University of Pisa
Department of Civil and Industrial Engineering

SEMINAR

ASSESSMENT OF EXISTING STRUCTURES

MONITORING AND NDT

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Pisa, 15 marzo 2013

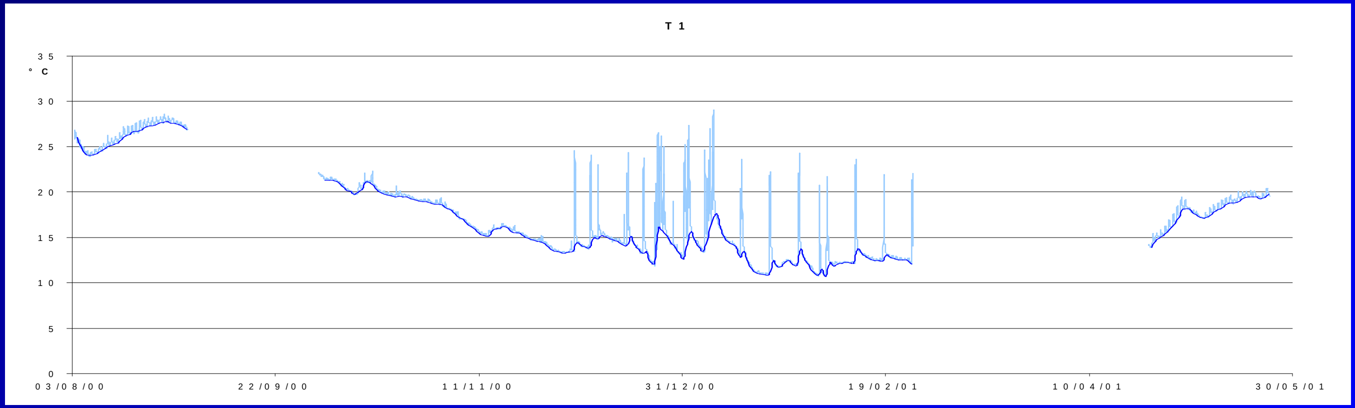
STRUCTURAL MONITORING

- monitoring of the progress of pathological phenomena (degradation, instability) $\Rightarrow$ long-term monitoring
- to know the behavior of a structure under the service loads, environmental actions (vibrations, etc.), or cyclic phenomena (temperature variations, etc.) $\Rightarrow$ short-term monitoring

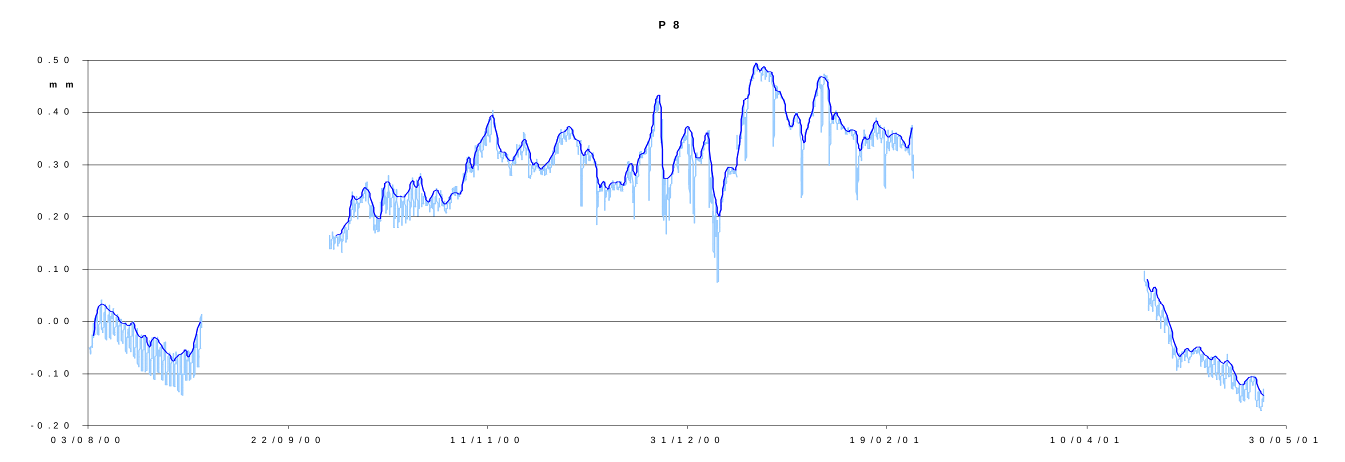
LONG TERM MONITORING

To distinguish the evolution of instability by cyclical phenomena, it is necessary that monitoring is carried out for quite long time, at least one year

temperature



crack width



Monitoring of cracks

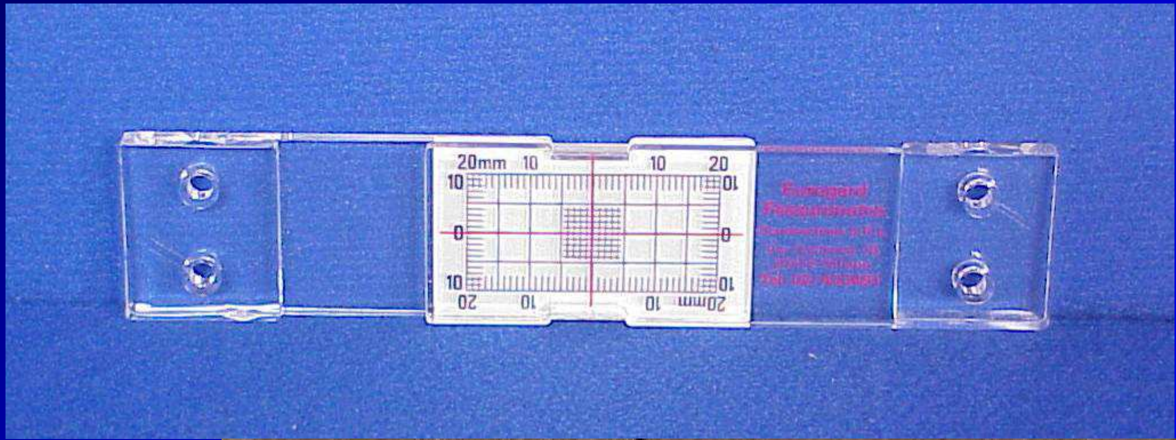
consists in detecting, not the amplitude value of the cracks, but the amplitude change over time: opening or closing

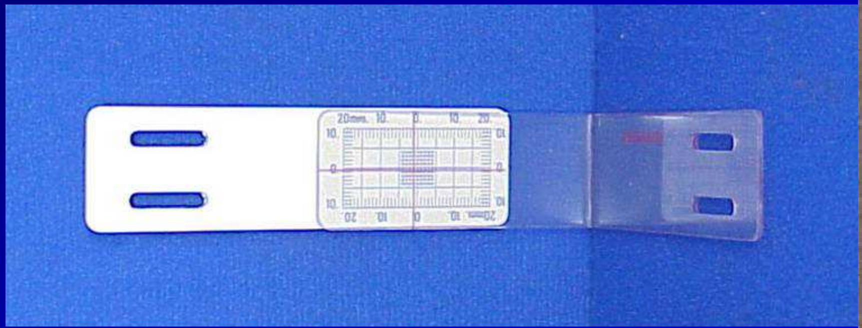
- mechanical instruments
  - cheaper
  - practical to use
- electronic instrumentation
  - continuous monitoring
  - remote control
  - data storage

