WORKSHOP

Conservation of concrete-based artworks and buildings and electrochemical sensors: innovative devices for degradation monitoring by immediate, low cost, and non-invasive multiparameter diagnosis

December 10th , 2020

On the way to monitor the corrosion process in the reinforced concrete structures

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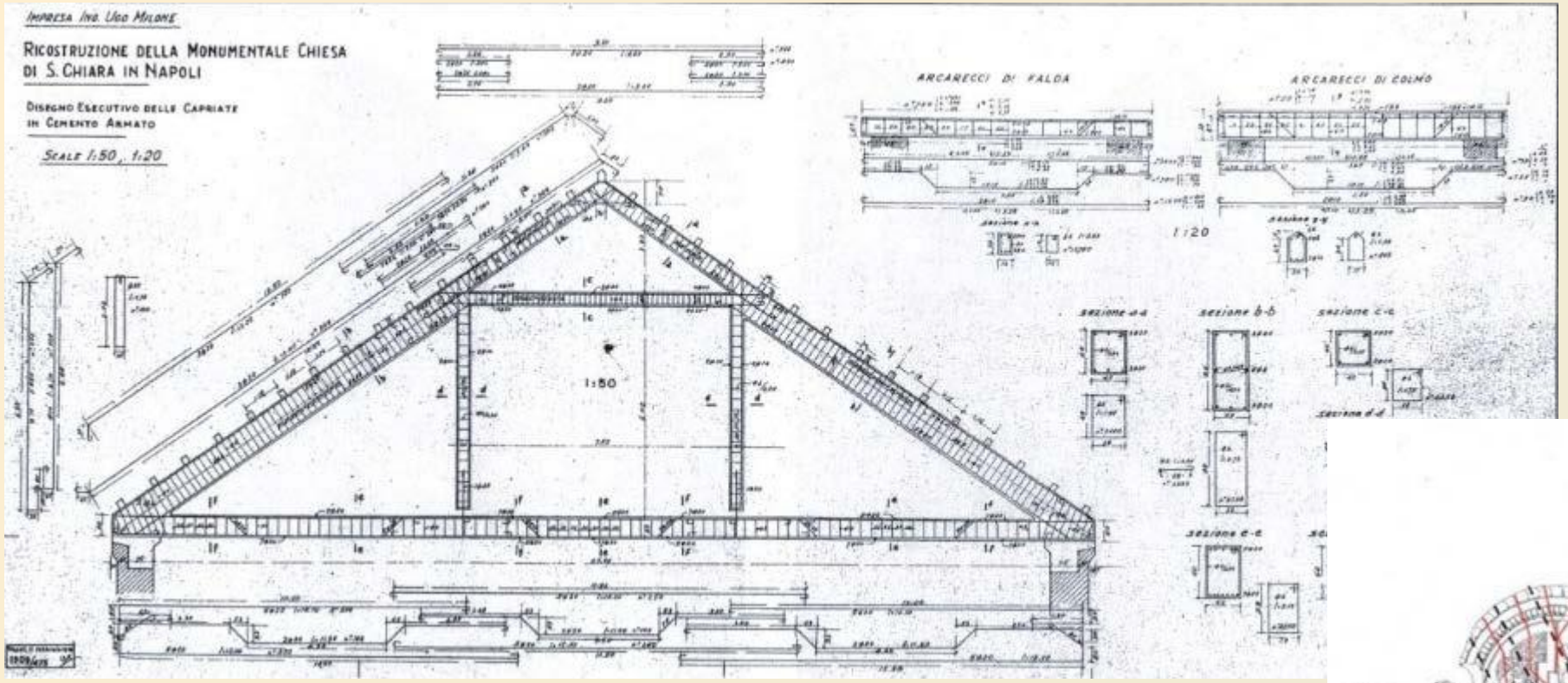
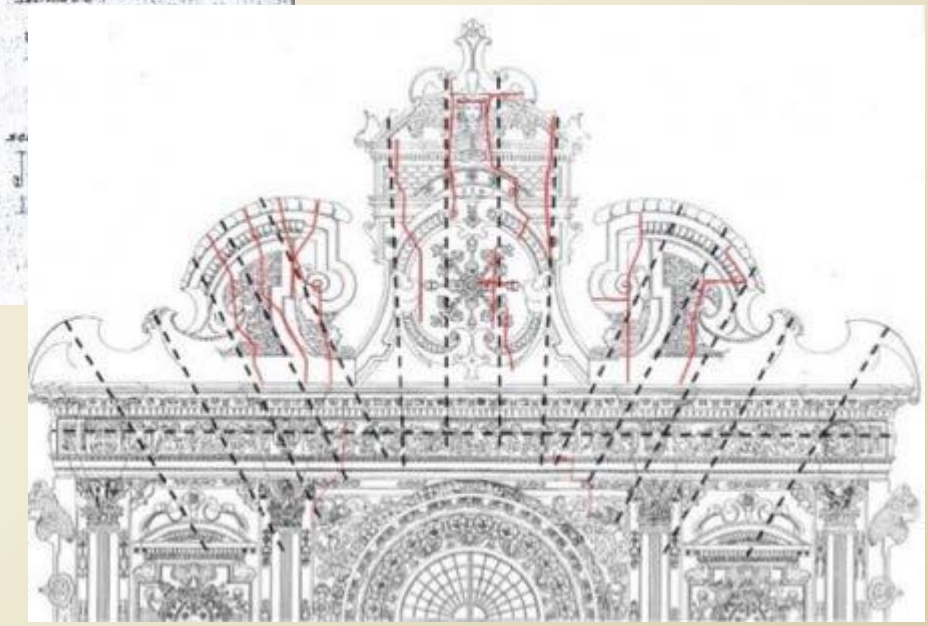
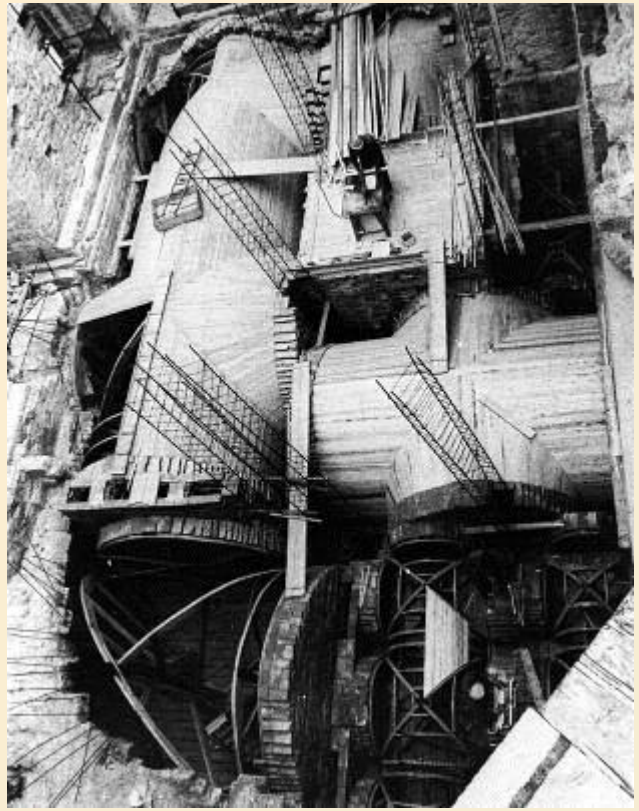


