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Sustainable Urban Rehabilitation in Europe

Methodological approach to conservation

Erasmus+

Sustainable Urban Rehabilitation in Europe

3rd Semester

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Methodological Approach to Conservation: Physical Approach

2 ECTS

SH
Sustainable Heritage

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SURE
SUSTAINABLE URBAN REHABILITATION IN EUROPE

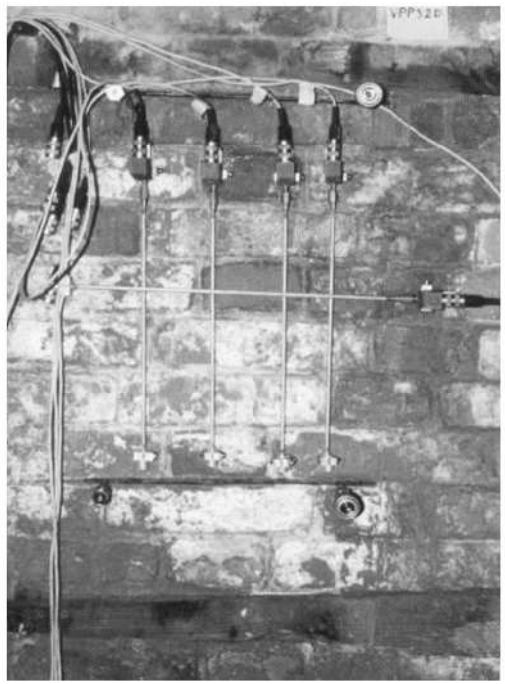
UNIVERSIDAD POLITÉCNICA DE MADRID

Sustainable Urban Rehabilitation in Europe

Methodological Approach to Conservation: Physical Approach

1. Introduction to Methodological Approach
2. Geometrical Survey
3. Geometrical Survey: traditional method
4. Geometrical Survey: new tools
5. Material Survey.
6. Mechanical Survey.
7. Damage maps I: degradation problems
8. Degradation types.
9. Damage maps II: fissure and crack problems
10. Damage maps III: moisture problems
11. **Damage tests on masonry constructions I**
12. Damage tests on masonry constructions II
13. Survey, maps and tests on wooden contruction.
14. Archaeology.
15. Stratigraphy.

Methodological Approach to Conservation: Physical Approach



LESSON 11. DAMAGE TESTS ON MASONRY CONTRUCTIONS I

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SURE
SUSTAINABLE URBAN REHABILITATION IN EUROPE

UNIVERSIDAD POLITÉCNICA DE MADRID

DAMAGE TESTS IN MASONRY

Introduction: the necessity of undertaking tests

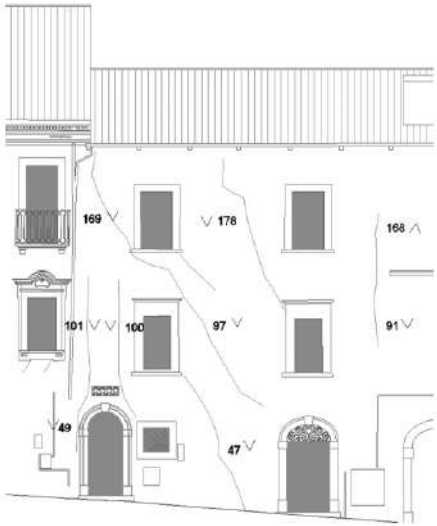
Following an accurate structural survey and an in-depth and critical historical analysis, it is possible to identify possible extensions, tampering, raised areas, closures and openings in rooms, hidden cavities, shallow or deep lesions, further manifestations of static instability (detachment, rotations,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

The above cannot always be detected through a simple direct visual examination of the monument by resurrecting 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 are however legal in the temporal reconstruction of the successive construction phases and sometimes overlapped over the centuries.

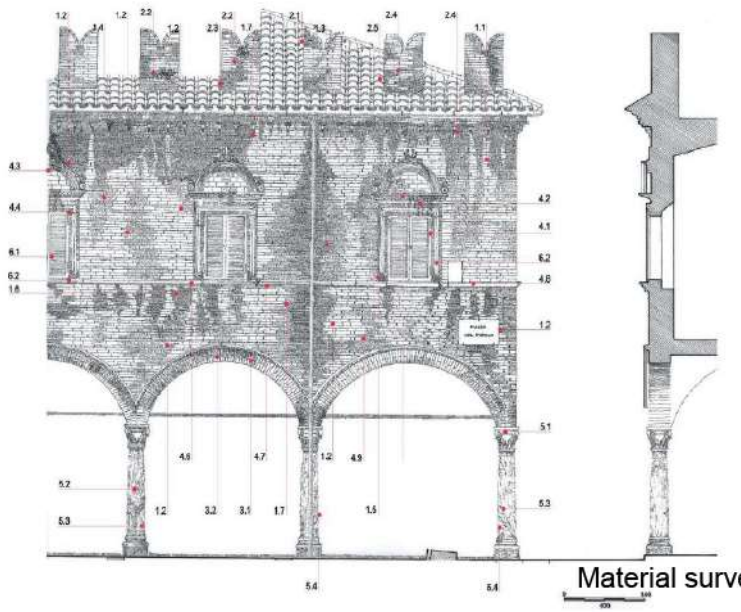
DAMAGE TESTS IN MASONRY

Starting point

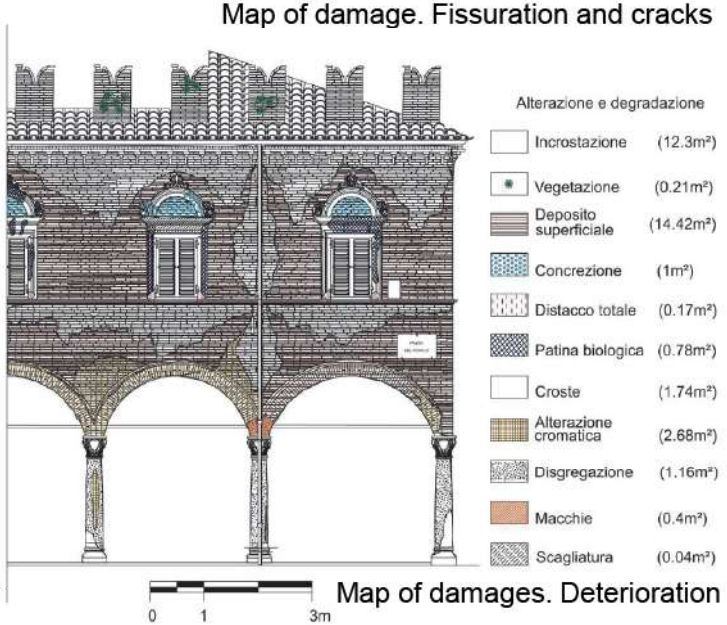
The starting-point for the planification of the test are the material and mechanical survey and the maps of damage, including the different damage couses (deterioration, mechanical lesions and humidity problems).