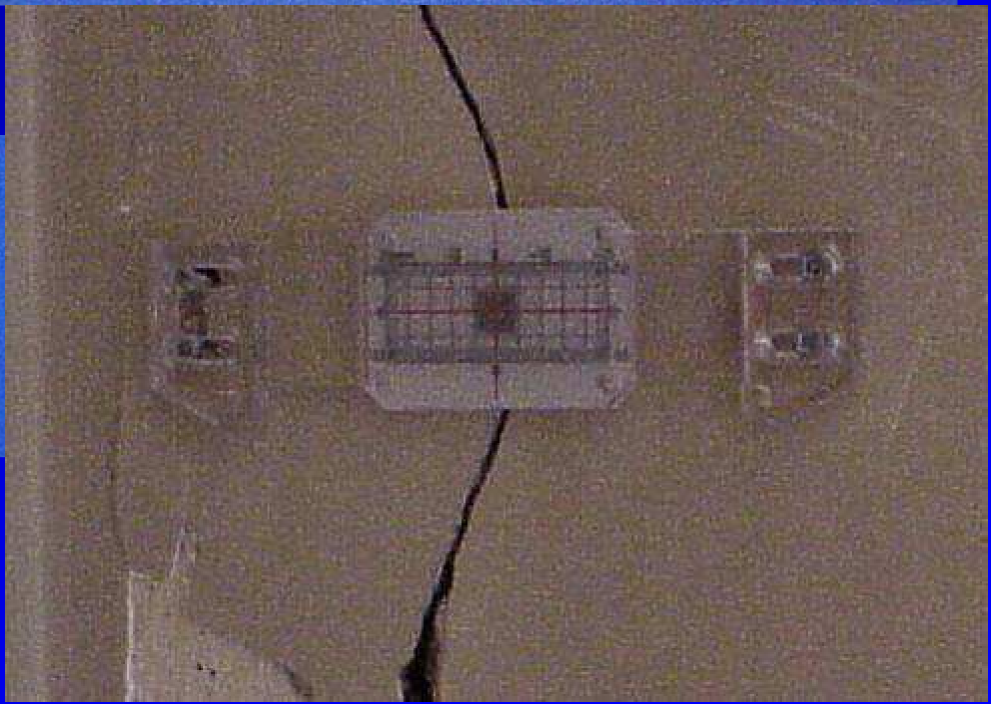
Mechanical instruments

crackmeters

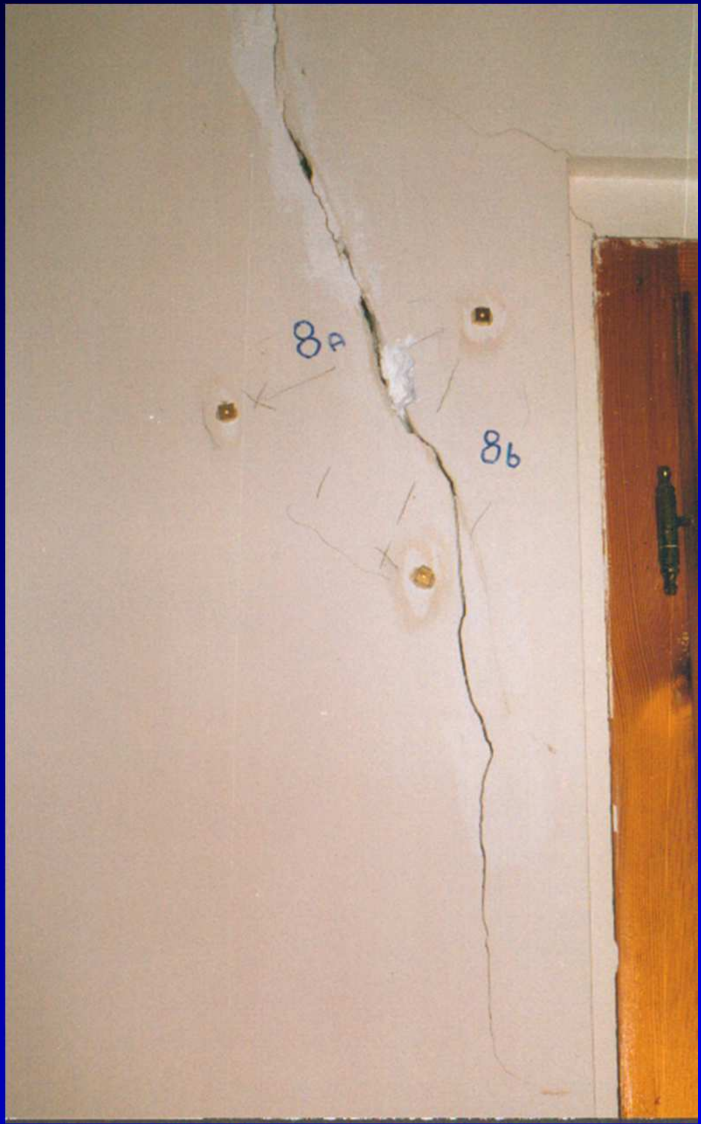
- low cost
- low precision







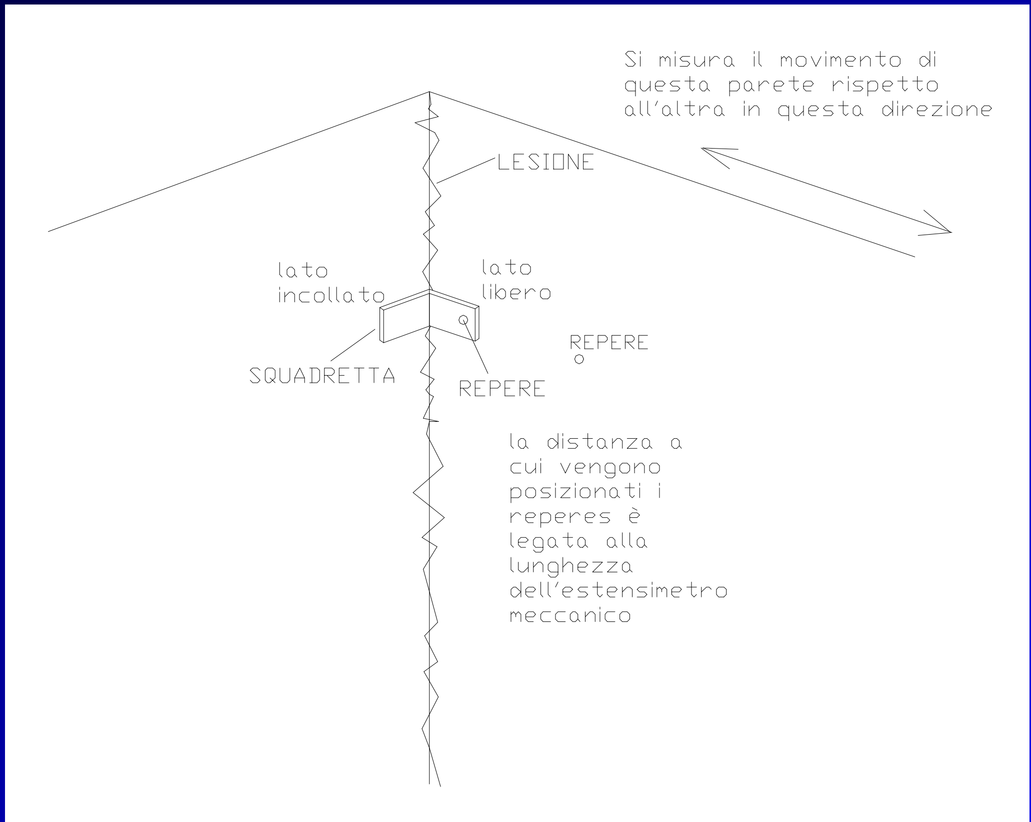
removable deformometer

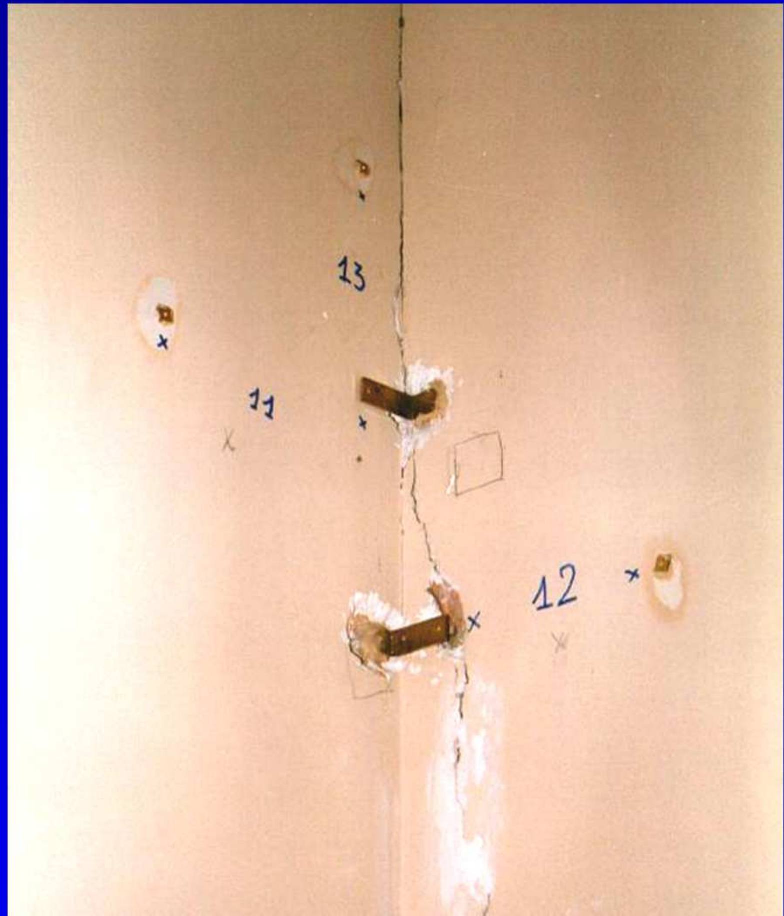


allows to measure relative movements between two reference pins

- accurate
- not invasive, allows monitoring for long periods of time

layout for monitoring corner cracks



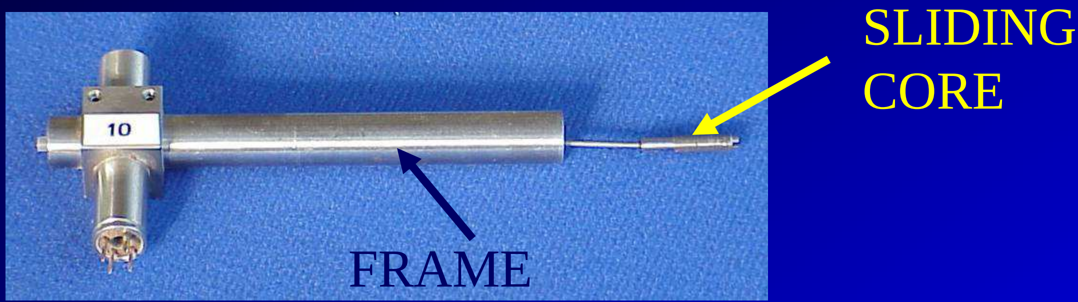


Electronic instruments

instrumentation:

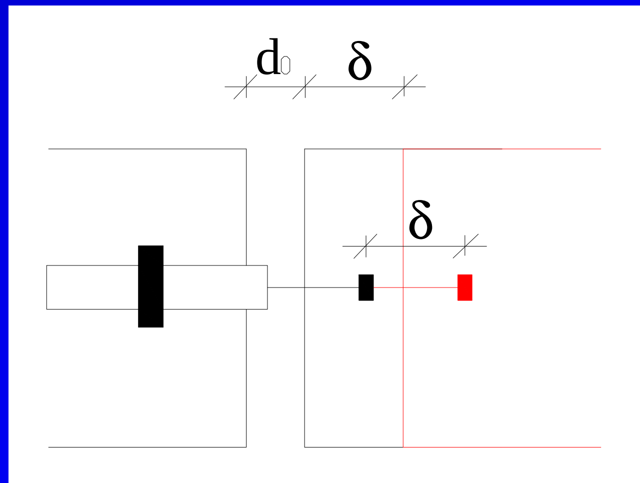
- transducers
  - displacement transducers
  - inclinometers
  - special transducers
  - temperature transducers
  - etc
- data acquisition system