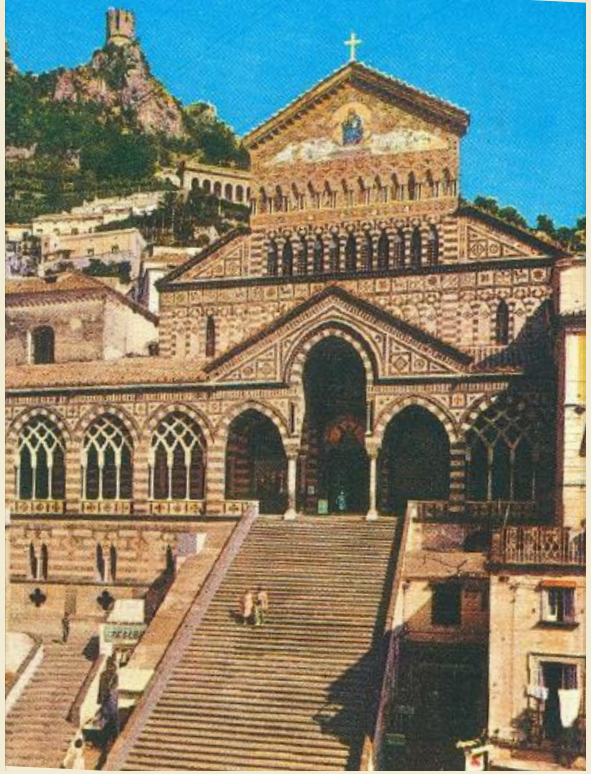
''Santa Chiara' Abbay/Church-Napoli –
Reconstruction of the wooden roof truss with r.c. beams
– 1958



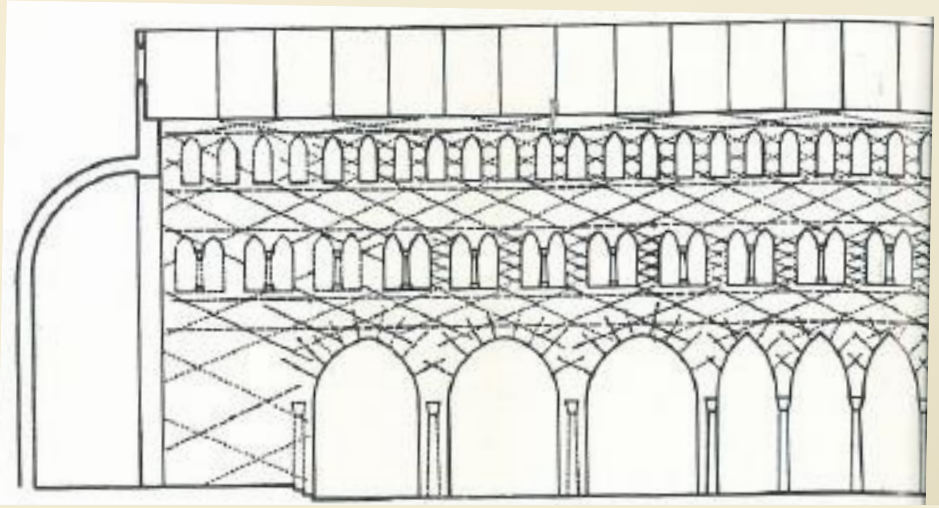
''Santa Croce'' Church -Lecce.
Reinforcement of the facade with simple iron bar drilled and concrete injected -1980