Map of damage. Fissuration and cracks



Material survey

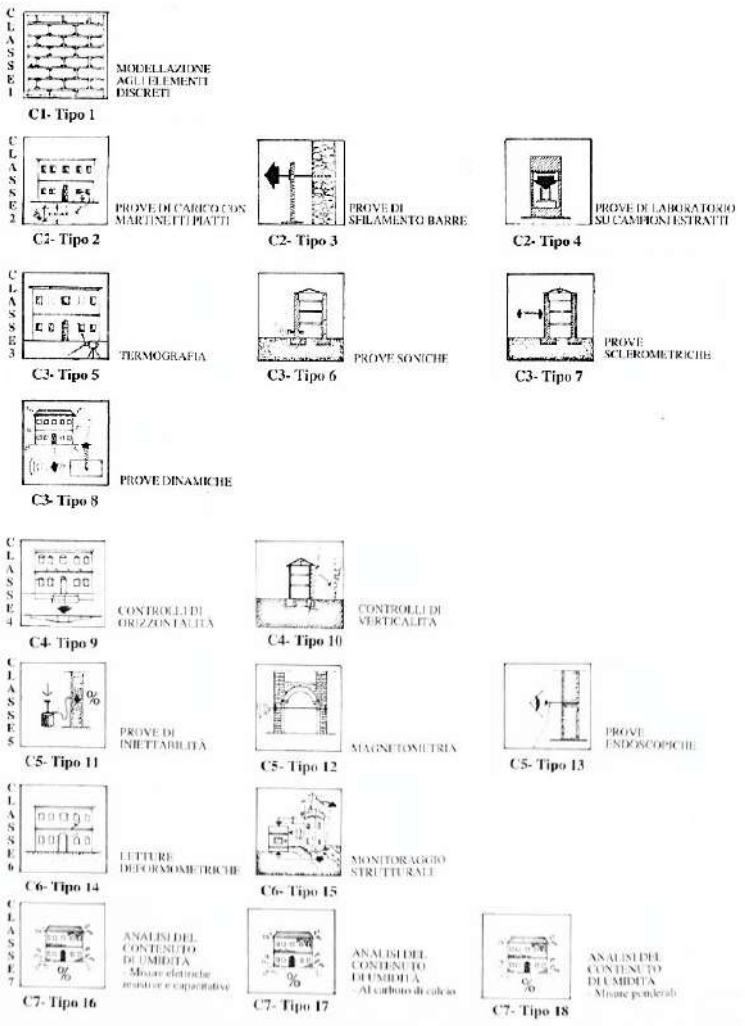


Map of damages. Deterioration

DAMAGE TESTS IN MASONRY

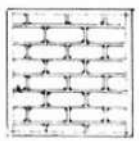
Test classification

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



CLASS I: Theoretical analysis

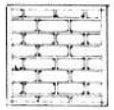
CLASSE I



MODELLAZIONE AGLI ELEMENTI DISCRETI

C1- Tipo 1

DAMAGE TESTS IN MASONRY



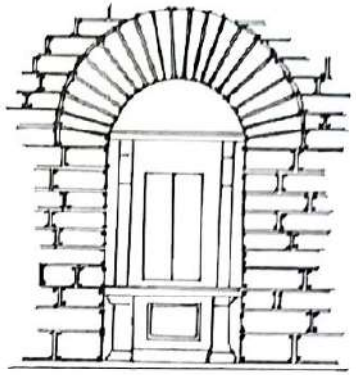
CLASS I THEORETICAL ANALYSIS

Type 1 Discrete element modeling

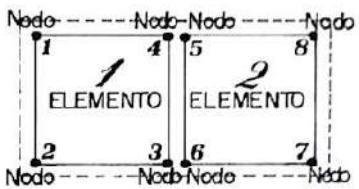
DESCRIPTION

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.

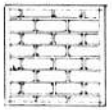


DISCRETIZZAZIONE DELLA STRUTTURA
UN NUMERO VARIABILE DI ELEMENTI



INDIVIDUAZIONE DEGLI ELEMENTI
DEFINITI DA PUNTI DETTI NODI

DAMAGE TESTS IN MASONRY



CLASS I THEORETICAL ANALYSIS

Type 1 Discrete element modeling

EXECUTION

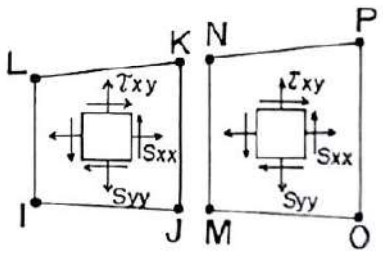
a) Discretization of the structure into single elements delimited by nodes.

b) Following the solicitation 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.

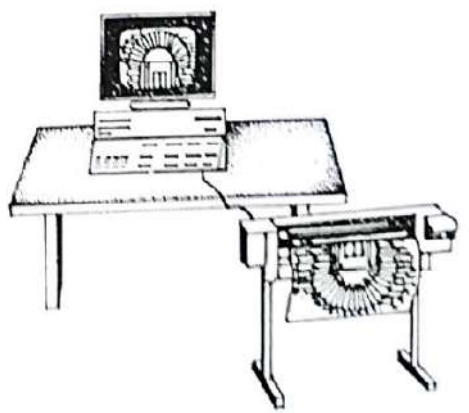
c) Forecasting of loading conditions and analysis, by computer processing, of a static or dynamic type.

