALS

- High density wood
  - · Plywood boards made of sheets of wood treated with high pressure phenolic glues.
  - · The edges must be protected, as rainwater can attack the plywood through the joints.
  - · There is no standard fixing system. Generally, the opening system or overlapping joints facilitates assembly and allows for the same as advantage in ventilated façades.
- Bakelite panels finished in smooth or printed wood veneer.
- Reinforced cellulose fiber boards
  - · Homogeneity, high density, mass colour and fireproof up to grade M-1 if placed in a ventilated façade.

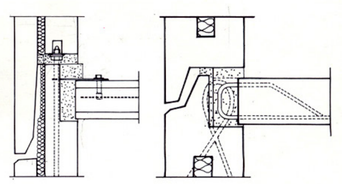
DISADVANTAGES

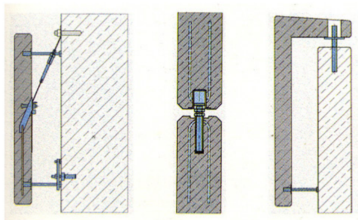
- Absence of thermal inertia.
- Protection against fire.
- Propagation speed 0.7 mm/min depending on the squaring type.
- They need a vapour barrier.
- Rapid ageing.
- The edges of the panels must be protected from water accumulation.

CONCRETE FAÇADES



Conection of panels using poured concrete in the joint. Metal pieces are also used to connect and to facilitate the laying out.





Fixings for concrete panels

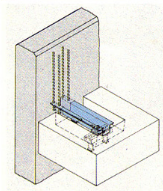


Fig. 17. Designs by Alfonso García Santos.

CONNECTION WITH THE LOADBEARING HORIZONTAL STRUCTURE

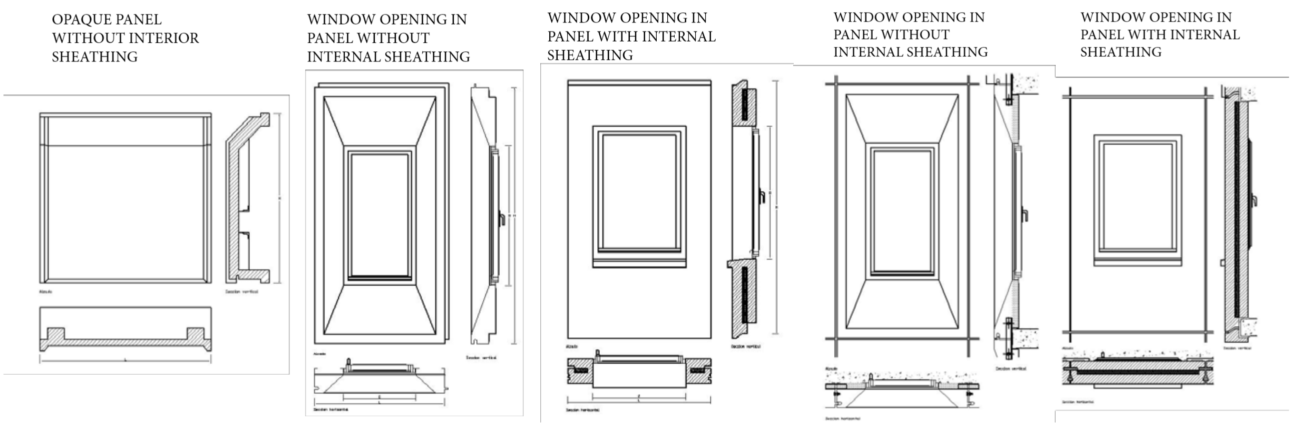


Fig. 18. Designs by Alfonso García Santos.

CONCRETE PANELS

There is an external concrete wall completely suspended from the inner sheet (without a perimeter frame).
That way, the thermal insulation reaches the edges of the panel to completely separate the two sheets.

COMPACT SYSTEM: CURTAIN WALLS

- Courtain walls
    - · Studs and transoms system
- Modular façade system
- Structural glass system
- Union with slabs
- Insulation
- Openings formation
- Fire resistance
- Complementary elements
    - · The framing
    - · The glass
    - · Façade fixing and anchorages

GENERAL OVERVIEW

Since functions, liability and external agents related to façades have already been discussed in the previous chapter in a general overview, the following content will focus on the particularities of façades' compact systems and curtain walls.

FAÇADE FUNCTIONS

- Waterproofing.
- Insulation:
    - · Hygrothermal (thermal transmission, surface and interstitial condensation), acoustic (airborne noise and impact noise).
- Solar radiation, solar protection, greenhouse effect, optical performance.
- Compatibility of elements. (Mechanical, chemical, dimensional). Interaction of the structure with the façade. Stability and structural resistance. Deformability.
- Durability. Dirtying factor.
- Fire resistance.
- Safety of use.
- The integration of solar energy capture systems. Ventilation, lighting, etc.

WATERPROOFING

Façades exposed to wind pressure: Risk of water entering through any crack or open joint. The interior of the building will have less pressure than the vented façade.

The uniformity of the pressure inside the chamber can produce water inlets, because the external pressure changes in the same façade: higher pressure on top of the façade, or, at the same height, pressure has different intensity and sign depending on the orientation facing the wind (leeward or windward) or also because of the situation with respect to the changes of plane (external corners, internal corners, eaves, etc.).

The only option is to confine the chamber, giving rise to a new type of façade with confined chamber (or sectorized).

INSULATION

Hygrothernal performance:

· Thermal transmission.

· Superficial and internal condensation.