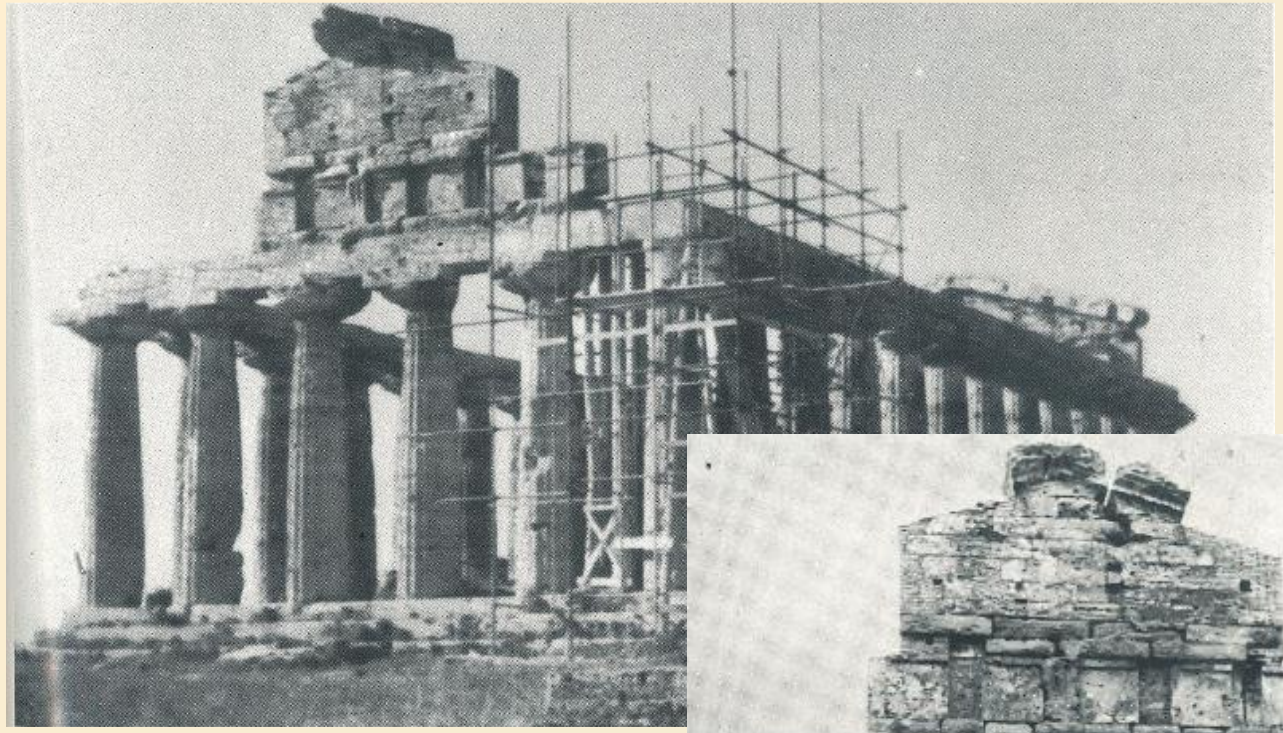
''La Zisa''-Palermo. Reconstruction of the collapsed vaults with r.c. – 1978-1980

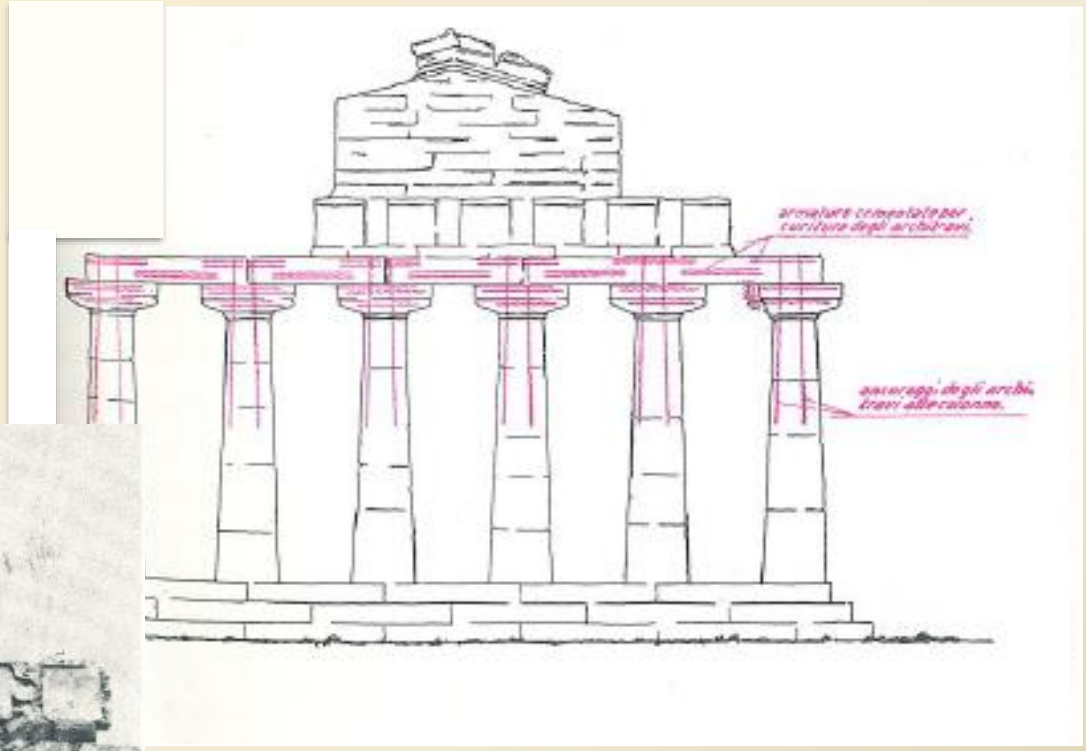


Amalfi Cathedral, X c.