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.



SOLLECITAZIONI PRESENTI NEI SINGOLI ELEMENTI



CLASS II: Mechanical analysis

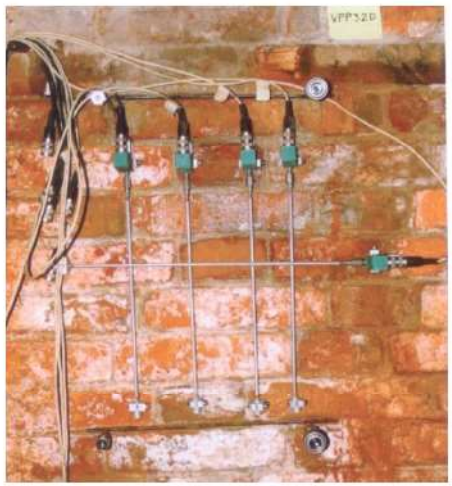
DAMAGE TESTS IN MASONRY

CLASS II MECHANICAL ANALYSIS

Type 2 **In situ flat-jack load test**

DESCRIPTION

The load test with the 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 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 the seismic area.



DAMAGE TESTS IN MASONRY

CLASS II MECHANICAL ANALYSIS

Type 2 **In situ flat-jack load test**

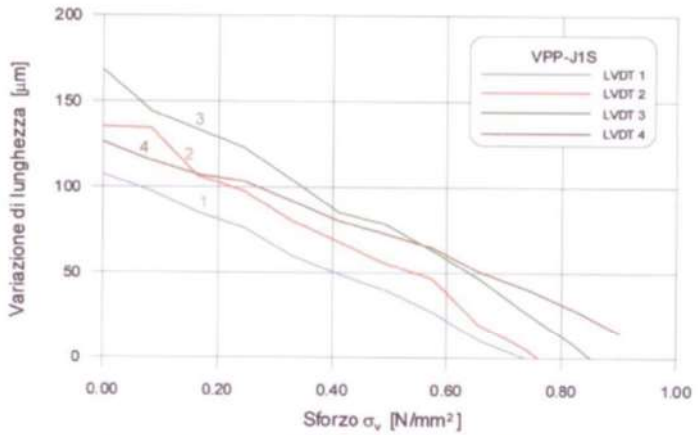
Reading of the vertical movements with the flat jack inserted in the masonry wall.

Hydraulic system connected to the flat jack inserted in the masonry wall.

Single flat jack tests
(PP.MM. Laboratory, Politecnico di Milano)

CLASS II MECHANICAL ANALYSIS

Type 2 **In situ flat-jack load test**



Prova VPP-J1S. Andamento della distanza tra le basi di misura in funzione dello sforzo applicato

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)

Single flat jack test results (PP.MM. Laboratory, Politecnico di Milano)

DAMAGE TESTS IN MASONRY

CLASS II MECHANICAL ANALYSIS

Type 2 **In situ flat-jack load test**

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 δ_O.

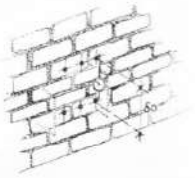
c)Execution of a horizontal cut in the normal direction to the surface and of two lateral cuts to allow free transversal expansion; reading $\delta_1 < \delta_O$.

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 δ_O, 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.

INDIVIDUAZIONE DELLA ZONA PIÙ RAPPRESENTATIVA



LETTURA INIZIALE δ_O PRIMA DELL'ESECUZIONE DEL TAGLIO

LETTURA δ_1 DOPO L'ESECUZIONE DEL TAGLIO

INSERIMENTO DEL MARTINETTO COLLEGATO A CIRCUITO IDRAULICO

DAMAGE TESTS IN MASONRY

CLASS II MECHANICAL ANALYSIS

Type 2 **In situ flat-jack load test**

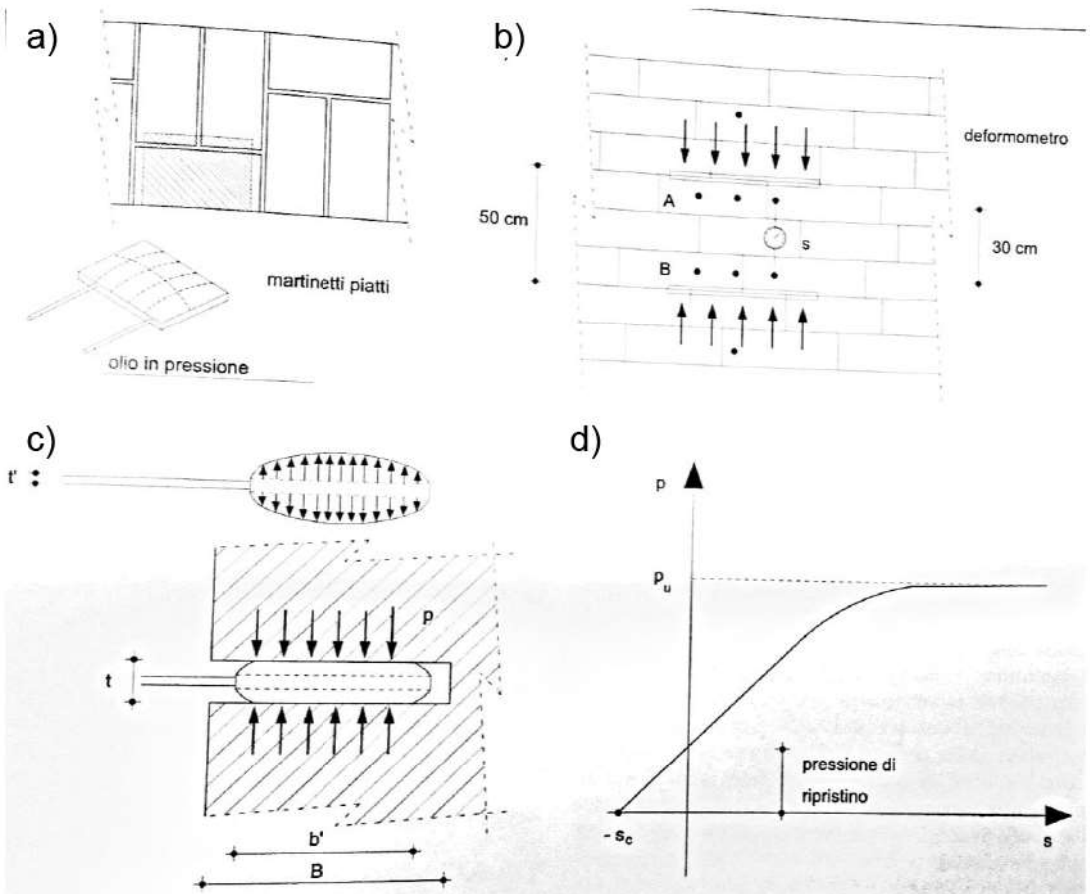
EXECUTION

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.