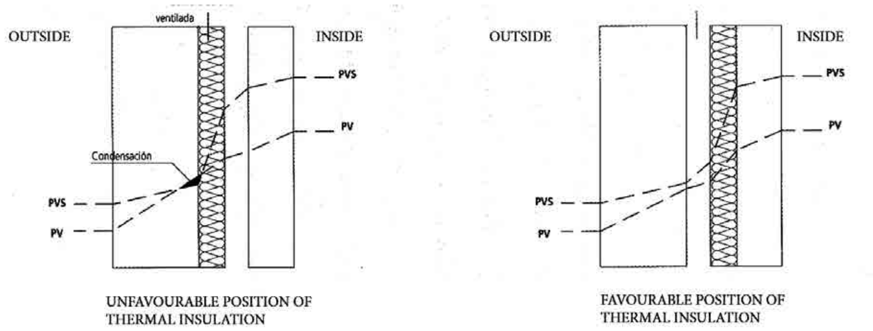


Fig. 19. Diagrams representing vapor pressure through a façade. Designs by Alfonso García Santos.

ACOUSTIC INSULATION (AERIAL NOISE)

Multiple layers act as an insulating "mattress" space.

The insulation is increased by means of double sheets that combine materials of different compactness and thickness.

In the case of glazed surfaces, the insulation is increased by means of double or triple glazing that combines glasses of different thickness.

The greater the thickness of the air chamber between the sheets, the greater the insulation. However, it is advisable to introduce an absorbent material that eliminates potential resonance phenomena.

SOLAR ENERGY IN FAÇADES

Fig. 20. Photovoltaic modules. *Revista Tectónica*, Fachadas, Escuela Técnica Superior de La Coruña.

PHOTOVOLTAIC SOLAR SYSTEM

Fixture designed to convert solar radiation into electrical energy.

– Elements:
  · Photovoltaic modules
  · Regulator
  · Inverter
  · Batteries

Photovoltaic effect is the excitation of a semiconductor material, silicon, by the impact of solar radiation. It causes the movement of electrons inside the material which is transformed into direct electric current when the circuit is closed.

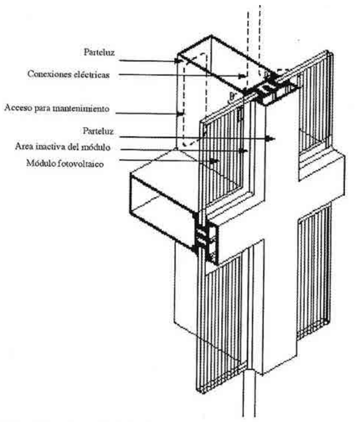


Fig. 21. Structure detail for the installation of photovoltaic modules in façade. Designs by Ramón Araujo.

PHOTOVOLTAIC MODULE

– Photovoltaic or solar cells, manufactured by the crystallization of silicon, and to be integrated onto the roof sheathing or roof cladding materials.
– External coating, generally glass, to facilitate the capture of solar radiation.
– Encapsulating material as protection for the cells. Products based on silicones are usually used.
– Rear coating. It serves as protection and enclosure. It is usually made of glass.
– Electrical connections.
– Metallic frame. It has to be watertight and ready to be fixed in another construction system.

CURTAIN WALLS ISSUES:

– Compatibility of structure-façade movements.
– Limit and service resistance.
– Lighting excess (glare).
– Heat losses in winter.
– Heat gains in summer.
– Watertightness.
– Air permeability.
– Acoustic insulation.
– Fire performance.
– Safety, maintenance and durability.

CURTAIN WALL COMPONENTS

1. Main structure.
2. Structure supporting the enclosure.
3. Vapour barrier.
4. Insulation.
5. Vapour membrane (optional).
6. Auxiliary structure for panels.
7. Open joint panels.
8. Infiltered water evacuation flashing.
9. Joint between pannels: open.

CURTAIN WALLS PROBLEMS

HARMONIC DEFORMATION WITH THE STRUCTURE

- Deformations and movements of the main structure.
- Deflection of the slab between supports: differential loads.
- Rotation in the plane of the façade: the glass is loaded.
- Lateral thermal expansion: precaution.

WATERTIGHNESS AND INTERNAL WATER DRAINAGE

- Studs and transoms connection with water drainage by draining channels included in transoms.
- Sealing or watertighness of the connection between stud and transom.

VENTILATION

- In single skin curtain walls it is not always possible to have natural ventilation.
- It is easy in double skin curtain walls: satisfied user.

ACOUSTIC INSULATION

- It can be improved with external screens and very low permeability frames.
- It depends a lot on the mass of the glass.

FIRE PERFORMANCE

- Slabs perforation. Demands:
  - · Acoustic insulation.
  - · Fire protection & fire insulation.
  - · Vertical expansion.
  - · Protection of the anchorage.
- Solutions:
  - · Blind panel for slab or glass passage through, with ventilated backing.
  - · Fixing of the glass with stainless steel.
  - · Metal sheet

TYPES OF CURTAIN WALLS

STUDS AND TRANSOMS SYSTEM

– Concepts:
  · Hanging façade (not supported).
  · Vertical expansion between different floors.
  · Horizontal expansion between studs.
  · Façade-structure adjustments: anchorage to the edge of the slab.
  · Loads: wind, death load, life load.
  · Not loadbearing glass (filling element).

– Advantages:
  · Common solution on the market.
  · Minimum supply costs.
  · Minimum project and supply time.
  · Easy delivery of extra components.
  · Two plants can be closed with only one stud.

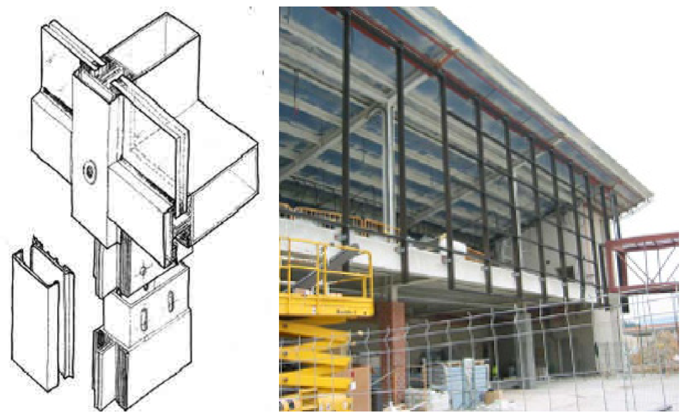


Fig. 22. Designs by Ramón Araujo.