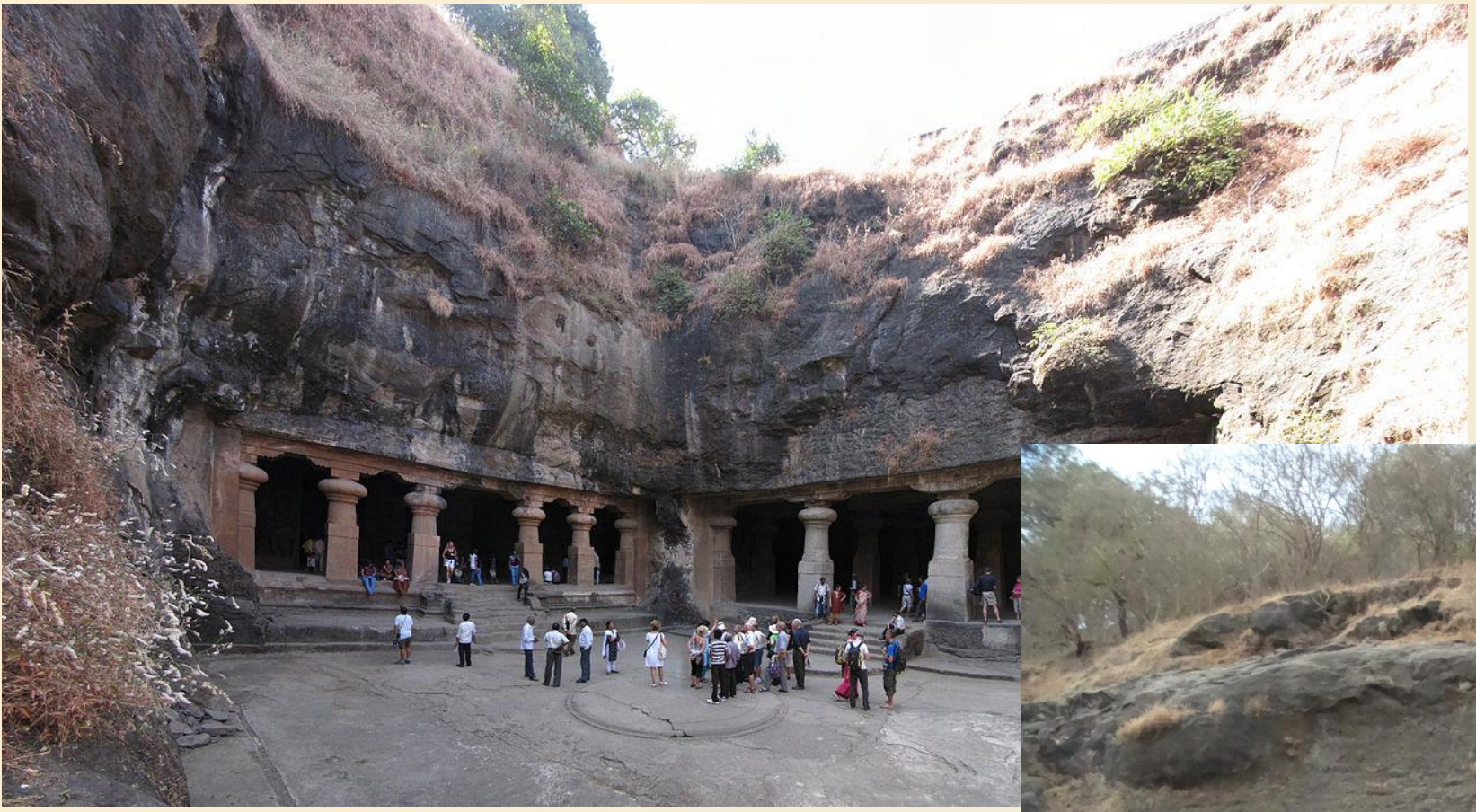
Global pattern of the diagonal grid constituted by iron bar inserted in the walls and columns with concrete injected holes – 1958





‘‘Cerere’’ greek Temple in Paestum (so
Static reinforcement transforming the
framed system, reinforced with iron ba

On the left: Few years after the intervention, during one rainstorm one thunderbolt hit the Temple, and one column exploded.
The engineers (in the news paper picture on the left) were happy because their intervention, they said, saved the entire columnade.



Elephanta Caves (Island) – Bombay –India. V-VIII a.C

Some example of reinforcement of the pillars made with concrete and iron bar, net, spiral, on 1970. The Temple is on a island, by the sea. The corrosion cannot be refrained by the limited concrete cover. 1962

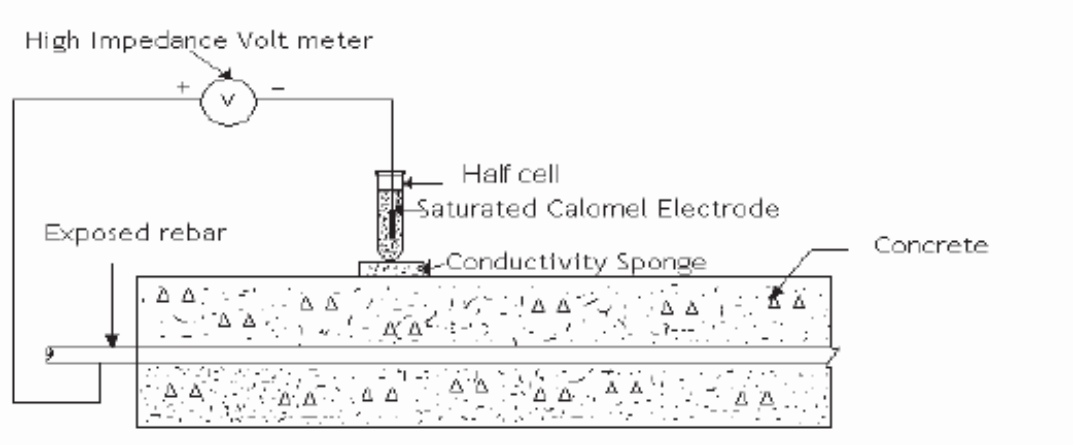
Where is the **compatibility** of the material?
The **compatibility** of the original static system?
The **reversibility**?