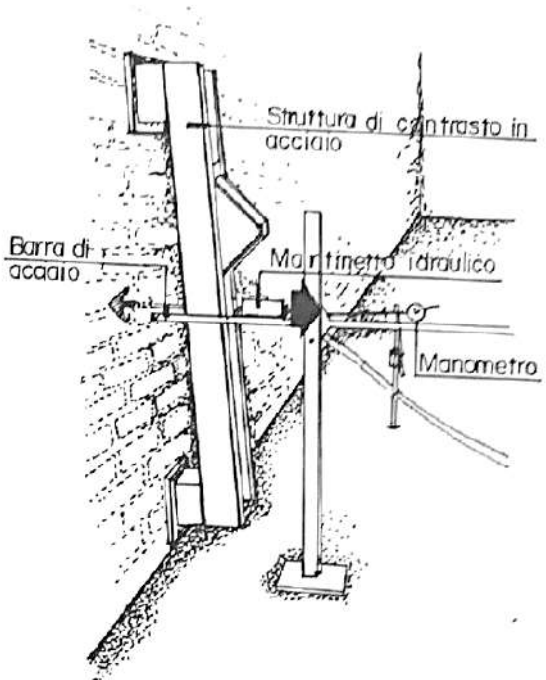


DAMAGE TESTS IN MASONRY

CLASS II MECHANICAL ANALYSIS
Type 3 In situ bar extraction test

DESCRIPTION

The in situ slip test allows 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.



Load application with hidraulic jack

CHARACTERISTICS

This type of methodology allows defining, 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 the direct verification of the values and is sometimes able to reconstruct very realistic conditions such as anchorages, chains.

DAMAGE TESTS IN MASONRY

CLASS II MECHANICAL ANALYSIS
Type 3 In situ bar extraction test

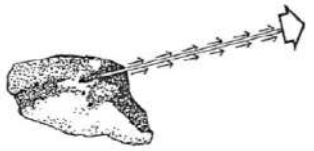
EXECUTION

a)Insertion and anchoring of a steel bar in the wall to be examined.

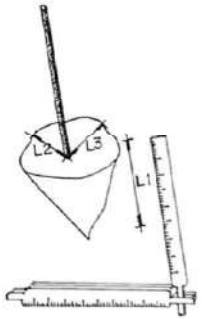
b)Applying a steel contrast structure and applying a pulling force by means of a hydraulic jack, driven by a pump, to the steel bar previously inserted.

c)Measurement of the applied load gradually, until it breaks, by means of a precision manometer inserted in the hydraulic circuit.

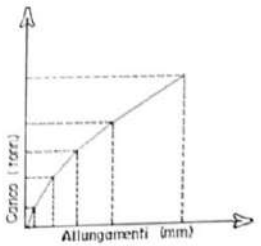
d)Relief of the extracted solid, of conical shape, and determination of the limit tangential tensions.



ESTRAZIONE DEL SOLIDO DI DISTACCO



RILIEVO DEL SOLIDO ESTRATTO



DETERMINAZIONE DELLE TENSIONI TANGENZIALI LIMITE

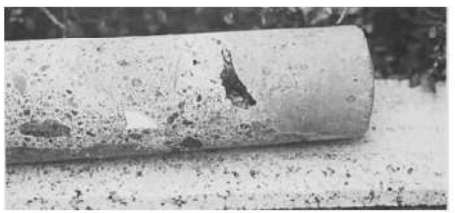
CLASS II MECHANICAL ANALYSIS

Type 4 Sample extraction for laboratory text

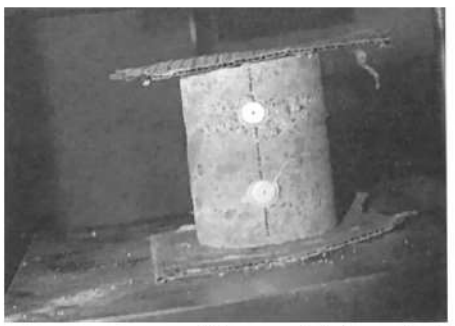
DESCRIPTION

The execution of direct tests on samples taken on site is of great use to the end of the quantitative evaluation of the mechanical, deformability and resistance characteristics, and of the chemical and physical characteristics of the examined motels. 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 carrot 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.

Sample extraction with rotating tube



Extracted sample



Mono-axial stress test

CLASS II MECHANICAL ANALYSIS

Type 4 Sample extraction for laboratory text

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:

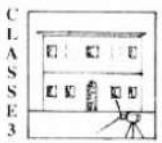
b1) monoaxial compression test; longitudinal stress; determination of the breaking load and the deformation diagram;

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;

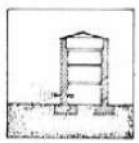
b4) indirect tensile test; stress, compression in a horizontal direction along two opposed generators and, indirectly, tensile.