– Disadvantages:
  · Simple architectural solution.
  · Tendency to attract low quality façades.
  · The assembly is carried out with scaffolding (cost and time).
  · High assembly time.
  · Quality of the assembly difficult to control.
  · Materials must be stored on site.
  · Studs without the capacity to absorb large horizontal movements.
  · Sealing of joints on site good quality control is not easy.
  · Filling panels with rubber gaskets, possibility of water inlet.
  · Fixing of the glass from the outside.
  · Cutting and assembly of not a perpendicular profiles is difficult and provides poor final results.

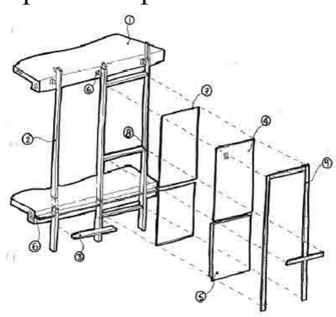


Fig. 23. Designs by Ramón Araujo.

– Studs and transoms system elements:

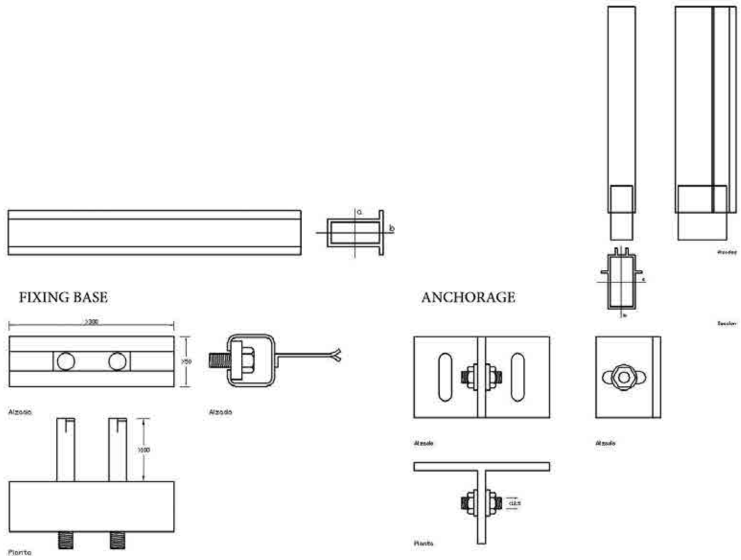


Fig. 24. Designs by Ramón Araujo.

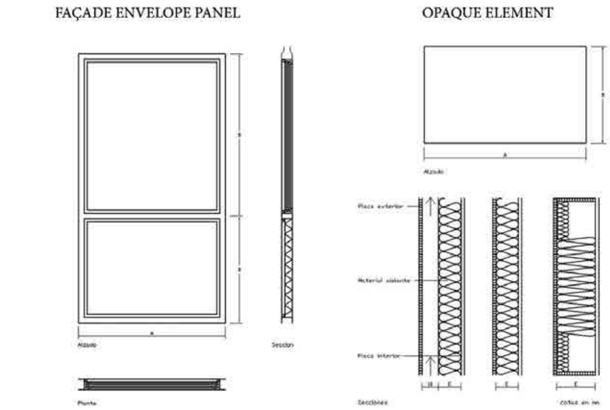


Fig. 25. Designs by Ramón Araujo.

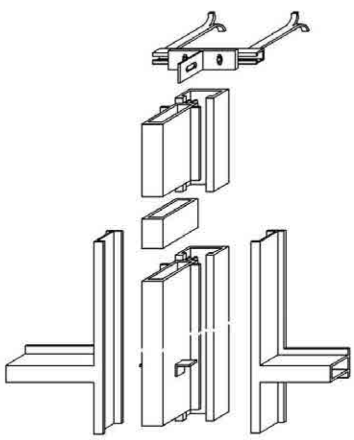


Fig. 26. Designs by Ramón Araujo.

MODULAR FAÇADE SYSTEM

– Concepts:
  · Hanging façade (not supported).
  · Vertical expansion between different floors (double transom).
  · Horizontal expansion between semi-studs.
  · Façade-structure adjustments: anchorage to the edge of the slab.
  · Loads: wind, load weight, live weight.
  · Not loadbearing glass (filling element).

– Disadvantages:
  · Higher supply cost (not always) than a studs and transoms system.
  · Longer project time and pre-delivery.
  · Requires more skilled site personnel.
  · Transportation and crane planning for unloading and lifting panels on site.

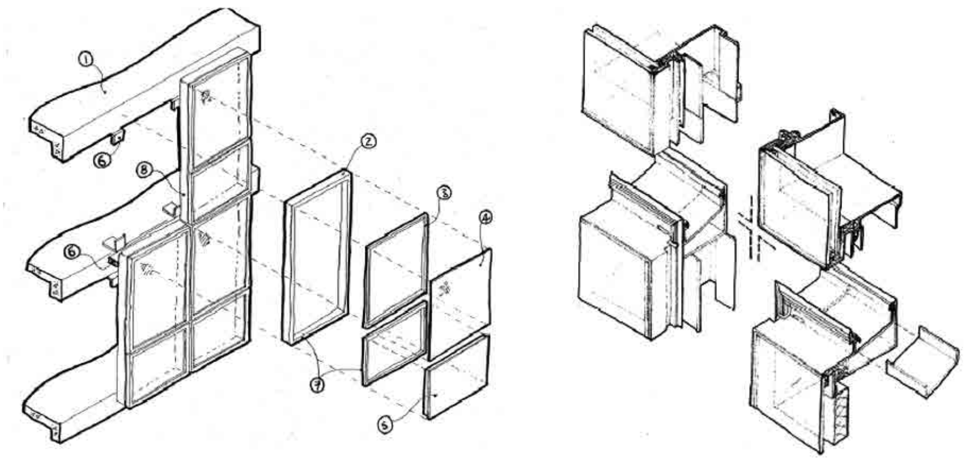


Fig. 27. Designs by Ramón Araujo.