Displacement transducer

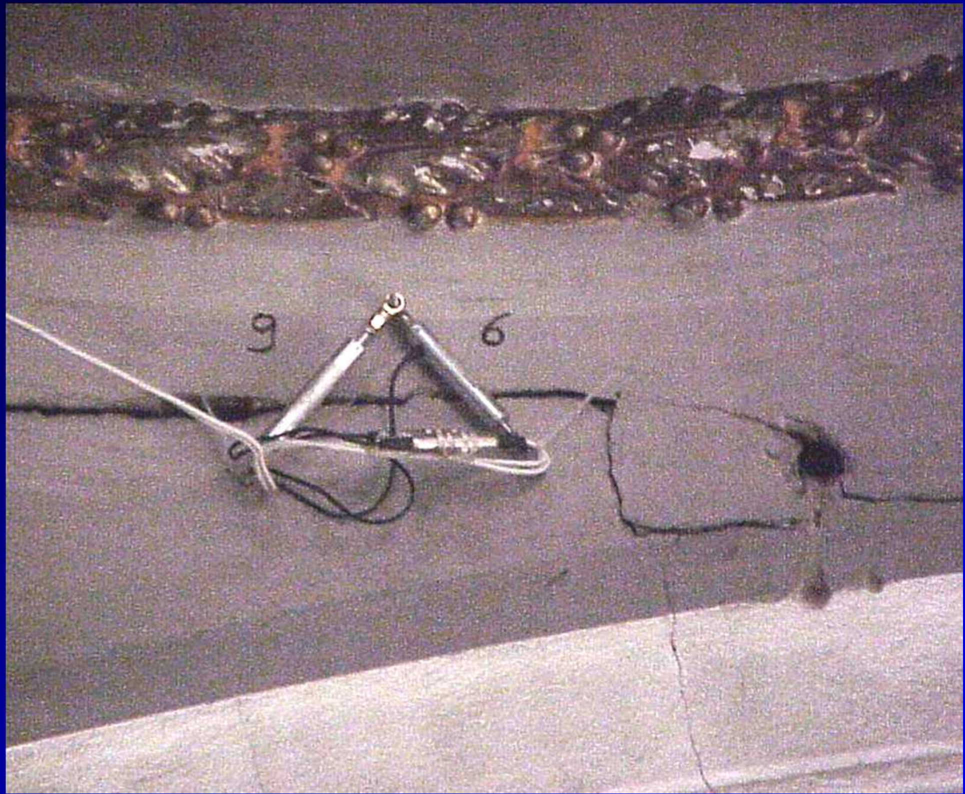


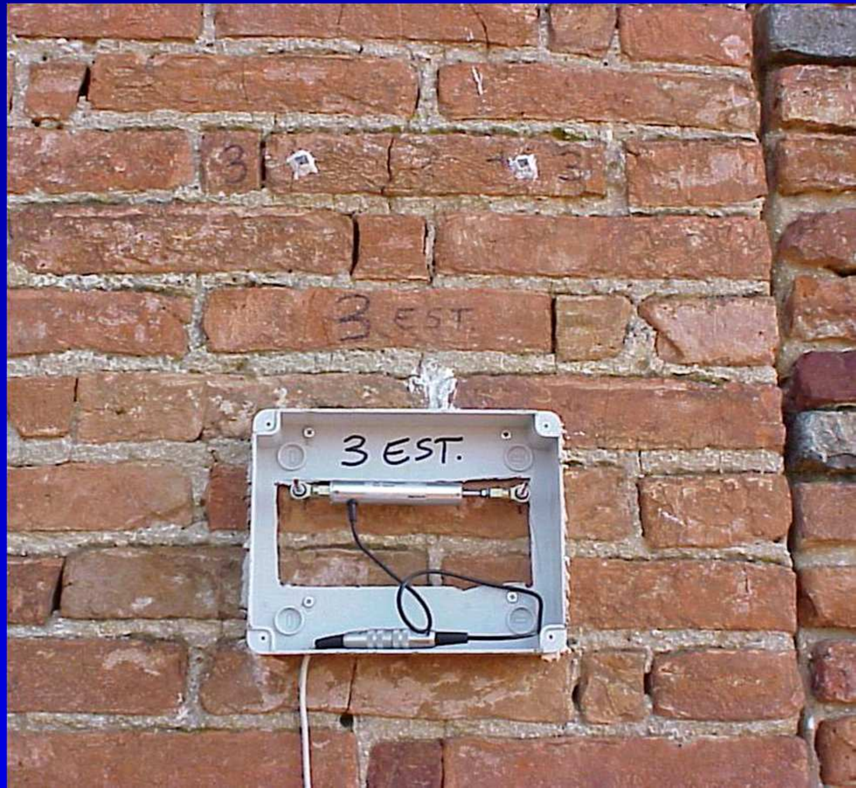
it measures the relative displacement between the point where the frame is fixed and the point where the core is fixed

if the frame and the core are fixed on both sides of a crack, it acts like a crackmeter



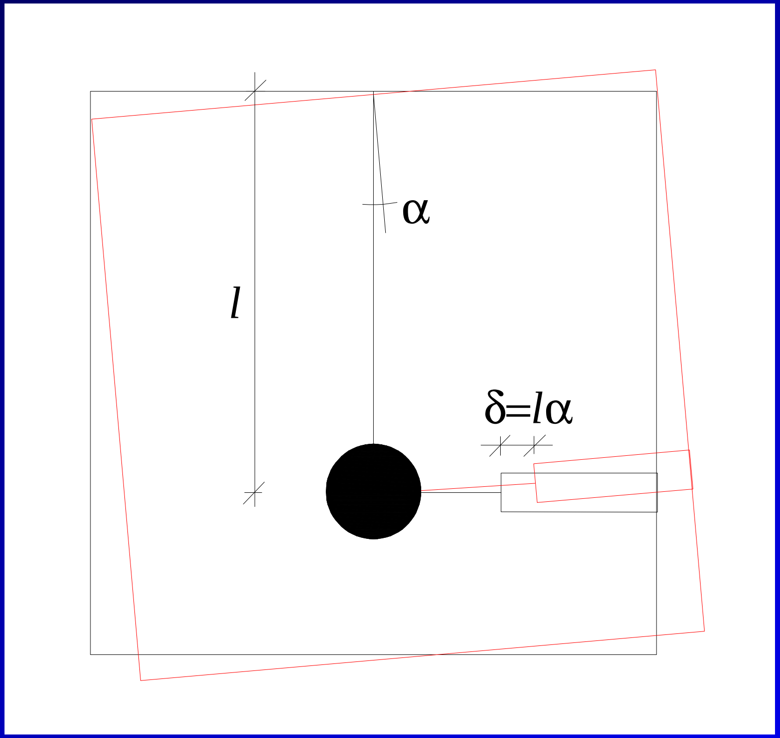
examples of application





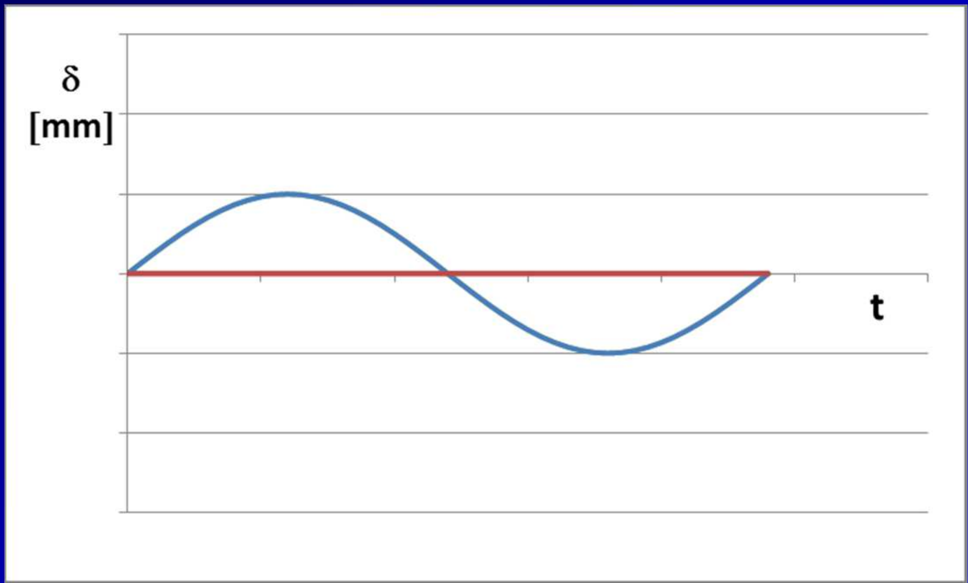
Inclinometer

it measures the increase of the lead out of a structure, eg. a wall



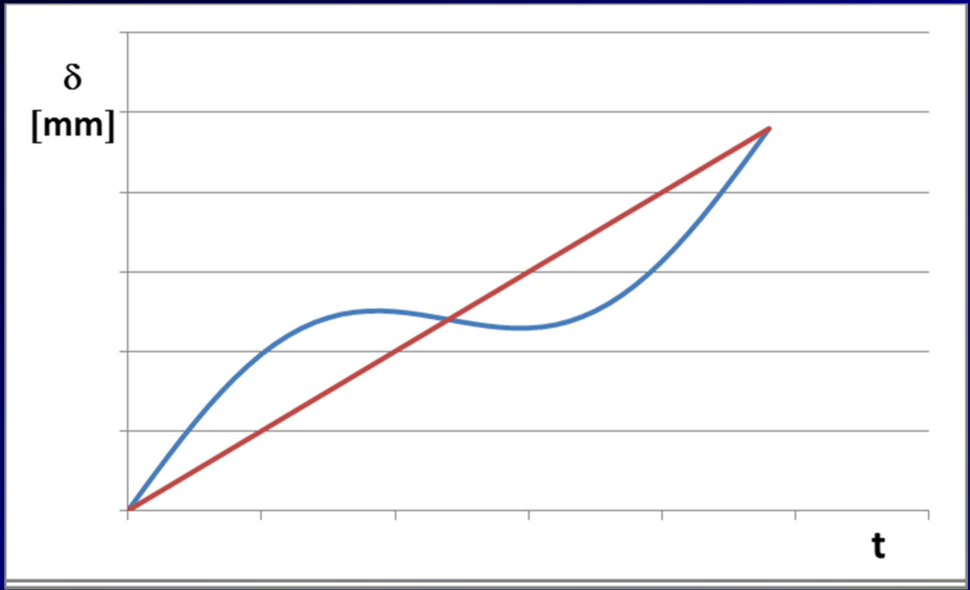
Results of the structural monitoring

usually we analyze the results after a quite long period, in order to detect cyclic phenomena: effect of temperature, etc.



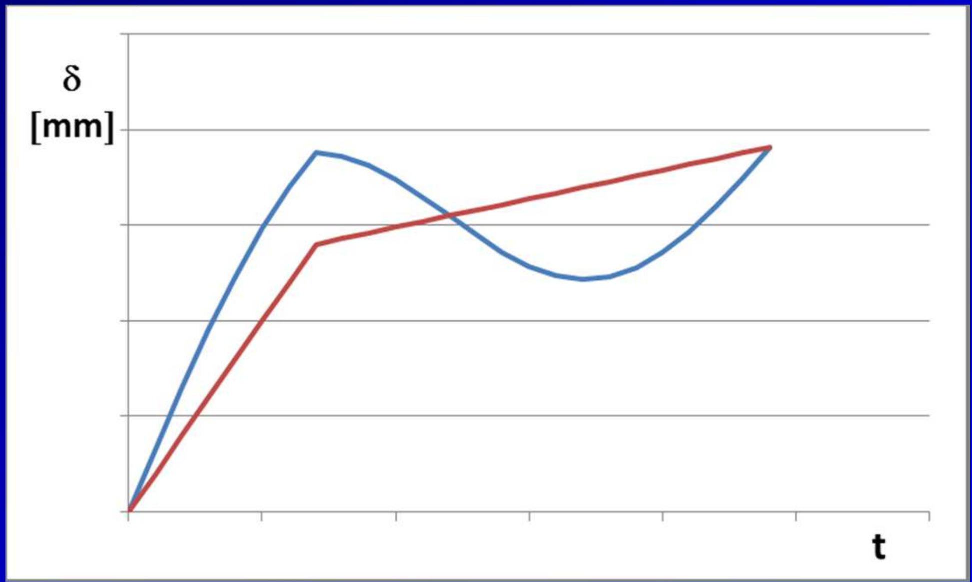
the phenomenon is STABLE

measures may be less frequent



the phenomenon is INCREASING

repair or continue the monitoring



the phenomenon is probably STABILIZING

continue the monitoring

Short-term monitoring

monitoring the response of the structure to imposed loads:

- environmental actions
- loads specially applied
    - static load test
    - dynamic test

STATIC LOAD TESTS

Usually, it consists in applying loads on a floor and monitoring the inflection

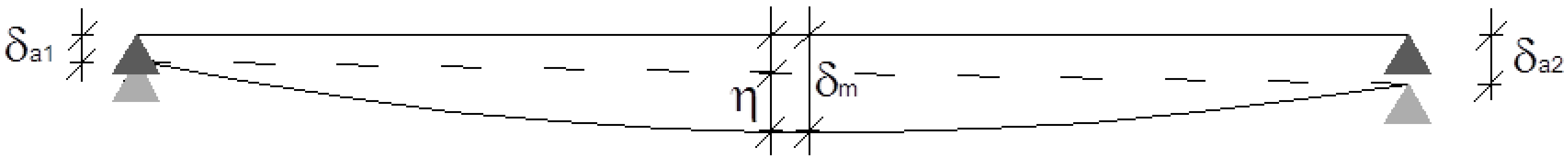
It's important, previously, to make an accurate survey of the structure and a theoretical computation of the results of the test

The result of a load test is not the RESISTANCE of the structure, but only its STIFFNESS

If experimental results in terms of stiffness match with theoretical ones, then we can deduce that also actual resistance will be similar to the computed one