CLASS III: Quantitative analysis



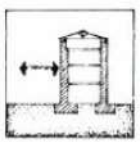
TERMOGRAFIA

C3- Tipo 5



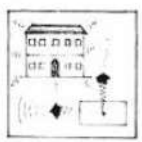
PROVE SONICHE

C3- Tipo 6



PROVE SCLEROMETRICHE

C3- Tipo 7



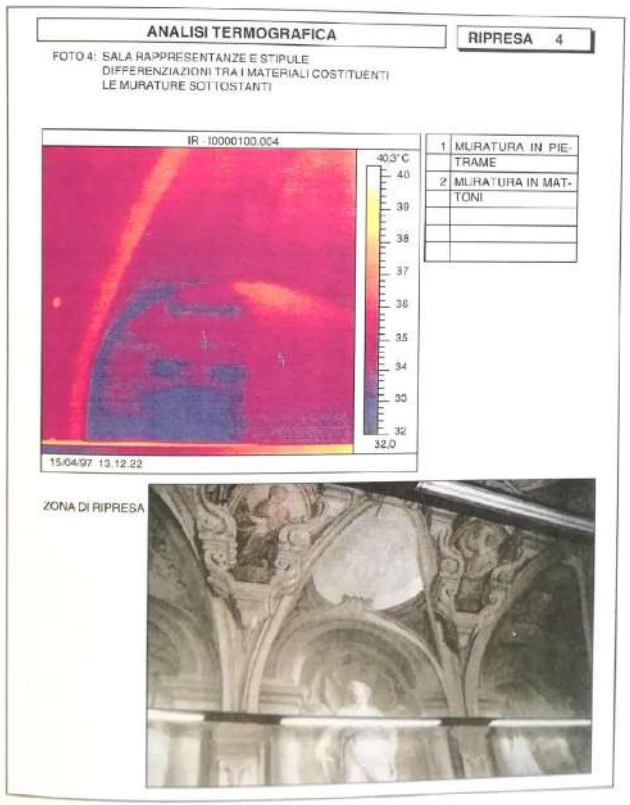
PROVE DINAMICHE

C3- Tipo 8

CLASS III QUANTITATIVE ANALYSIS
Type 5 Thermography

DESCRIPTION

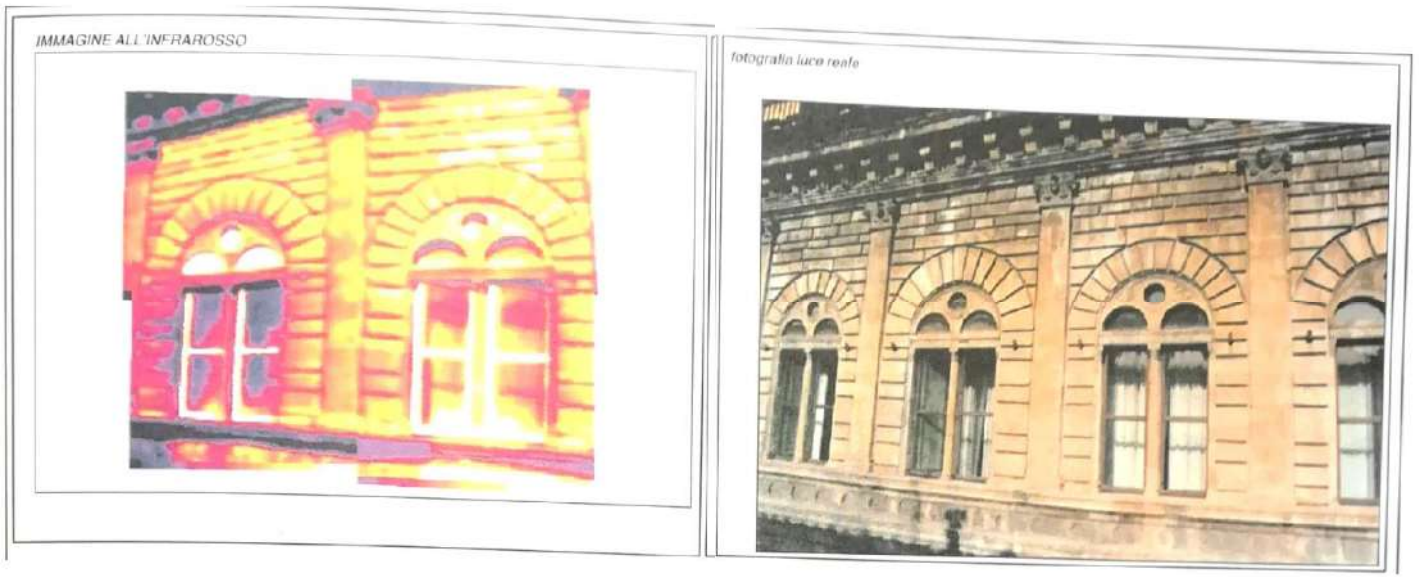
The thermographic analysis allows a quick and non-invasive detection of a series of information on structural and construction elements hidden by the presence of plaster. In particular, it makes it possible to identify the presence of: load-bearing structures, reinforced concrete elements, hidden stone 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, on 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.



DAMAGE TESTS IN MASONRY

CLASS III QUANTITATIVE ANALYSIS

Type 5 **Thermography**



DAMAGE TESTS IN MASONRY

CLASS III QUANTITATIVE ANALYSIS

Type 5 Thermography

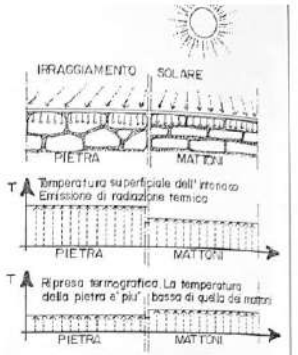
EXECUTION

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.

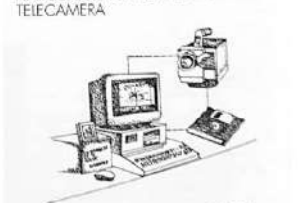
c) Formation of an image in different shades of grey where the lighter areas correspond to the points of greatest radiance and therefore of greater temperature.

d) Recording of the digitized images on magnetic tape or photographic print of the same directly from the monitor.