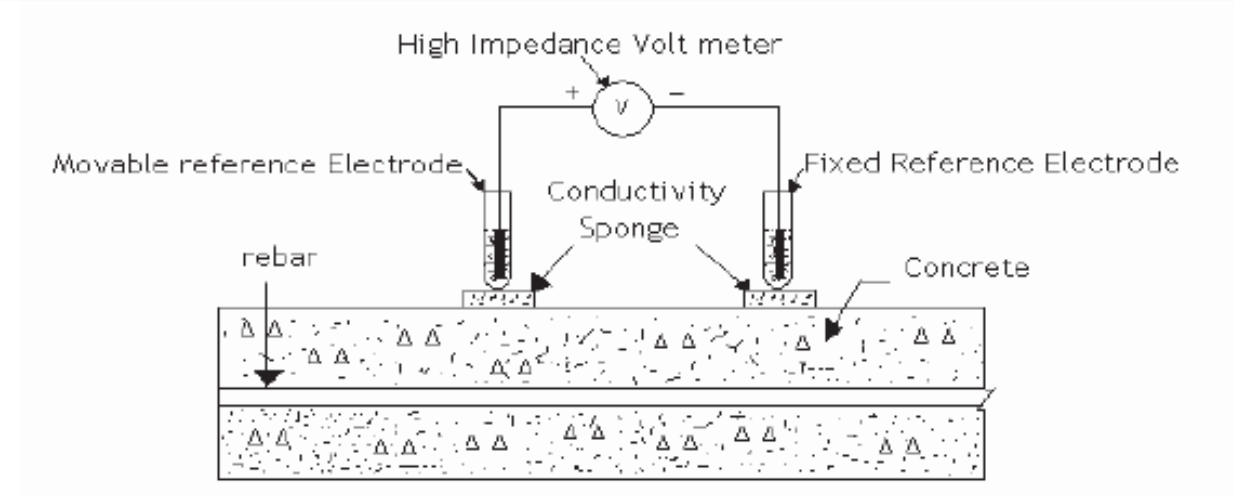
see Antonino Giuffre' in ''Pietà per i monumenti'' (Please have pity on the monuments), 1984

An overview on the state-of-art for risk corrosion control

Infrared Thermograph
new technique for acquiring the information about chloride content

High-frequency ultrasound (0.5–1 MHz), to quantify chemical damage in concrete, mostly the cover



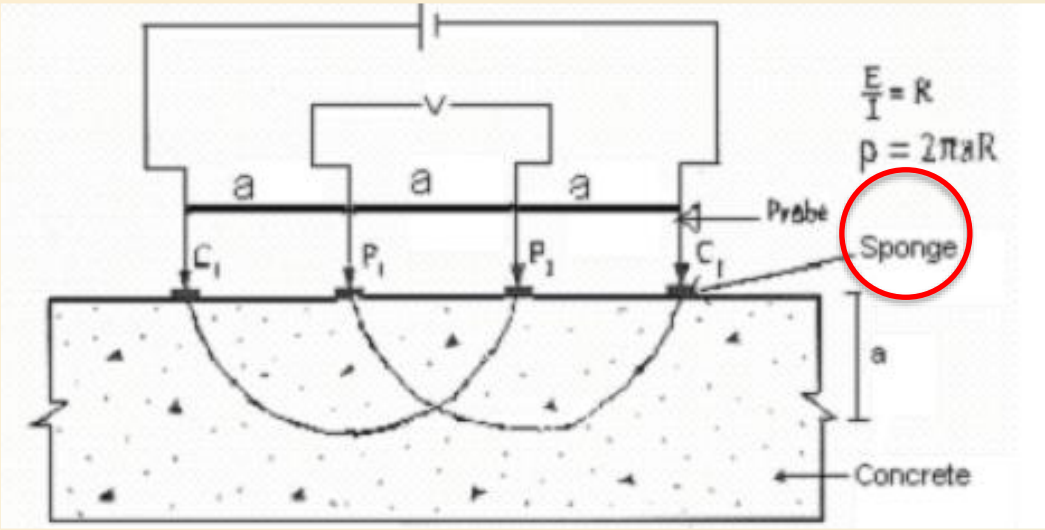


Typical "Open circuit potential "(OCP) measurement

"Surface Potential" (SP) measurement

Large uncertainty – several parameters and factors affecting the results. Need of multiple and dense measurements in order to map large areas, and assess the risk of potential corrosion

Concrete Resistivity Measurement



High Resistivity:

less risk of corrosion, since more difficult the current flow from one anode to the cathode

Low Resistivity:

more favorable situation for communication between anode and cathode → corrosion risk

Measurement affected by the porosity of the concrete, humidity, reinforcing bar distribution

Most probably we need a ‘’multiple embedded sensor’’ , able to measure several property of the environment, and give a more ‘’smart’’ assessment of the reinforcing bar condition.

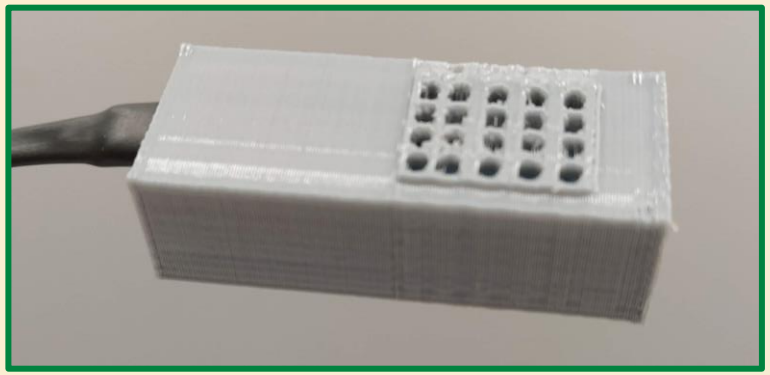
Embedded device means also to integrate sensors and micro A/D converter and controller in order to send digital data, avoiding noise due to the analog connection.

In this moment we are focusing on a triple sensor, equipped in such a way to measure:

- humidity
- pH of the concrete
- potential of concrete – rebars

Embedded Corrosion Instrument

Limits:
- the conditions in the construction site are quite different from the laboratory;
- the reinforcing bars behave like a ‘’cage’’;
- the measurements needs always the contact points to be wetted;
- it is necessary train some worker in order to install properly the devices.