It's important to consider the collaboration of non structural elements

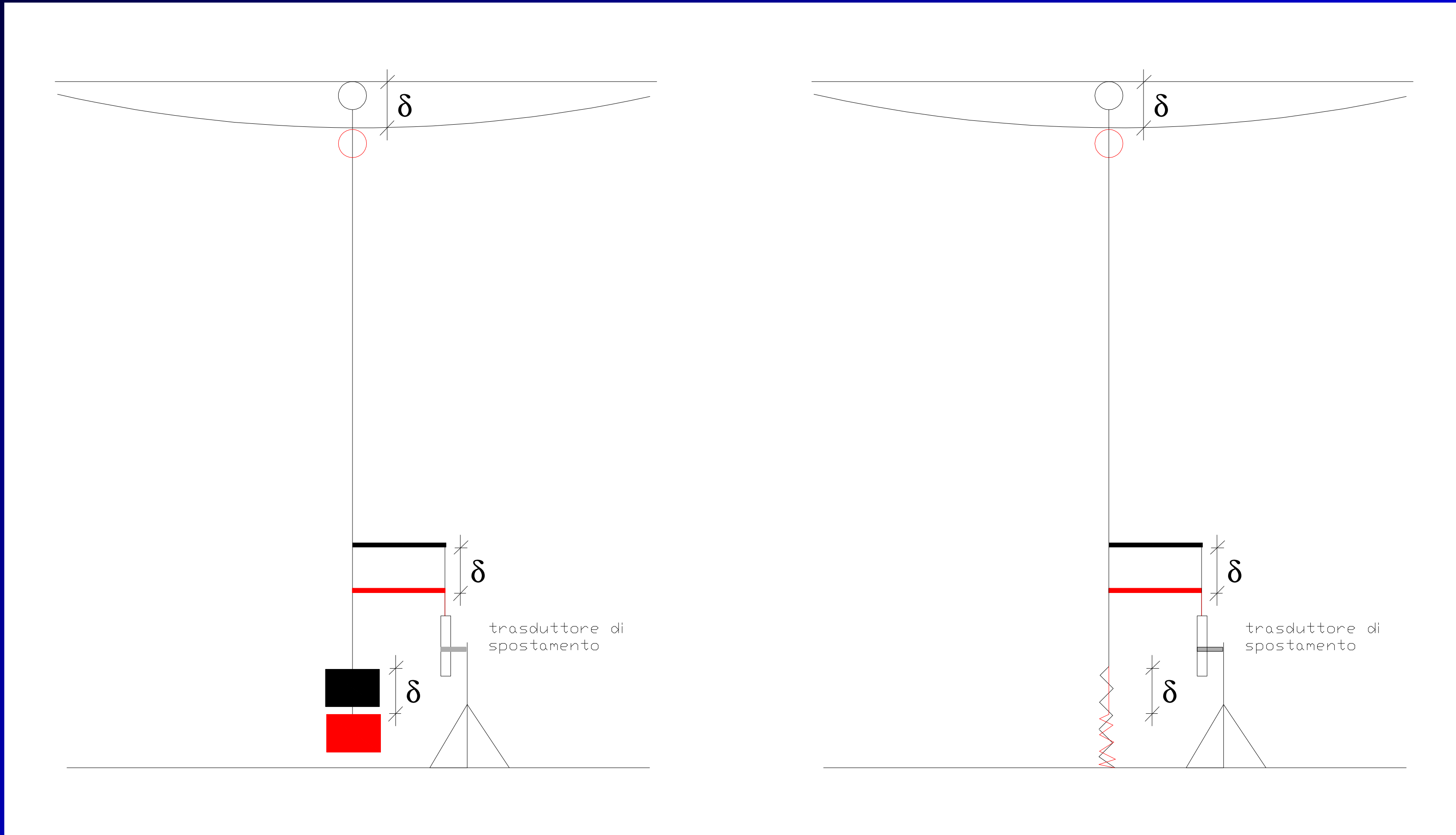
In addition to the measurement of the inflection of the floor, it's necessary to measure the lowering of the supporting elements – beams, walls, etc.



$$\eta = \delta_m - \frac{\delta_{a1} + \delta_{a2}}{2}$$

Loads

Inflection transducers



CONDUCTING A LOAD TEST

- measure of inflections at "0" step
- application of load, step by step
- measure of inflections at each step
- measure at maximum load
- the maximum load is left on the structure for at least 15 min
- unloading (possibly step by step)
- measure when unloading is completed
- if the test results are not clear or unexpected, the test will be repeated

Test result

Test result is positive when:

- the structure is not damaged
- the results are similar to the expected ones
- inflections are proportional to the loads
- residual inflection is little (about 10%) with respect to maximum

example

ora	10.05	10.20		10.37		11.04		11.22		11.50		12.10		12.32		12.45	
T (°C)	25.8	25.6		25.9		25.9		26.0		26.3		26.2		26.6		26.7	
Fase di carico	Atezza del battente in acqua [cm]																
	0	5.0		12.0		12.0		18.0		32.0		32.0		5.0		0.0	
Comparatore N°	[mm/100]																
	lettura	lettura	η	lettura	η	lettura	η	lettura	η	lettura	η	lettura	η	lettura	η	lettura	η
1	635	637	2	639	4	639	4	641	6	646	11	646	11	640	5	639	4
2	858	864	6	871	13	871	13	877	19	890	32	891	33	870	12	866	8
3	782	788	6	798	16	798	16	807	25	824	42	826	44	796	14	790	8
4	804	807	3	814	10	814	10	821	17	834	30	835	31	813	9	808	4
5	949	949	0	952	3	952	3	953	4	956	7	956	7	951	2	949	0
6	813	819	6	824	11	825	12	830	17	840	27	840	27	823	10	819	6
7	679	686	7	696	17	696	17	706	27	725	46	725	46	696	17	689	10
8	674	677	3	687	13	687	13	691	17	715	41	716	42	689	15	686	12
9	674	680	6	687	13	687	13	693	19	704	30	704	30	687	13	683	9