– Advantages:
  · Flexible architectural solution.
  · Attracts quality façade consultants.
  · No need for scaffolding (time/cost saving).
  · Assembled off-site (quality/speed).
  · Prevents the assembly from being the bottleneck for timing on site.
  · Good quality control in manufacturing.
  · Reduces quality control on site.
  · It does not need storage on site.
  · It admits major movements in the joints.
  · Very effective sealing between panels.
  · Incorporates guide rails for the cleaning gondola.
  · Access from the inside to glass maintenance.

STRUCTURAL GLASS SYSTEM

– Components:

1. Main structure.
2. Supporting structure of the enclosure:
   · Metallic pillar.
   · Connecting rods.
   · Glass studs.
3. Glass fixing hubs:
   · Spider.
   · Swivel.
4. Glass:
   · Monolithic, laminated or double glazing.
   · Toughened with HST.
5. Sealed with neutral silicone.

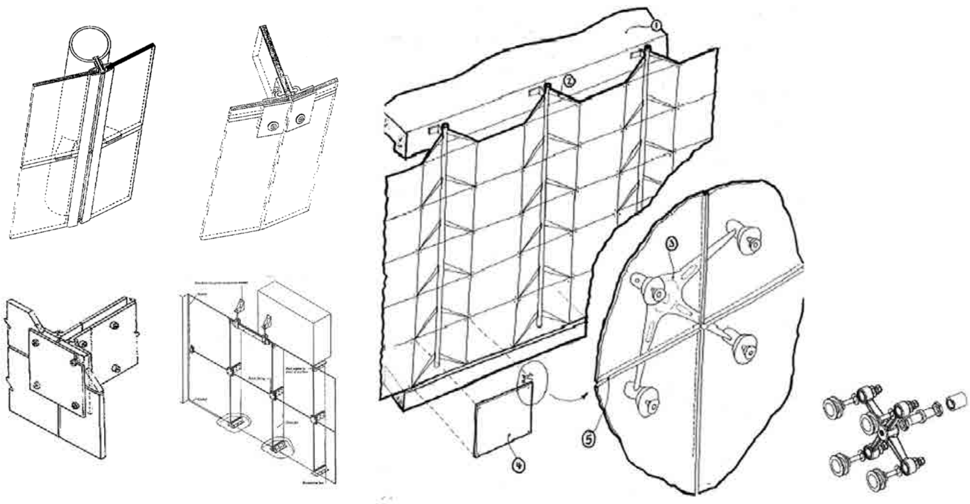


Fig. 28. Designs by Ramón Araujo.

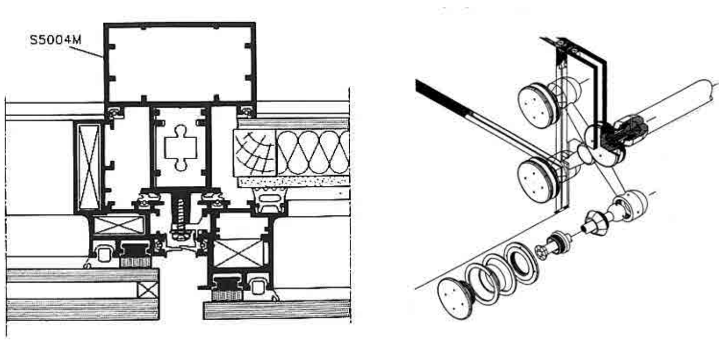


Fig. 29. On the left: Structural silicone solution. Glued external glass. On the right: Mechanically hanging glass. Designs by Ramón Araujo.

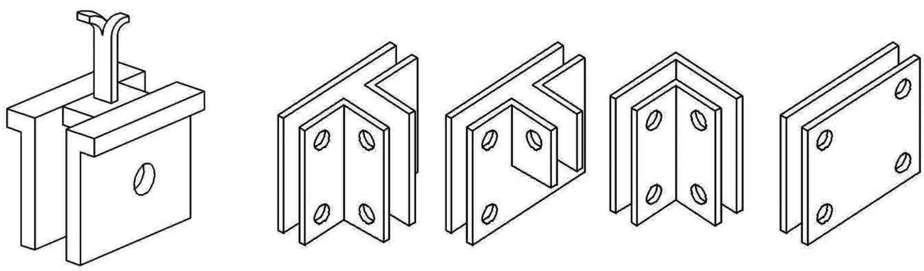


Fig. 30. Fixing and connection ironwork. Designs by Ramón Araujo.

COMPLEMENTARY ELEMENTS:

FRAMING:

– Materials:
  · Aluminium.
    - The most used.
    - Variable quality.
    - If the same price, less reliable than pvc.
  · Wood.
    - The least used.
    - High quality.
    - 1000 times less conductivity than aluminium.
  · Pvc.
    - Intermediate used.
    - Medium quality.
    - 3 times more expansion than aluminium.
    - 1000 times less conductivity than aluminium.
    - High thermal and acoustic insulation.
  · Beads. EPDM (ethylene propylene dimethyl monomer).
  · Tbb (thermal bridge breakage) polyamide 6.6 (reinforced with glass fiber).
  · Ironmongery and fixings.
    - European standard ironmongery chamber.
    If quality carpentry is prescribed, the fittings are not "European" (preventing them from being interchangeable).
  · Watertighness:
    - There must be two chambers, with a central sealing.
    - The drainage covers (1) must be placed.
    It is necessary to install drip edge flashings.
    In curtain walls, rain flashings should also be placed in the upper part of the window.
    - In the case of a heavy rains climate, rubber gaskets can be placed on both sides and bottom profile.
  · Fixings or closing points.
    - For high > 1.2 m, 3 fastening points per side.
    - For length > 1 m, 1 fixing point above and below.
  · Glass:
    - Double glazing does is not insulating at the edges.
    - Low emissivity is achieved with an adhered plastic foil.
  · Inertias:
    - Ironmongery up to 100 kg.
    - Shape of the leaves: vertical or oblong.
  · Adjustment to the opening of the wall:
    - It is convenient to place rough frames fixed every 50 cm and every 25 cm in the corners, filled with polyurethane foam to avoid the entrance of water.
  · Fixing of the glass:
    - The rebate must be placed to avoid the deformation of the profiles.
  · Building Regulations.