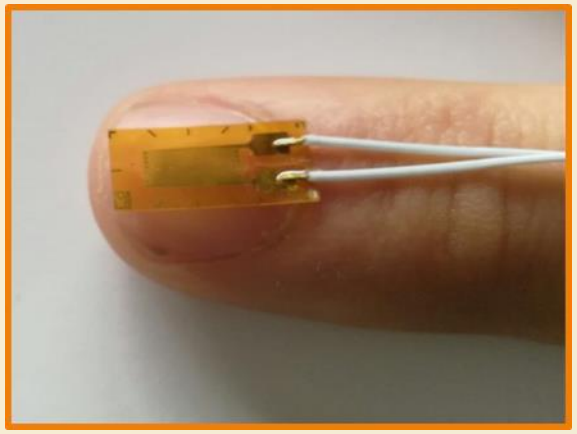
Probably the right way to assess the concrete condition and the corrosion in the reinforcing bar is to monitor permanently the ‘’environment’’ , from inside.

The actual technology allows us to install also a micro component inside the concrete at the moment of the pouring.

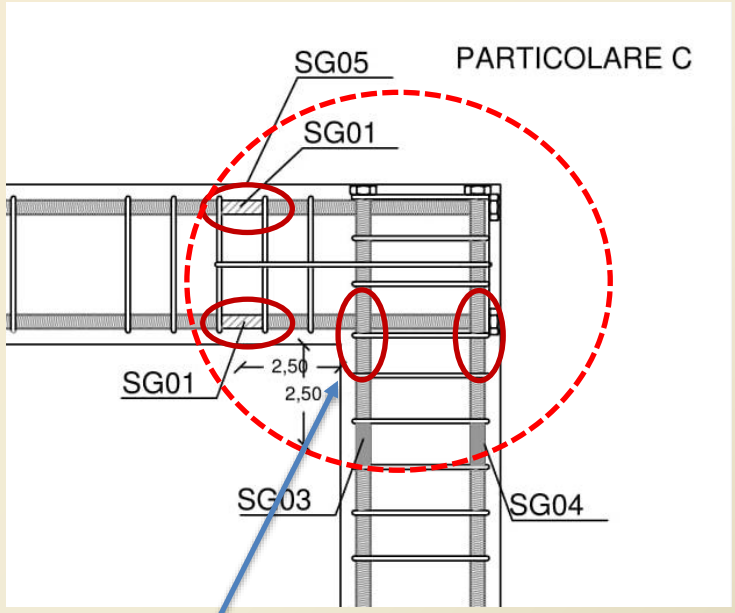
The future is to have control of all the volume of concrete including the reinforcing bars.

Miniaturized electronics are largely available and affordable, making the ‘’monitoring’’ feasible and reliable.

PERMANENT MONITORING

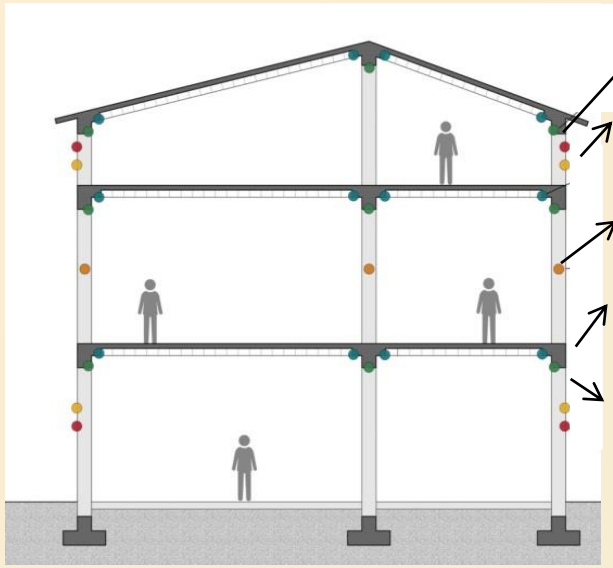


I o T - *Internet of (every)Thing*



Embedded sensors

The buildings' structural safety today is to save money (maintenance, durability, efficiency) and to save life in the extreme environmental or anthropic actions



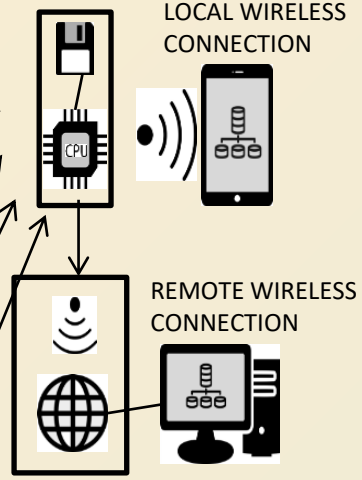
ACCELERATION
Structure-integrated accelerometers for monitoring the dynamic response.

STRAIN / STRESS
Monitoring of local stresses by means of strain gauges installed inside the structural members.

TEMPERATURE
Monitoring of the temperature inside the structural members for system calibration.

HUMIDITY /pH
Measurement of humidity and acidity of concrete to assess the risk of oxidation/corrosion.

OXIDATION
Monitoring of the level of oxidation of steel bars in reinforced concrete.