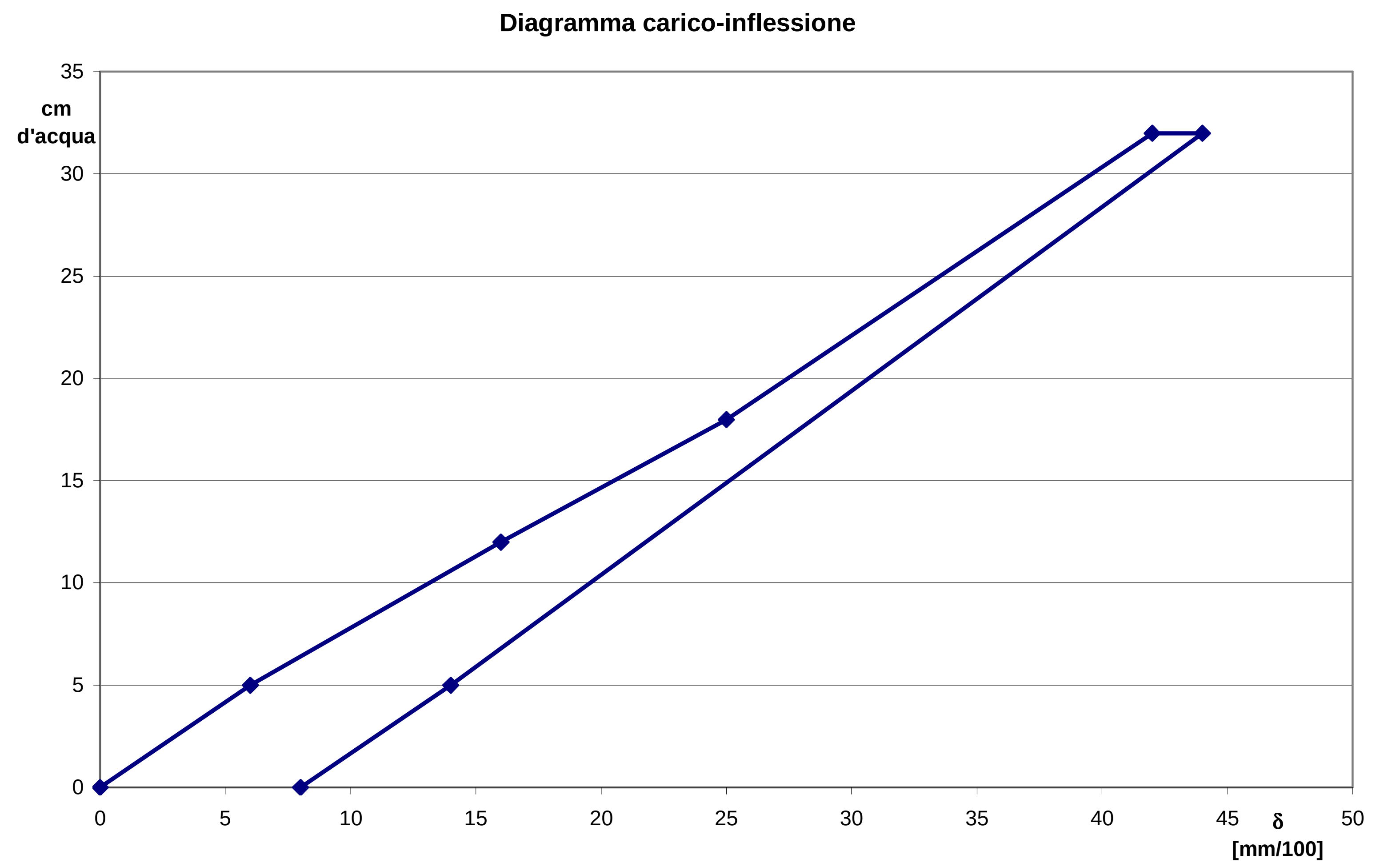


Diagramma carico-inflessione
cm
d'acqua
35
30
25
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5
10
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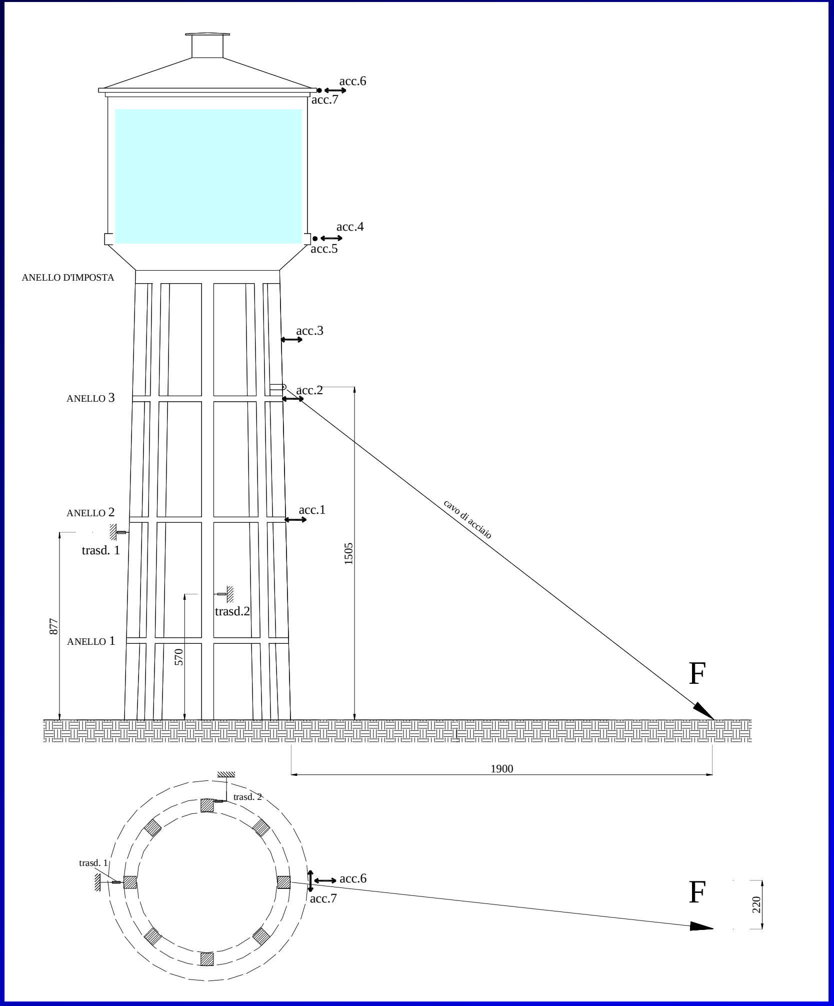
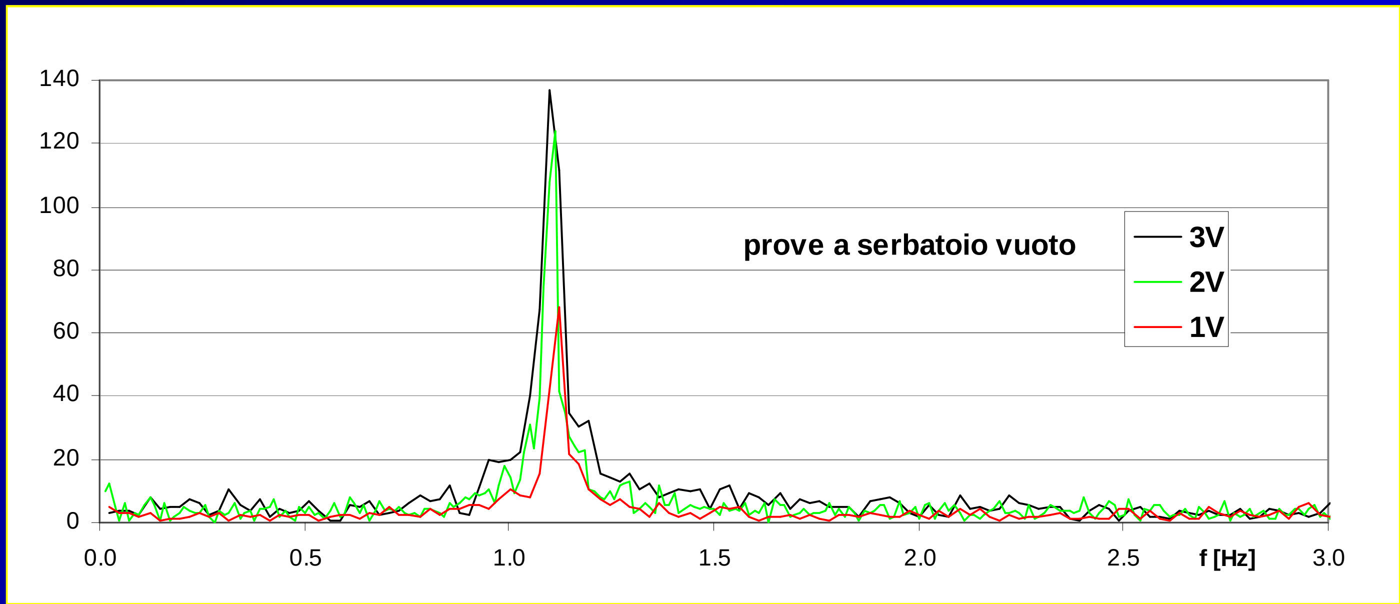
20
25
30
35
40
45
δ
[mm/100]
50

DYNAMIC TESTS



Results of a dynamic test

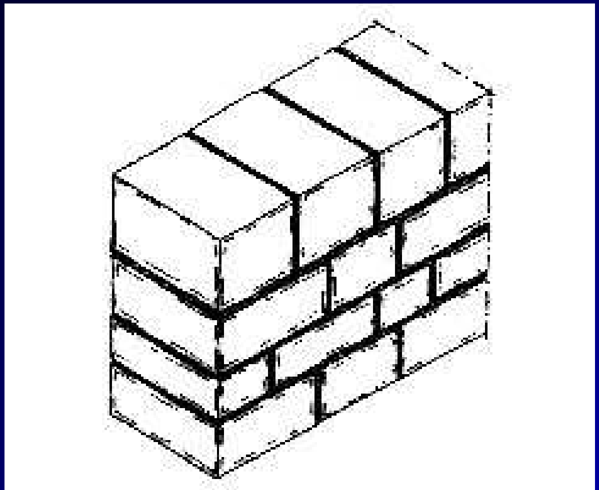


NON DESTRUCTIVE TESTS

EXISTING MASONRY BUILDINGS

- Detecting the typology and the arrangement of the blocks
- Mechanical characterization of the masonry
- Cracks pattern