NOTES

1) *Fachadas y cubiertas*, Libros ingerniería, 2000;

2) SÁNCHEZ ORTIZ A., *Cerramientos de edificios: fachadas*, Dossat, Madrid 2011;

3) See ARAUJO ARMERO R., *Construir con piedra*, in Arquitectura Viva, 2017; also from the same author, *El edificio como intercambiador de energía*, in Revista Tectónica, n. 28, Madrid 2009, pp. 4-27.

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CHAPTER 19. THE INTERNAL PARTITIONING LAYOUT. CONSTRUCTION PROCESS

- The concept of internal partitioning; partitions and insulation; hygrothermal and acoustic. (1)

- The typological concepts of internal compartmentation. Stability and structural resistance. Collaborating systems. Interaction between building structure and building enclosures.

- Deformability. Elements compatibility (mechanical, chemical, dimensional). Durability. Fire resistance. Safety of use.

- The construction process. Stability and continuous structural resistance. Deformability. Partial processes.

FUNCTIONS

- They are ordinatory walls, for the subdivision of spaces or with a compartmental function.
- They are conditioning walls, for all kinds of comfort, even visual acting in accompanying function.
- Always without structural function. Adaptable. Its location is not immovable.
- Mostly indoors.
- Privacy.
- Intrinsic resistance. Slams.
- Stability. Wind when windows are open.
- Thermal and acoustic insulation (thickness, with finishes $\geq$ 6 cm).
- Admit embedded installations (for $\varnothing \geq$ 2 cm, thickness $\geq$ 10 cm).
- Attenuate the noise transmission (to annul airborne noise, to attenuate noise from impact).
- Fire resistance.

Proportional costs in every case:

- Durability / economic maintenance / cleanliness.
- Modifiability
- Nailing possibilities. Support of suspended loads (sanitary ware, furniture).
- Relationship with slabs and structure.

EXECUTION SYSTEM

HUMID PARTITIONS:

- “On-site”
- Panels

DRY PRODUCTS

- Components
- Semi-products

SUBDIVISIONS:

- Fixed masonry partitions
- Fixed modular partitions
- Movable partitions
- Transformable partitons

COMPOSITION

LOADBEARING ELEMENT:

- Laminar Mass
- In frames Double Layer

CONFIGURATION:

- Single or double layer

COATING

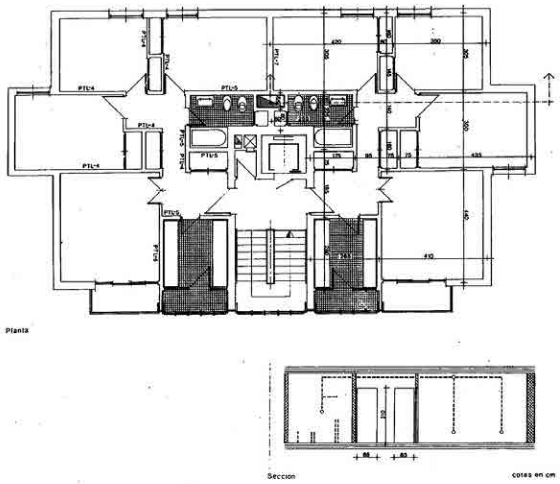
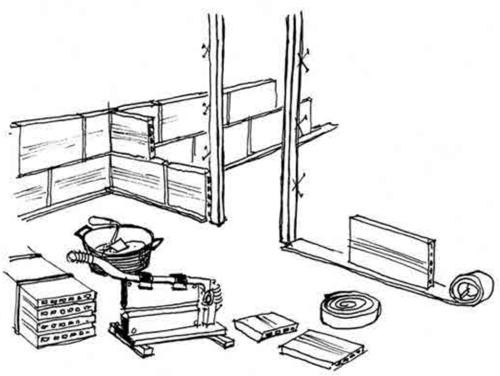


Fig. 1. Design by Fernando Ripollés.

WET PARTITIONS "ON-SITE"



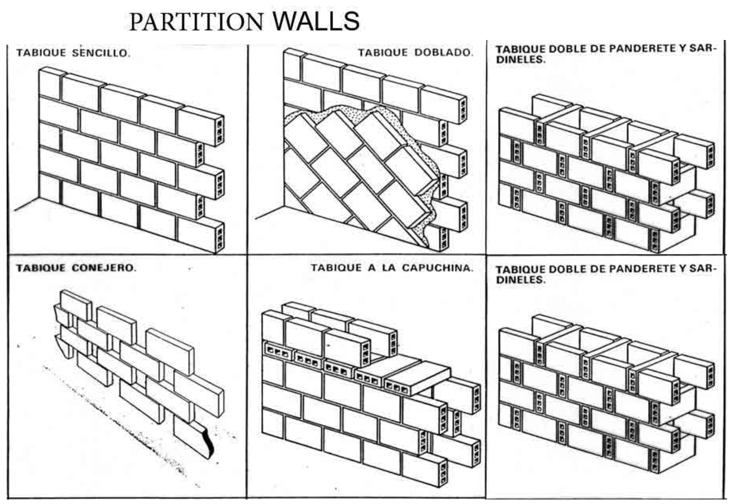


Fig. 2. Designs by Fernando Ripollés.