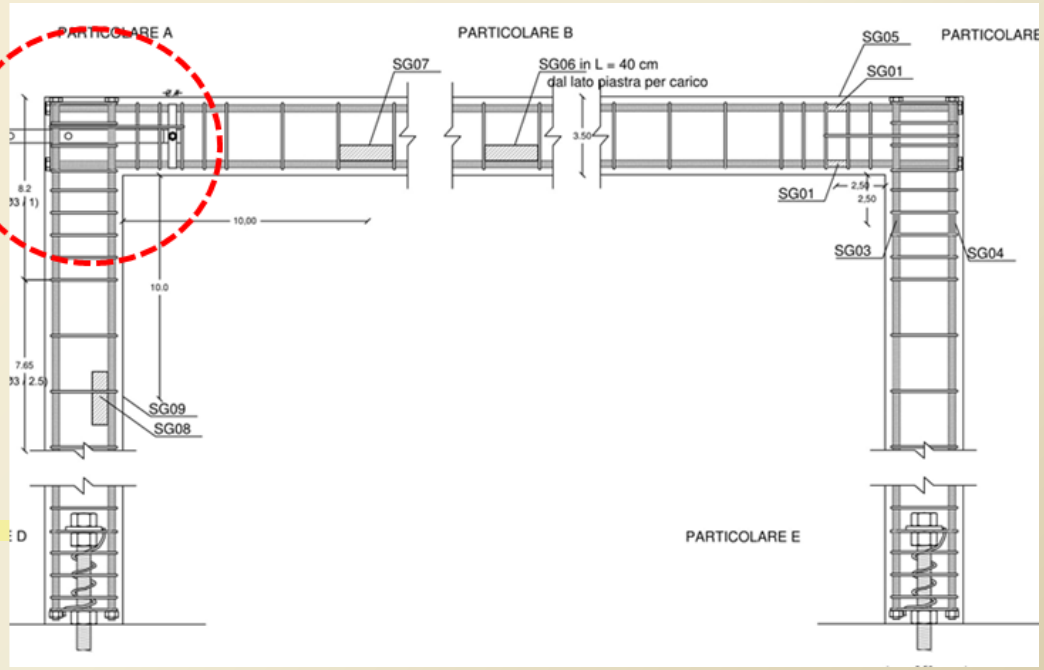


LOCAL WIRELESS CONNECTION

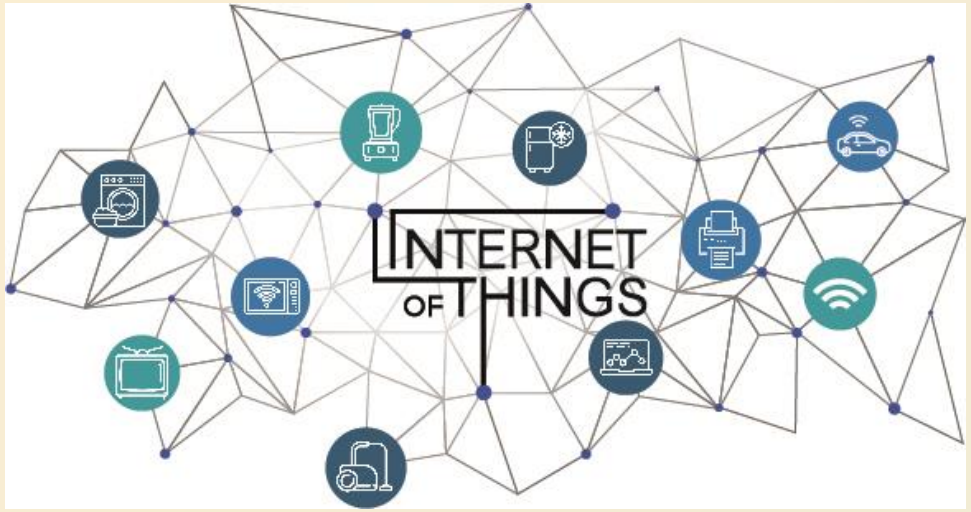
REMOTE WIRELESS CONNECTION

Local archive:
All sensors are connected to the monitoring system by a WiFI connection. Immediate and systematic check with portable WiFi devices during inspections on-site

The system is permanently connected to the internet Cloud database data transfer



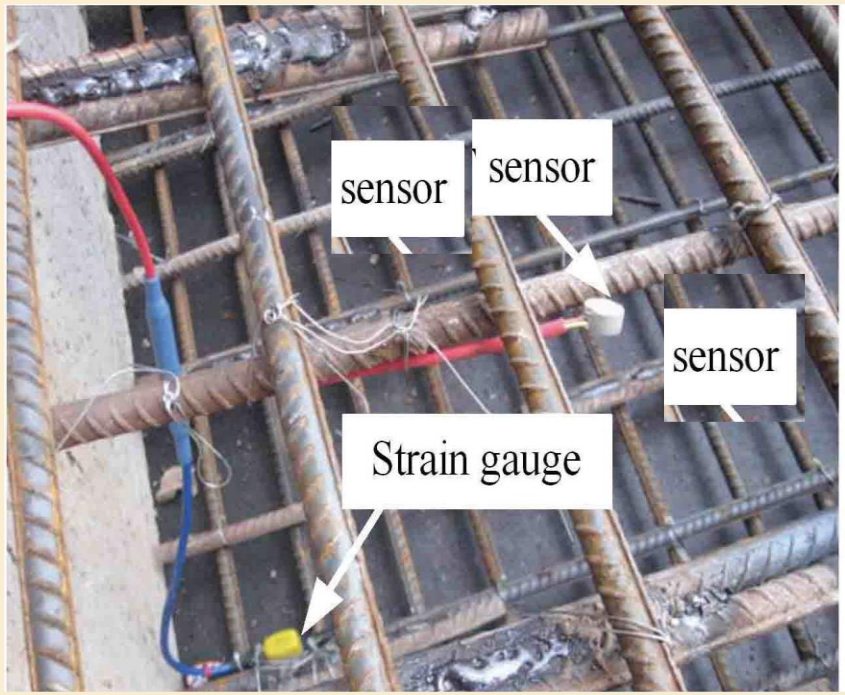
Permanent monitoring
at critical points of the structure, in order to give a continuous information of the stress level due to the acting loads and of the behaviour of the structure to the external events.