Typology and layout

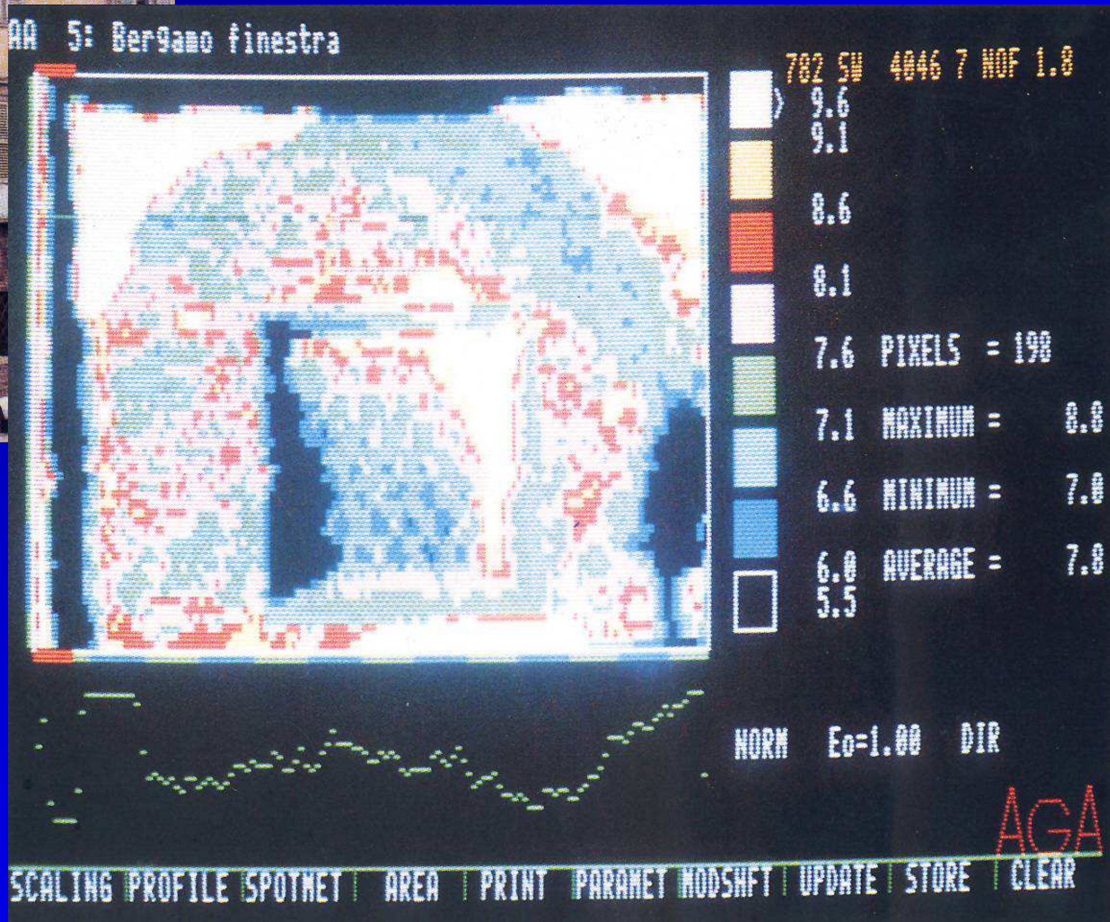


Layout of the blocks in the masonry wall

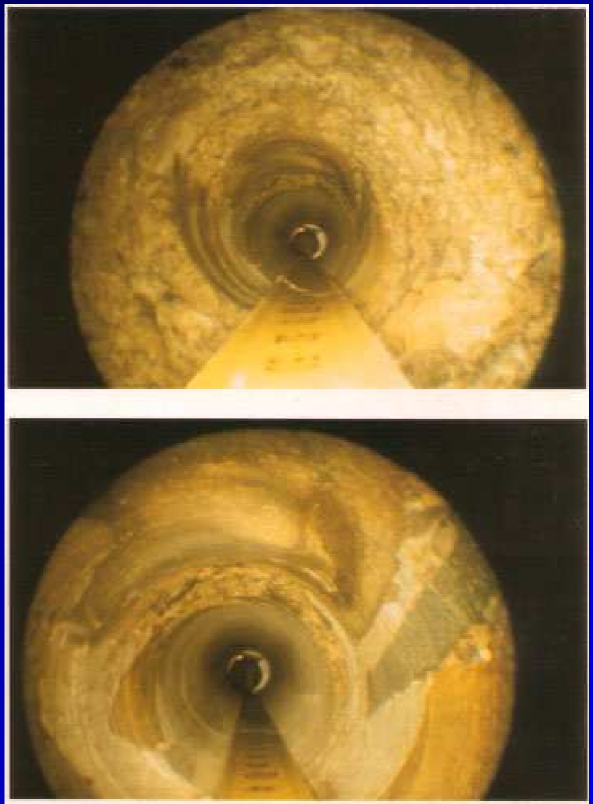
Quantity of
mortar

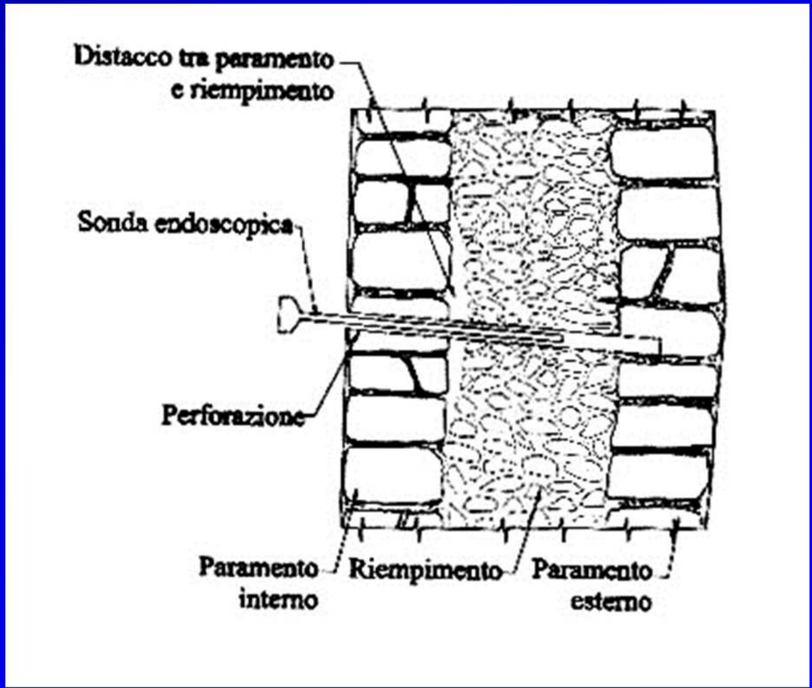
Presence of cavities

THERMOGRAPHIC INVESTIGATIONS



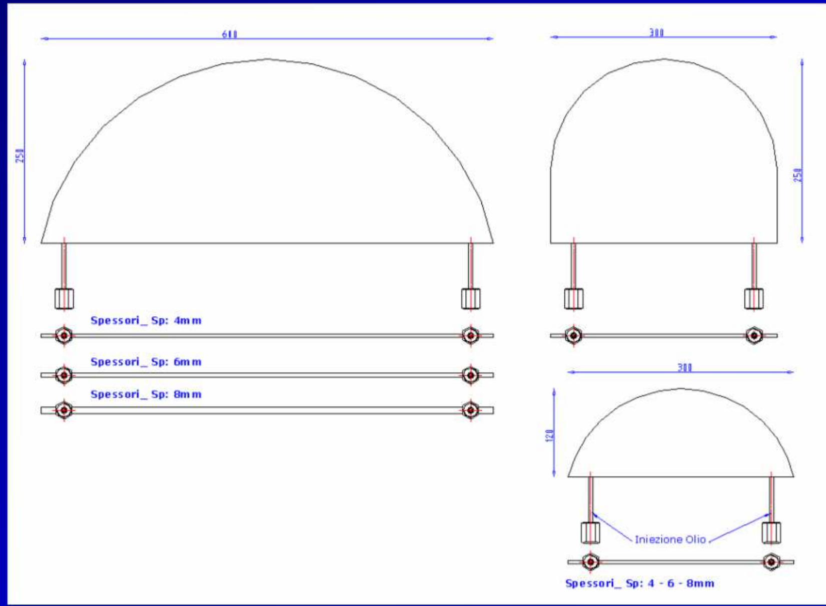
ENDOSCOPY

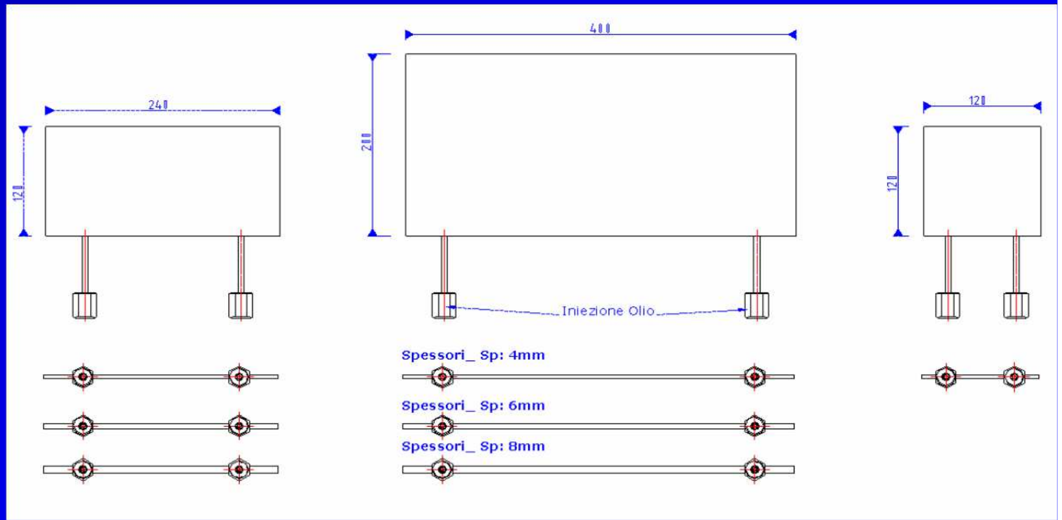



Distacco tra paramento
e riempimento
Sonda endoscopica
Perforazione
Paramento
interno
Riempimento
Paramento
esterno