PANELS

1. Presoelastic stripe of glued cork.
2. Frame.
3. Plaster plate.
4. Glasses-shape frame.
5. Glued expanded polystyrene stripe

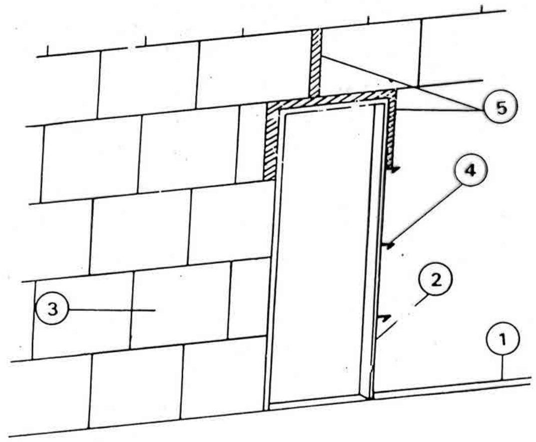


Fig. 3. Design by Susana Mora.

CONNECTIONS BETWEEN PARTITIONS

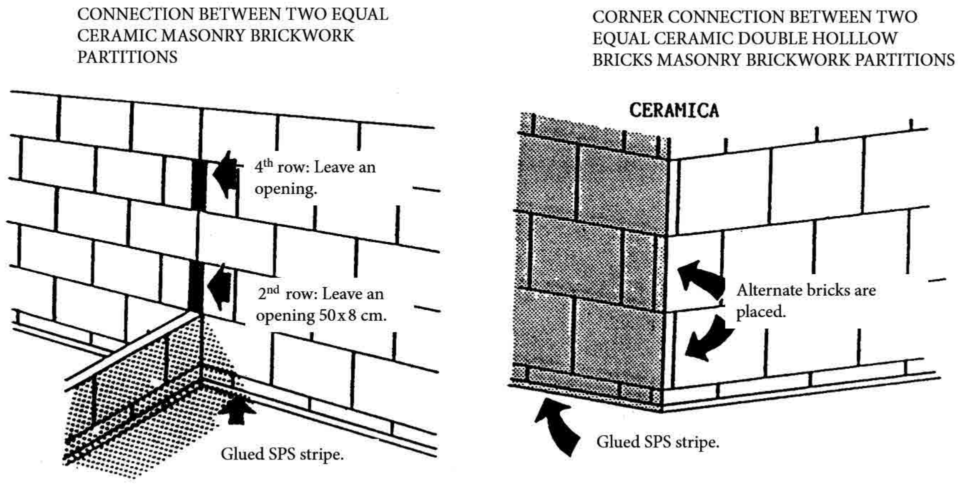


Fig. 4. Designs by Susana Mora.

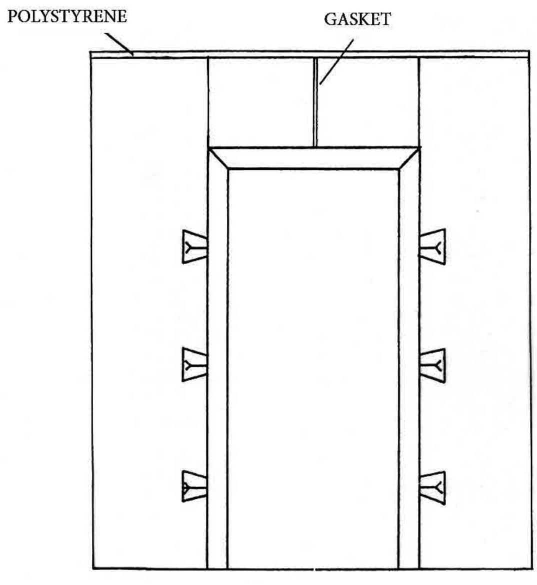


Fig. 5. Floor to ceiling connection details. Detail of the execution of the door lintel. Designs by Susana Mora.

GEOMETRICAL CHARACTERISTICS

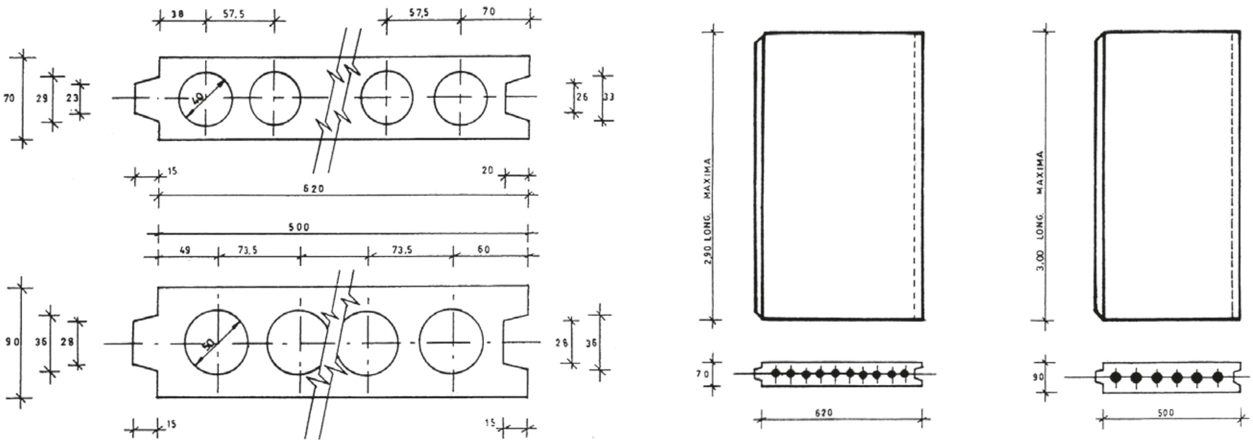


Fig. 6. Designs by Susana Mora.