COMPORTAMENTO TERMICO DI UNA STRUTTURA MURARIA

ANALISI DELLA SUPERFICIE MEDIANTE TELECAMERA

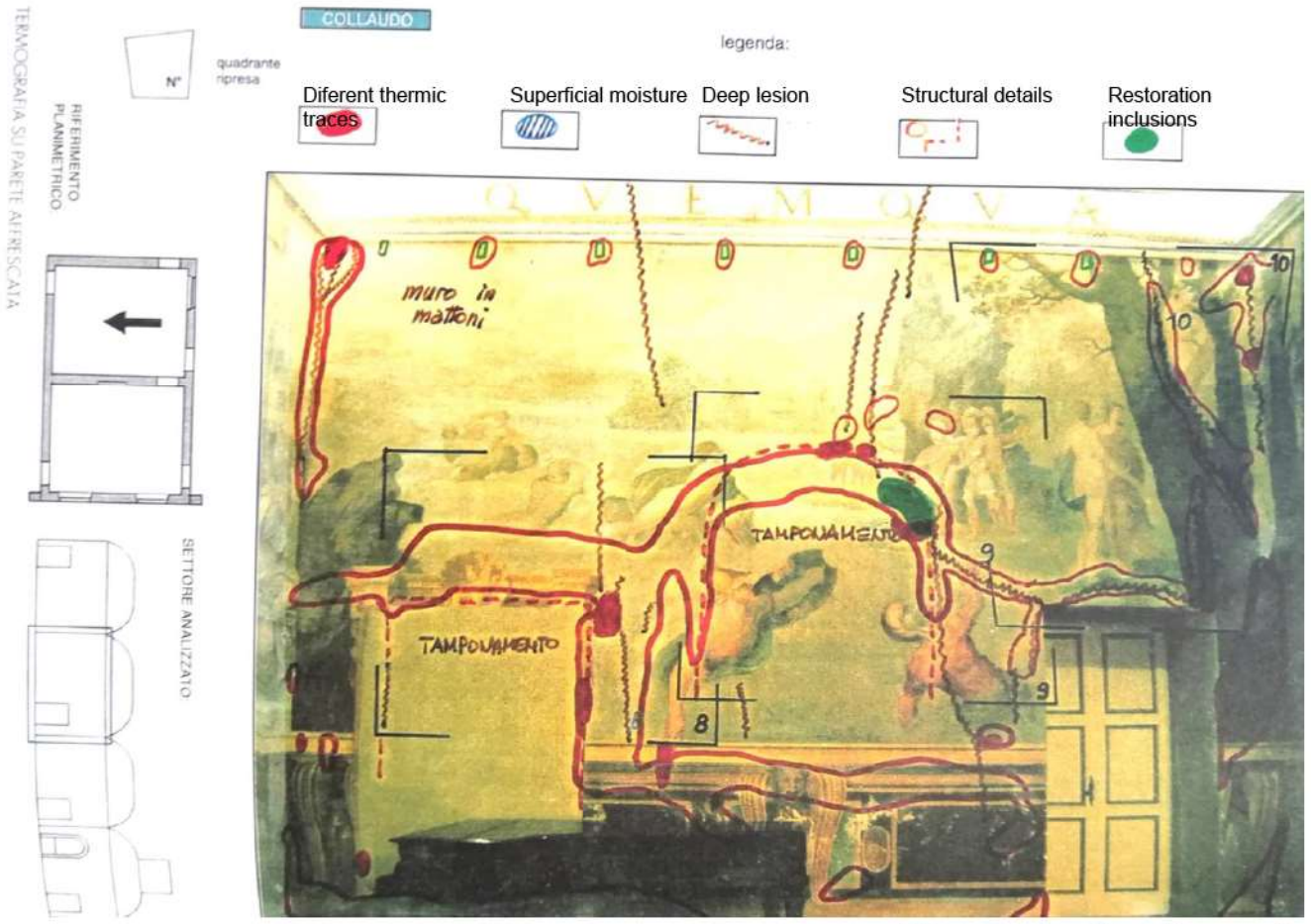


FORMAZIONE DI UNA IMMAGINE IN TONI DIVERSI DI GRIGIO E SUA REGISTRAZIONE SU NASTRO MAGNETICO

DAMAGE TESTS IN MASONRY

CLASS III QUANTITATIVE ANALYSIS

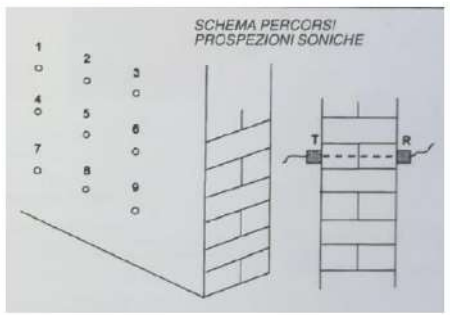
Type 5 **Thermography**



Thermographic disgnostic

DAMAGE TESTS IN MASONRY

CLASS III QUANTITATIVE ANALYSIS
Type 6 **Sonic test**



DESCRIPTION

The dynamic auscultation method of a material allows 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. The sonic investigations basically allow to verify the distribution of the state of degradation - usually unevenly variable in the historical walls - as a completion to the remaining static surveys.

DAMAGE TESTS IN MASONRY

CLASS III QUANTITATIVE ANALYSIS
Type 6 **Sonic test**

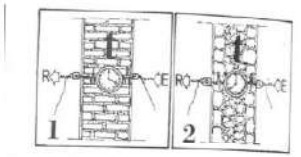
EXECUTION

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.

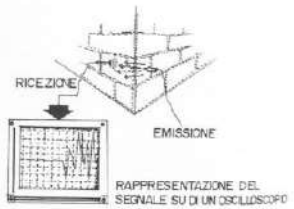
b) b) Measurement of the time "t" between the emission and reception and analysis of the following parameters: frequency, amplitude, damping, reflection.

c) 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.

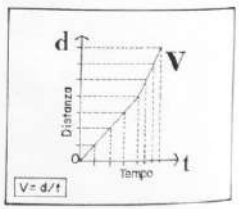
d) d) It is possible to carry out three different types of measurements according to the location of the two transducers: on the surface on the same face; radiated on two adjacent faces; for transparency on two opposite sides.