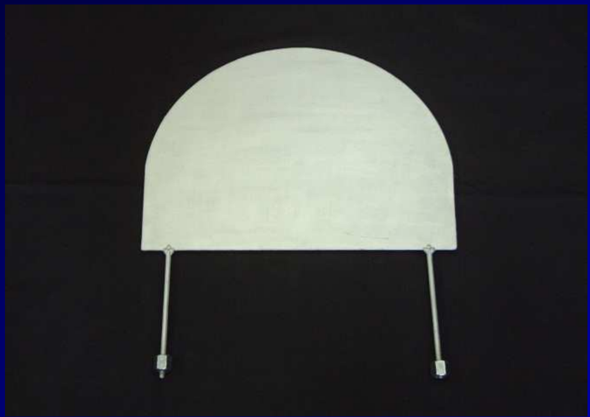
CORE DRILLING

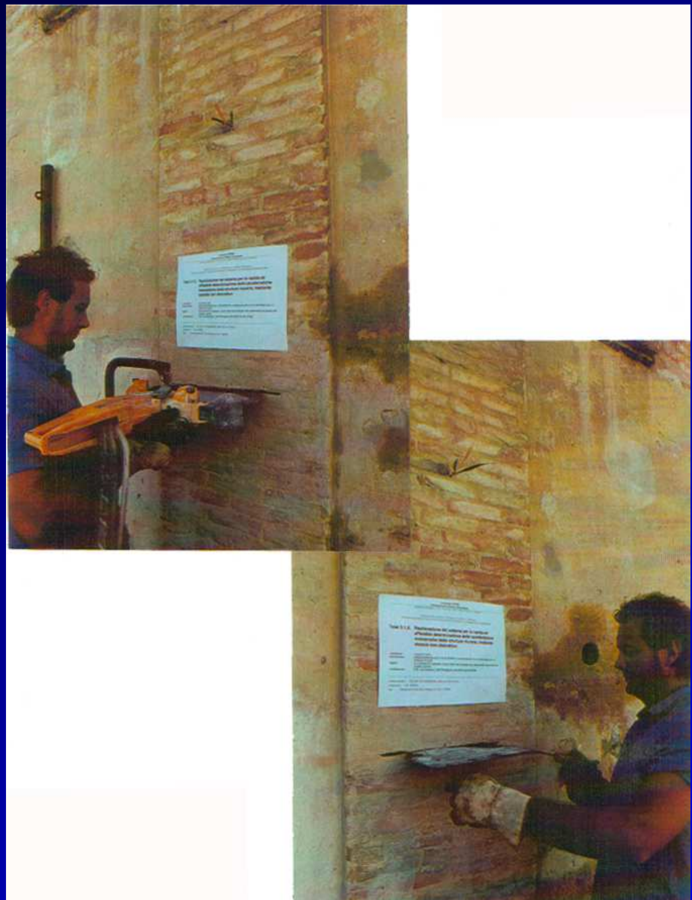
FLAT JACKS TEST





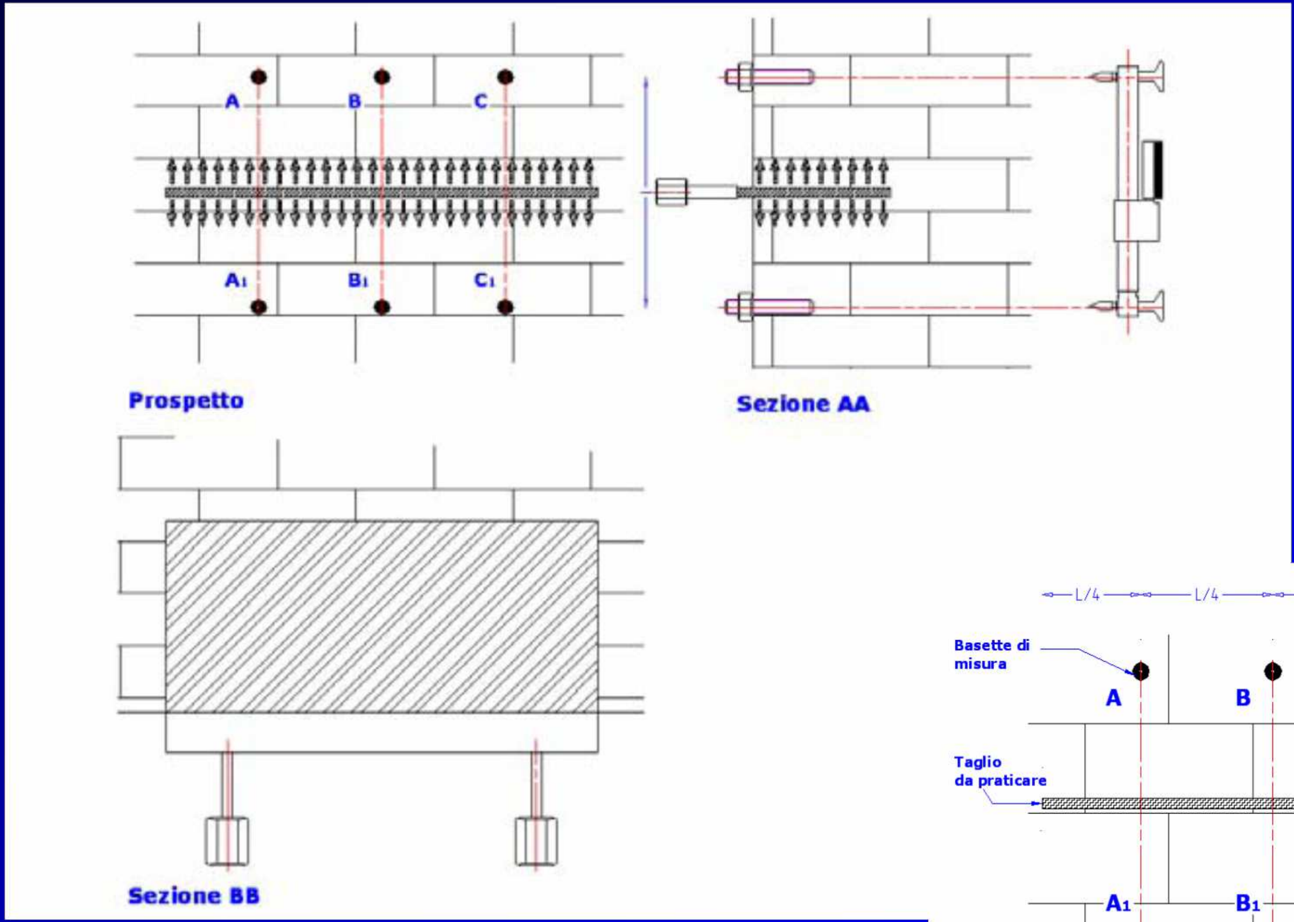
EQUIPMENT FOR FLAT JACKS TESTS

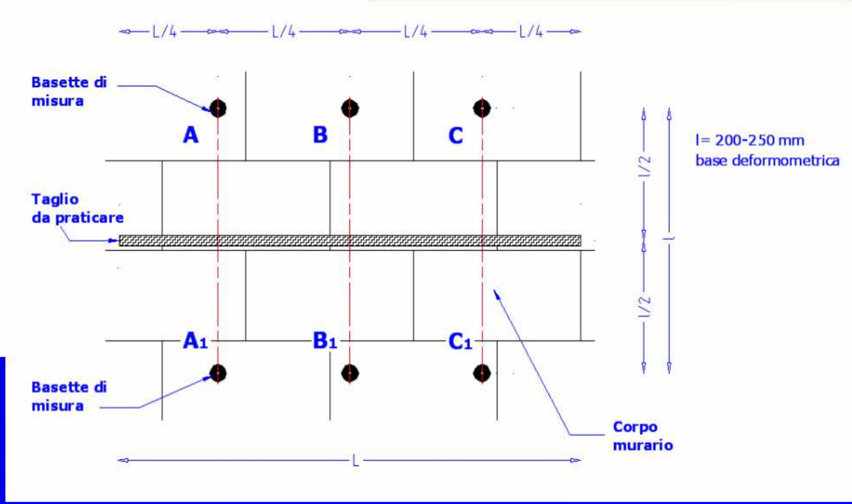




SINGLE FLAT JACK

Evaluation of the stress level

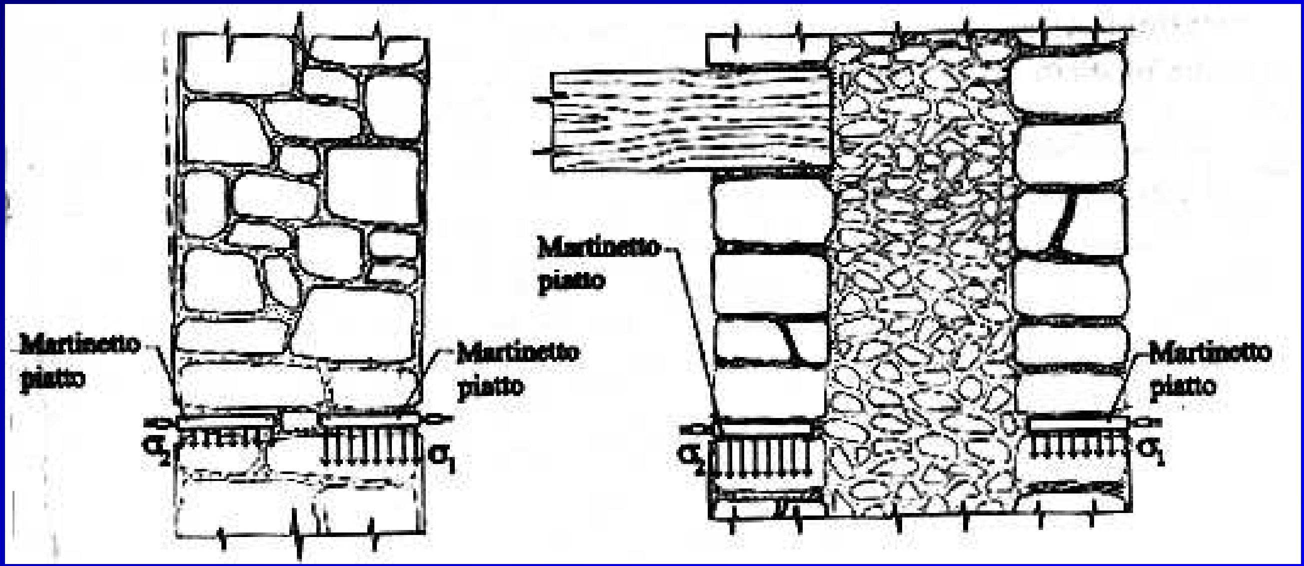




Useful for detecting different values of stress from a side to the other of a masonry wall, due to:

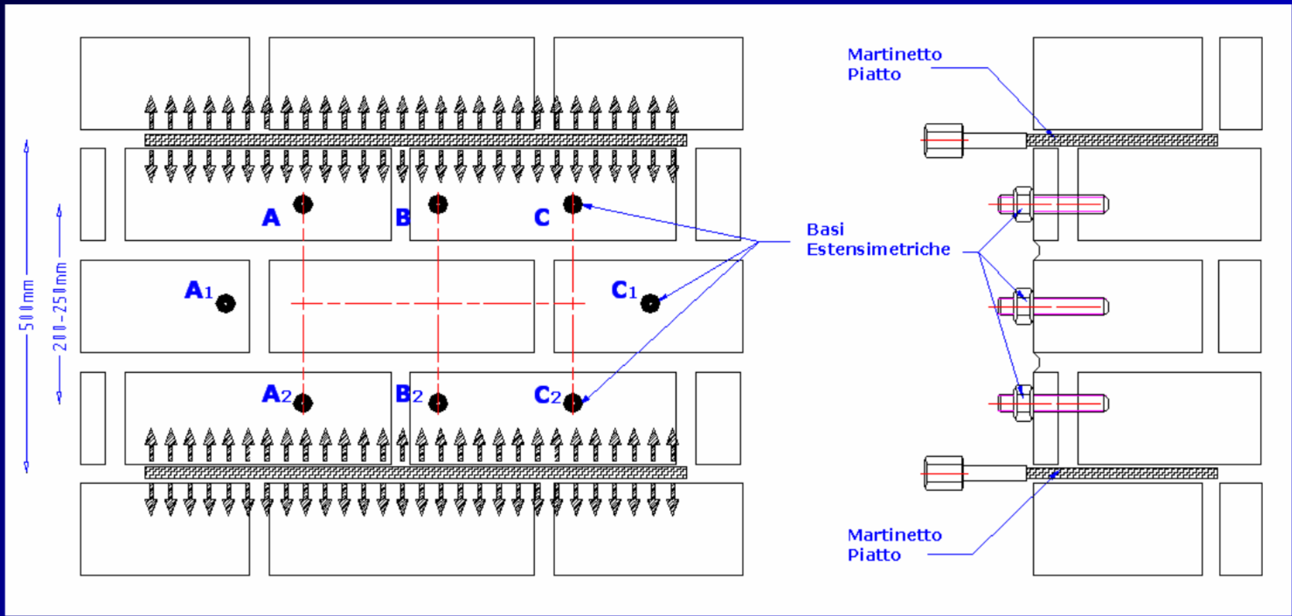
rotation, out of plumb

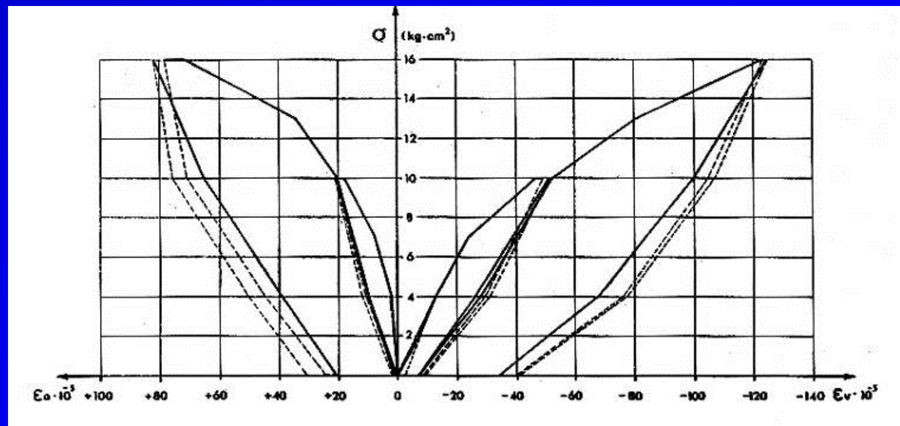
uneven distribution of the loads



FLAT JACKS TEST

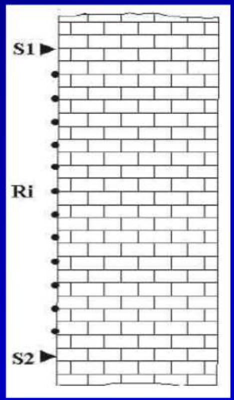
mechanical characteristics in compression





SONIC TESTS

They consist in measuring the velocity of sonic waves through the masonry wall

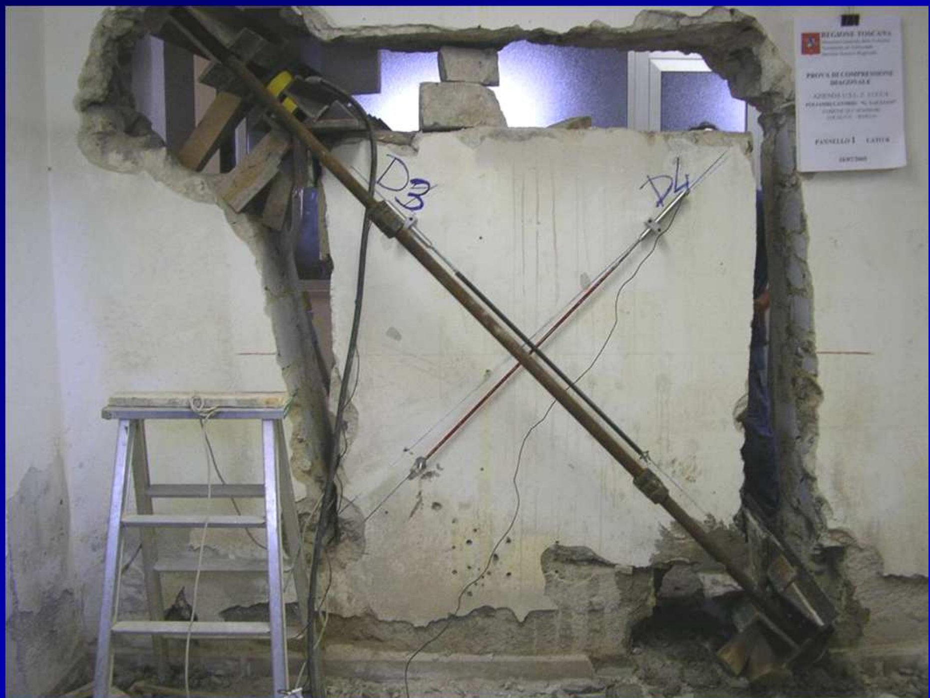


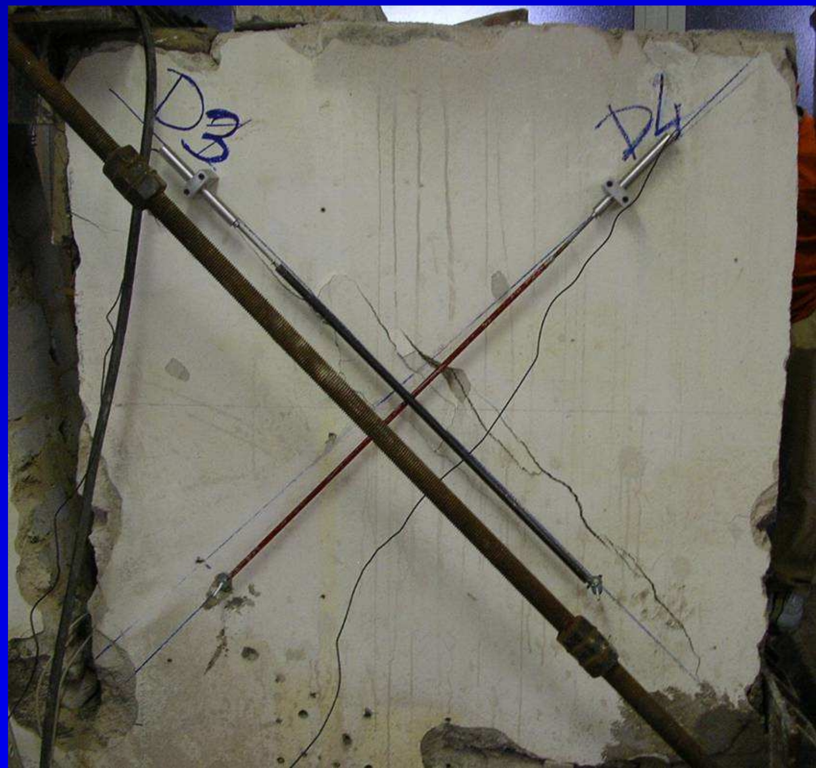
V < 1000 m/s bad quality masonry, presence of cracks or/and voids
1000 m/s < V < 2000 m/s typical of existing masonry wall
V > 2000 m/s good quality masonry