INTERACTION WITH FIXTURES

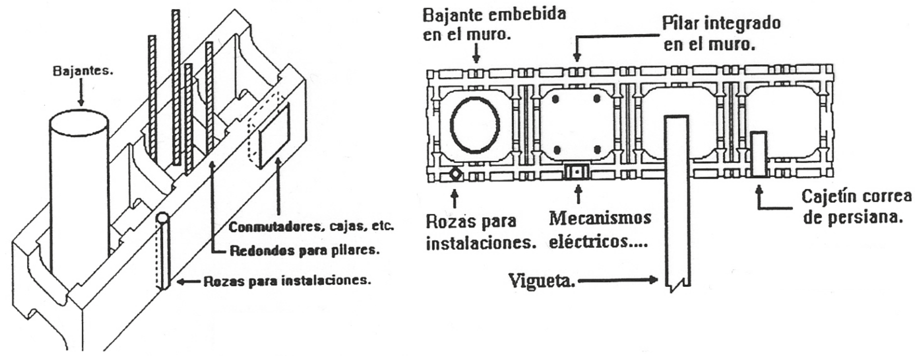


Fig. 7. Designs by Susana Mora.

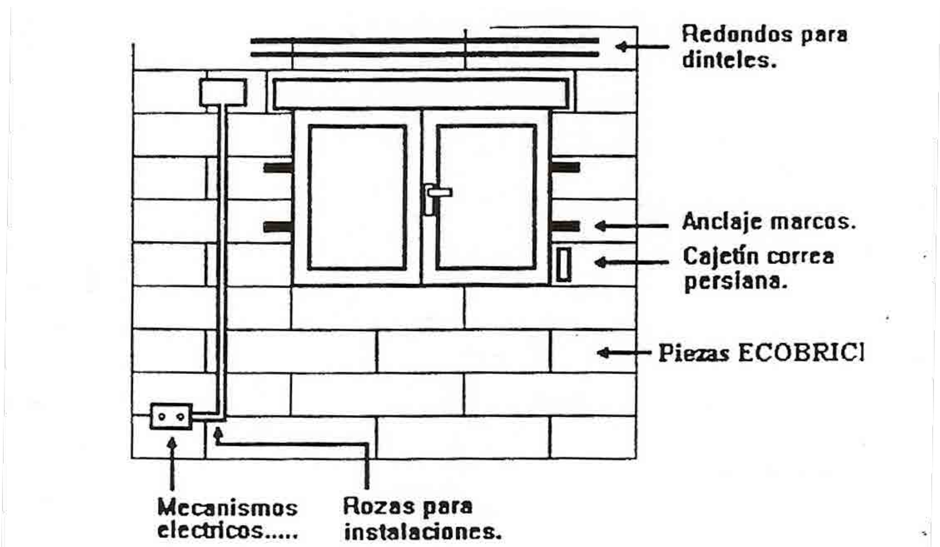


Fig. 8. Designs by Susana Mora.

PLASTERBOARD

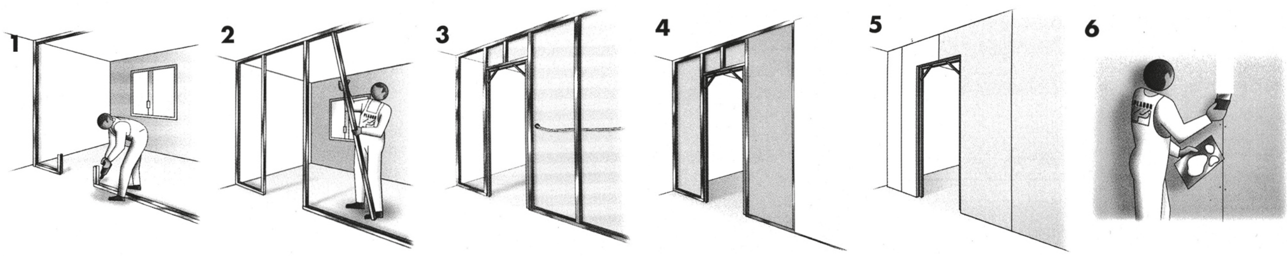


Fig. 9. Designs courtesy of Fernando Ripollés.

MOULDED GLASS BLOCKS

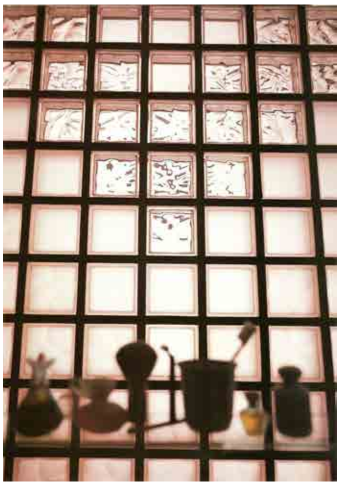
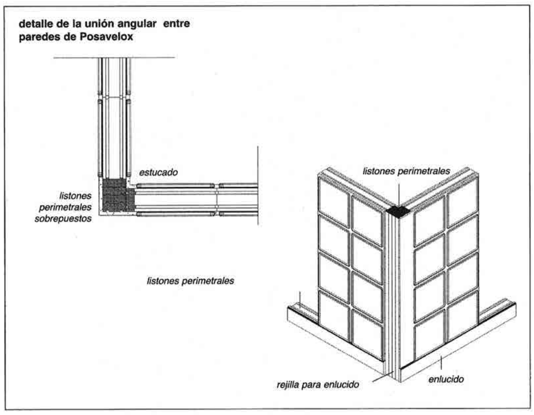
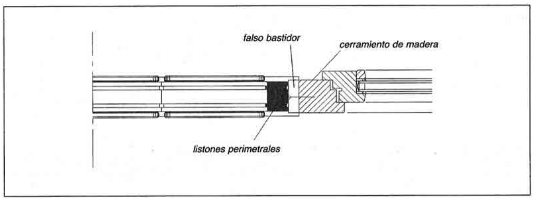


Fig. 10. Photo courtesy of Fernando Ripollés.