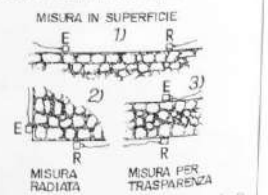
1 - MATERIALE PIÙ COMPATTO ED OMOGENEO DI 2 ⇒ V1>V2



EMISSIONE DI UN SEGNALE ACUSTICO E SUA RICEZIONE



MISURAZIONE DEL TEMPO «t» E CALCOLO DELLA VELOCITÀ «v»



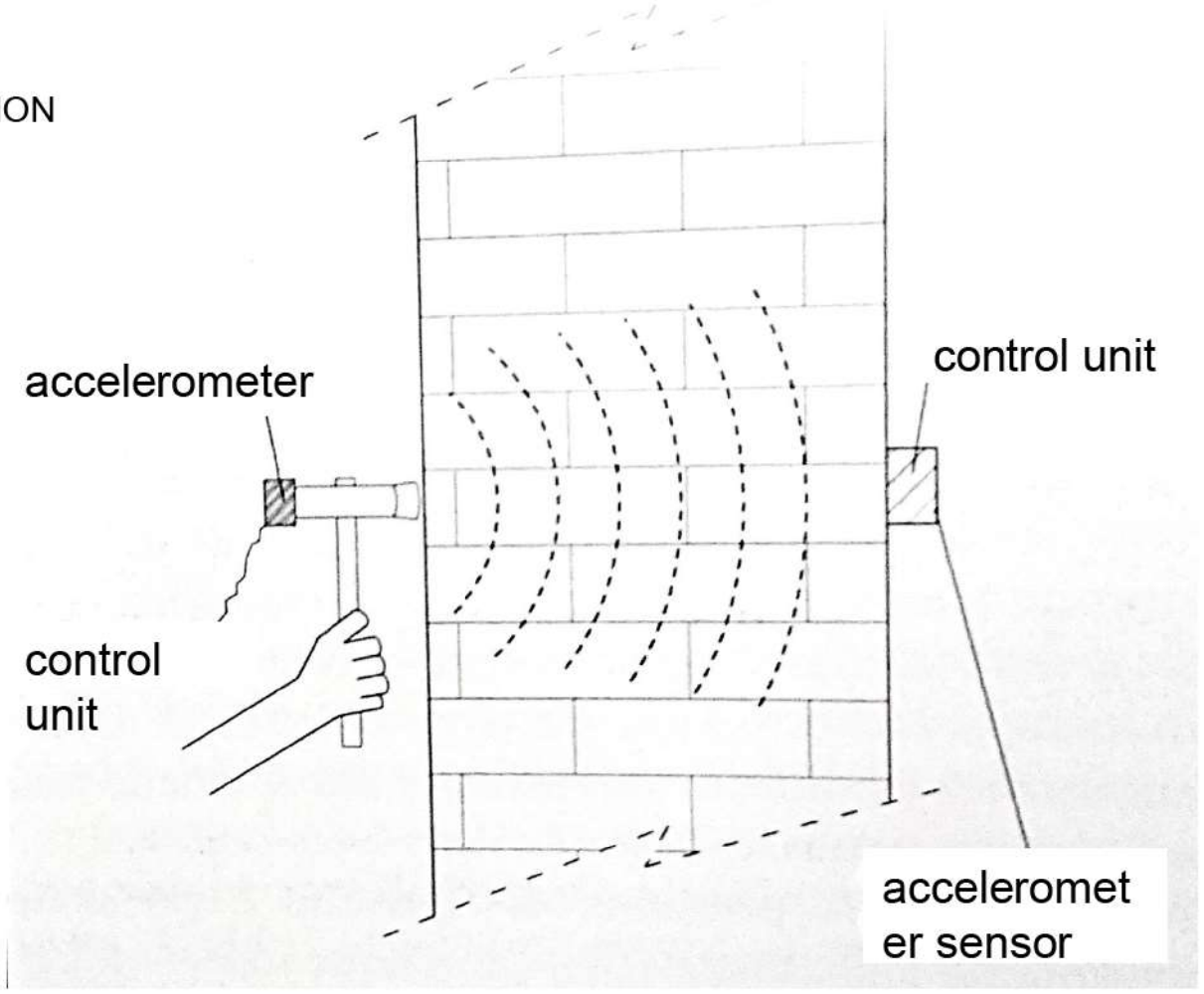
DIFFERENTI TIPI DI MISURA DI VELOCITÀ DEL SUONO CHE SI POSSONO EFFETTUARE

DAMAGE TESTS IN MASONRY

CLASS III QUANTITATIVE ANALYSIS

Type 6 **Sonic test**

TEST EXECUTION



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, superficial hardness of the material, allows the determination of the maximum breaking strength by compression of the investigated structure.

Sclerometre or Schmidt jack

Sclerometric test

DAMAGE TESTS IN MASONRY

CLASS III QUANTITATIVE ANALYSIS
Type 7 Sclerometric test

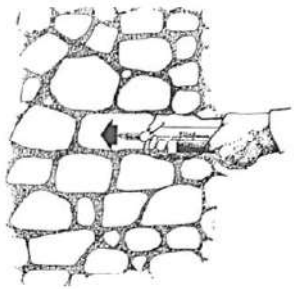
EXECUTION

a) Removal of the plaster for a wall portion such as to perform from 5 to 1 O 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 the examined surface is hard and compact.

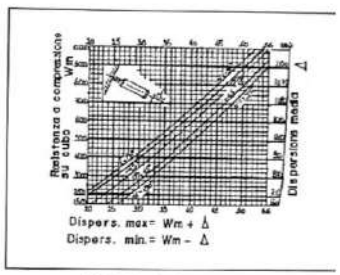
b) Reading of the value of the same rebound on the graduated scale from which, through a suitable diagram, according to the chosen stop angle, the corresponding value of the compressive strength is obtained.

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

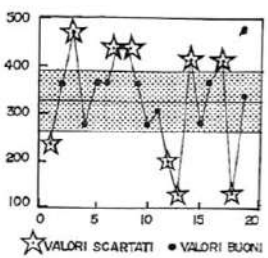
d) The instrument can be used both on vertical surfaces and on floors, ceilings, and inclined surfaces. Resenting the rebound of gravity uses different curves depending on the different positions or angles.