IN SITU DIAGONAL COMPRESSION TEST

used for detecting the shear behaviour of masonry walls

invasive test





IN SITU COMPRESSIVE AND SHEAR TEST

used for detecting the shear behaviour of masonry walls under different levels of compression

invasive test

NDT FOR R.C. STRUCTURES

Detection of reinforcing bars:

covermeter

Tests for qualification of the concrete:

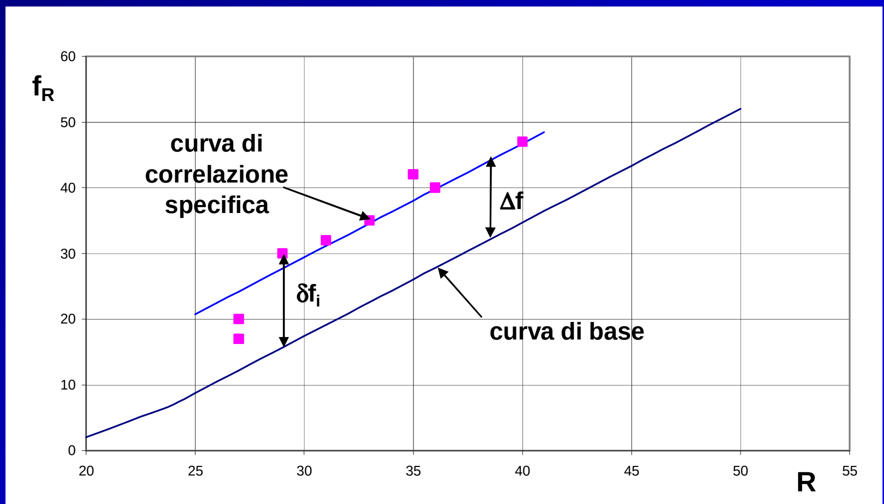
- semi-destructive tests: compression test on cores
- non destructive tests:

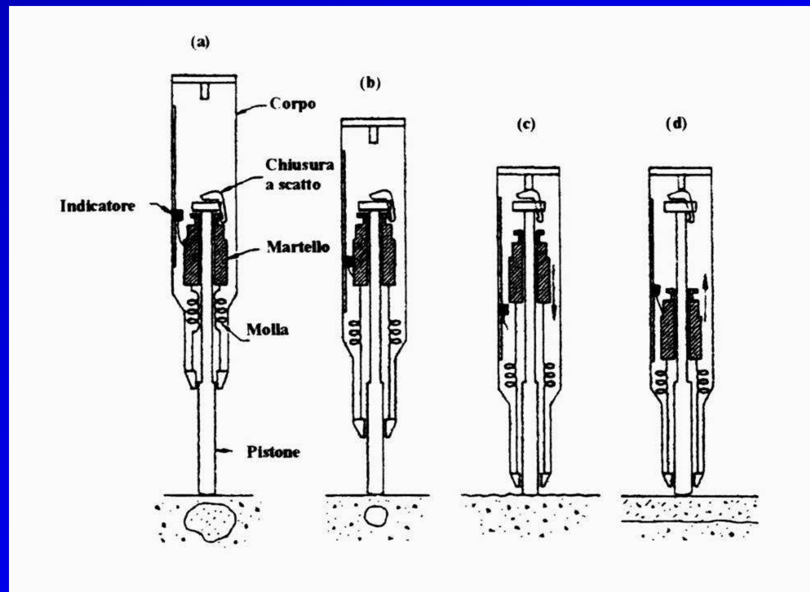
  rebound hammer, ultrasonic test, combined tests

Compression test on cores

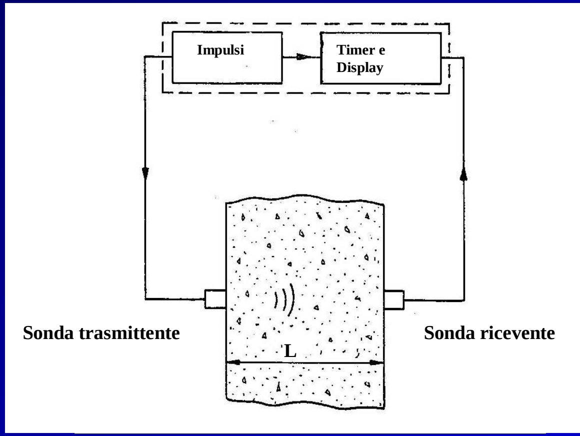
Rebound hammer

EN 13791

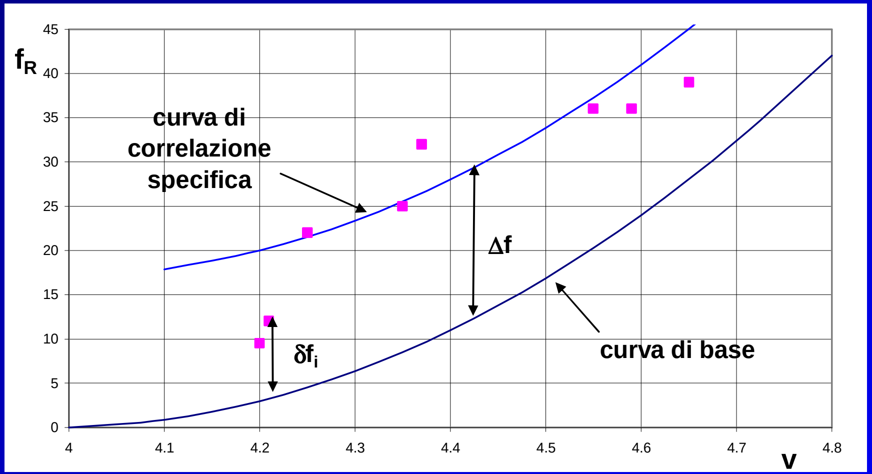




Ultrasonic test



EN 13791:2007

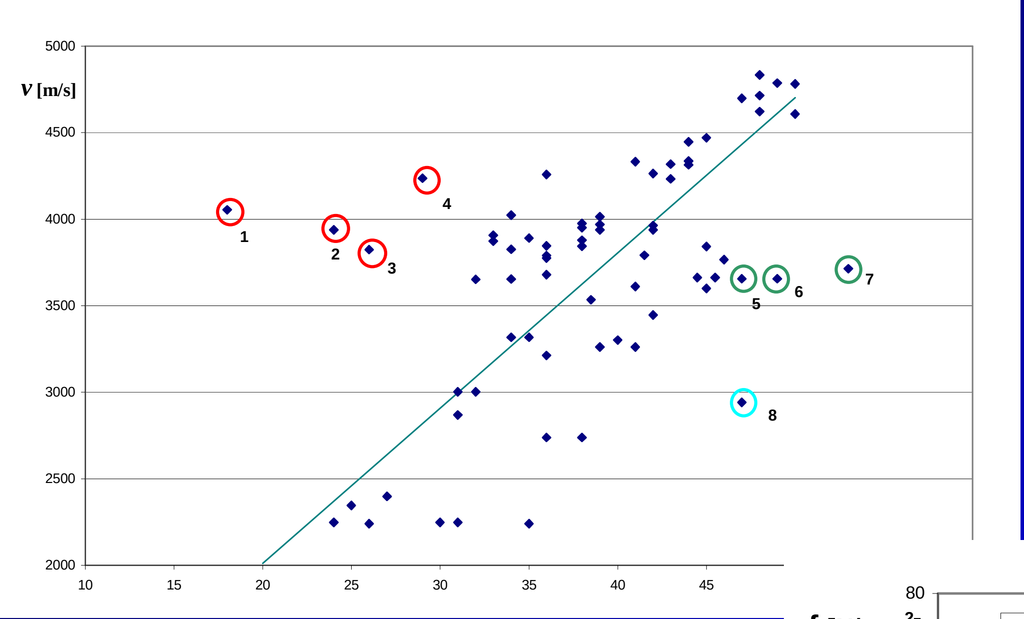


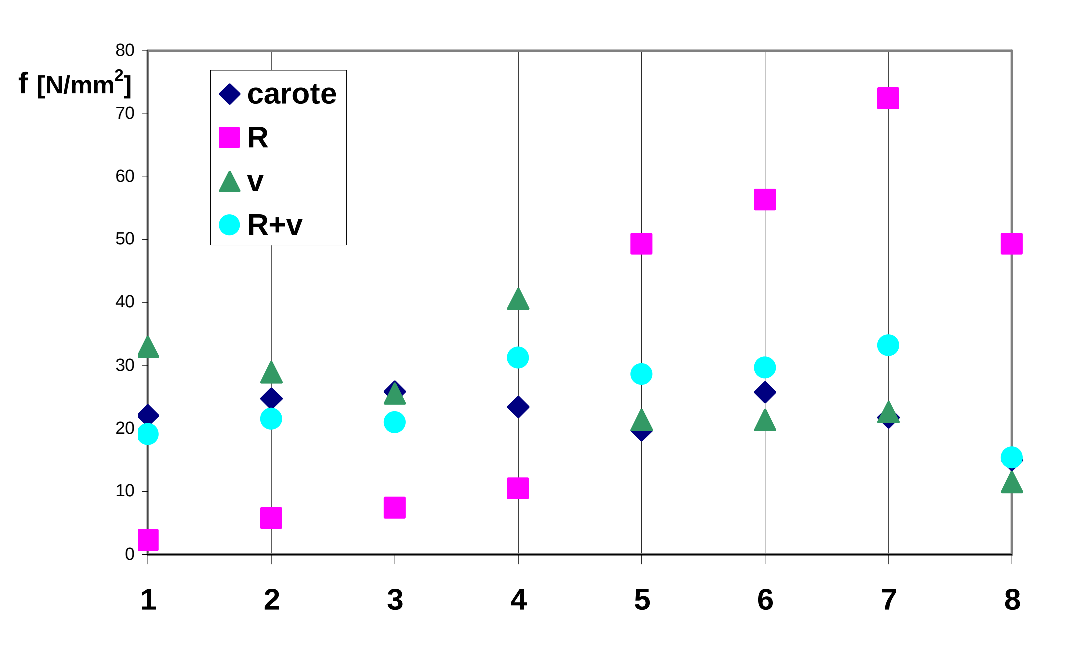
SONREB method

rebound index + ultrasonic velocity $\Rightarrow$ **concrete resistance**

$$f_c = 7.695 * 10^{-11} * R^{1.4} * v^{2.6}$$

Example





decayed surface

carbonated concrete