VERTICAL STRUCTURES. PROJECT AND INSTALLATION TECHNIQUES

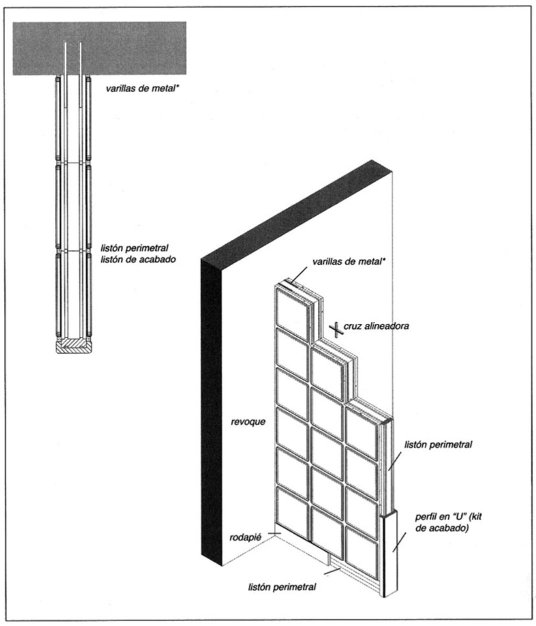


Corner unions



Doors and windows placement

Fig. 11. Designs courtesy of Fernando Ripollés.



Perimeter supports with metal rods.

Fig. 12. Detail of the anchorage between wall and structure. Designs courtesy of Fernando Ripollés.

MOVABLE PANELS

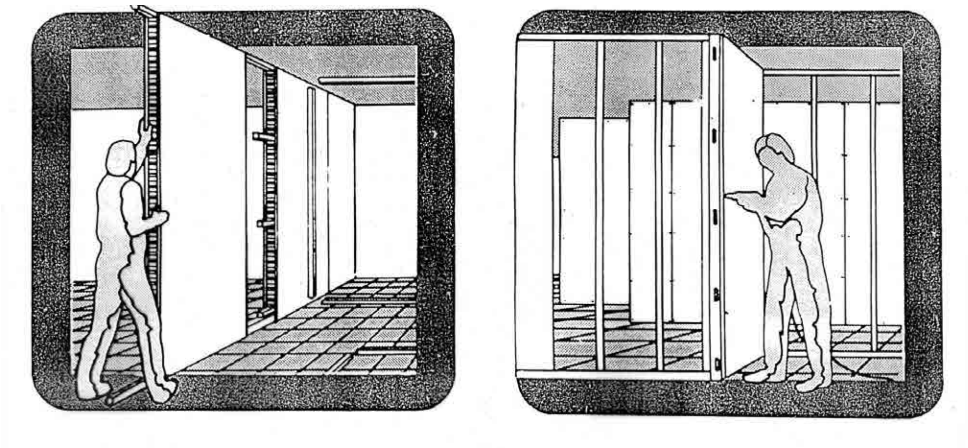


Fig. 13. Designs courtesy of Fernando Ripollés.

COMPARTMENTALISE. DRY SYSTEMS

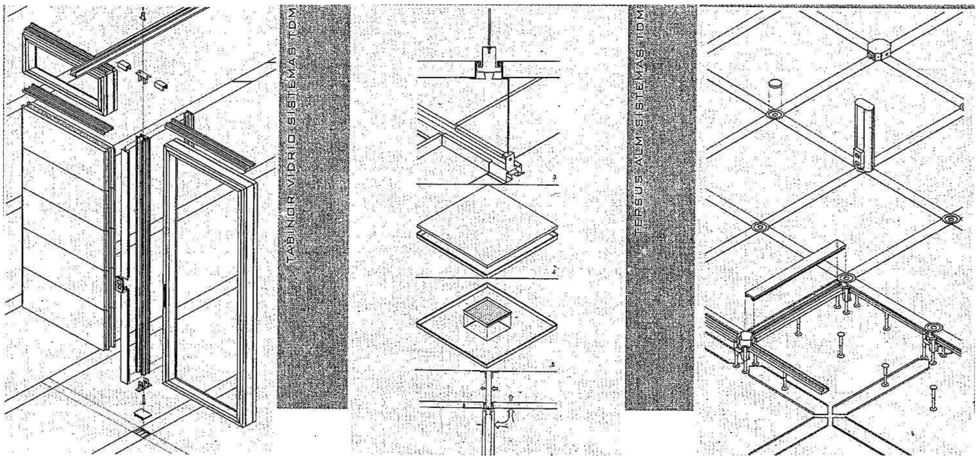


Fig. 14. Designs courtesy of Fernando Ripollés.

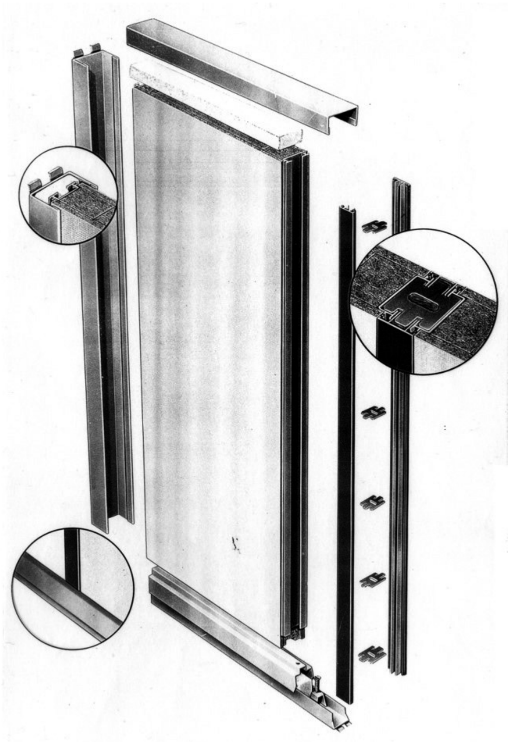


Fig. 15. Designs courtesy of Fernando Ripollés.

NOTES

1) See online: Pinterest; Construmática; Isover; Diccionario de la Construcción, s.d.

ARAUJO ARMERO R., *La Arquitectura como técnica*, ATC ed., Madrid 2007.

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