PRESSIONE DELLO SCLEROMETRO CC
CARICAMENTO DELLA MOLLA

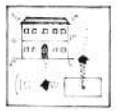


CURVA DI TARATURA



SOSTITUZIONE DELLE BATTUTE

DAMAGE TESTS IN MASONRY

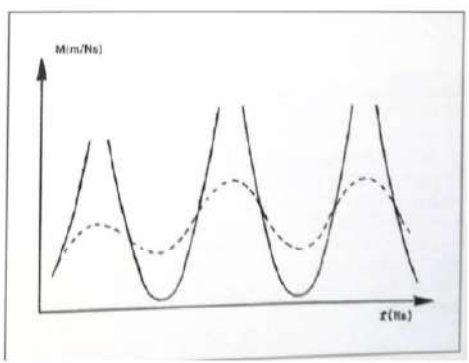


CLASS III QUANTITATIVE ANALYSIS

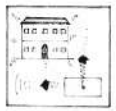
Type 8 Dynamic test

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.



DAMAGE TESTS IN MASONRY



CLASS III QUANTITATIVE ANALYSIS
Type 8 Dynamic test

EXECUTION

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

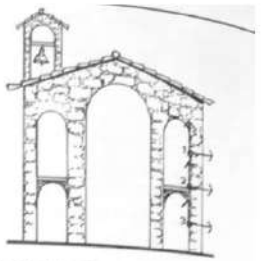
b) Possible recourse to an electrodynamic exciter:

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

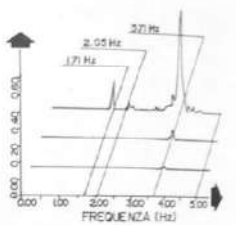
   b2) repetition of the excitation at regular intervals in two directions, parallel and normal, orthogonal to the plane of arrangement of the investigated structure.

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.

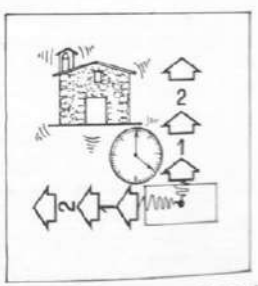
d) Interpretation of the response and evaluation of the structural integrity of the complex; possible realization of a finite element model, with proper distribution of masses and constraints.



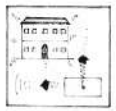
DISPOSIZIONE DEI SISMOMETRI A VARIE QUOTE



SPETTRI DI RISPOSTA RELATIVI A DIVERSE QUOTE E DEFINIZIONE DELLE RISONANZE STRUTTURALI

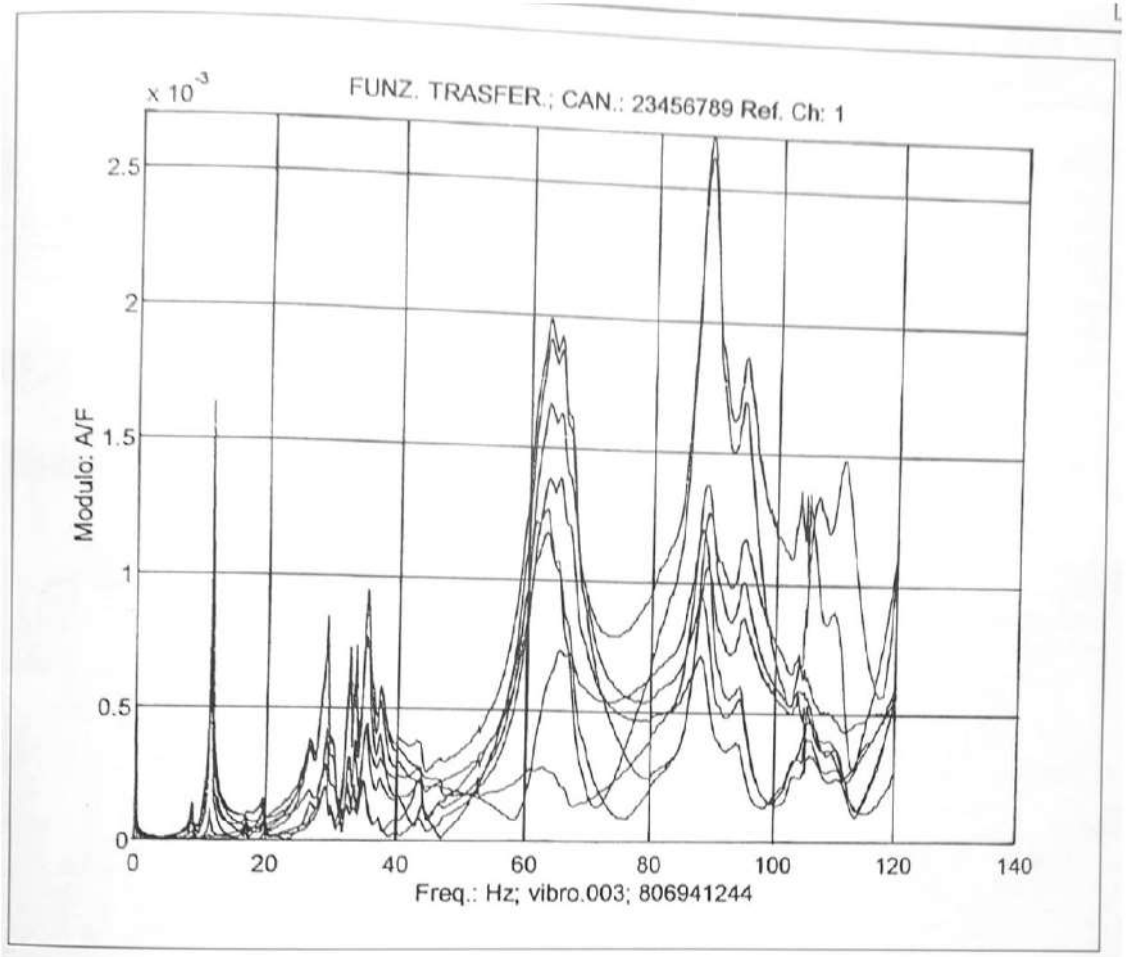


ECCITAZIONE AD INTERVALLI REGOLARI SECONDO DUE DIREZIONI



CLASS III QUANTITATIVE ANALYSIS

Type 8 **Dynamic test**



Curves related to the resonance of a seismometer

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