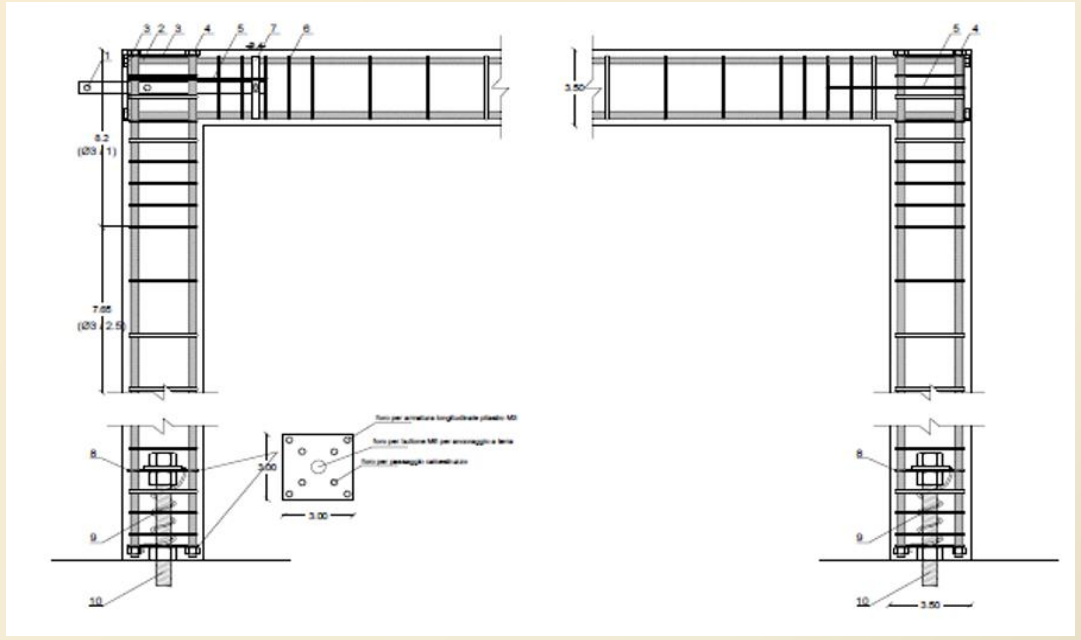


IoT
‘’Internet of Things”

To bring into the digital networks the things surrounding us during our life. To bring some objects in order to make them communicate between themselves and then with us. .

- The IoT approach and platform allows us to access any moment and from every where to the structure, and the structure trasnfer to us the information collected with sensors
- The control is facilitated. No need to be just on site to know what is happening
- It is possible also to connect the **«Smart Building»** functions;
- It is possible to plan more efficiently maintenance and recover in advance situation that could become worst.

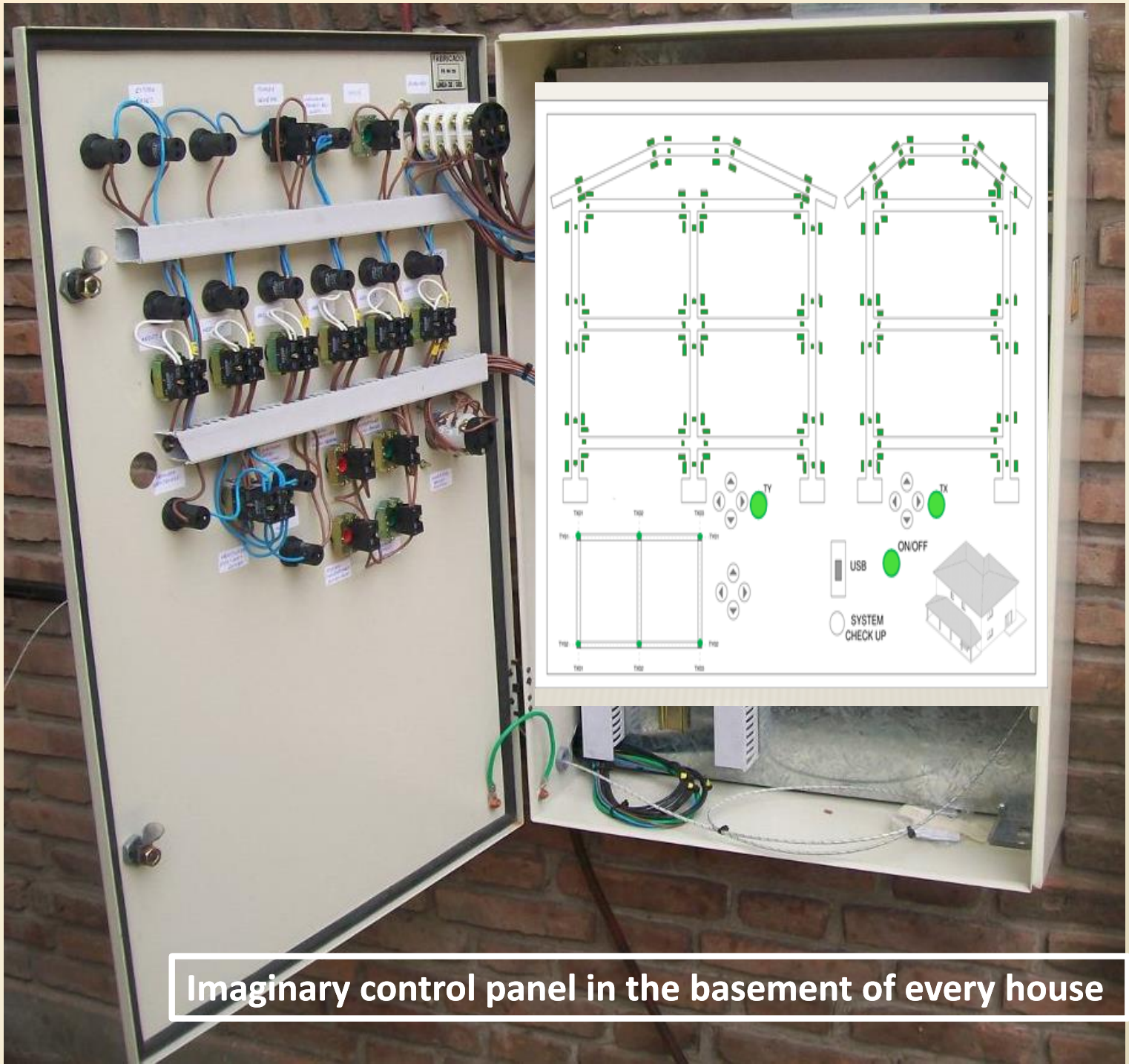




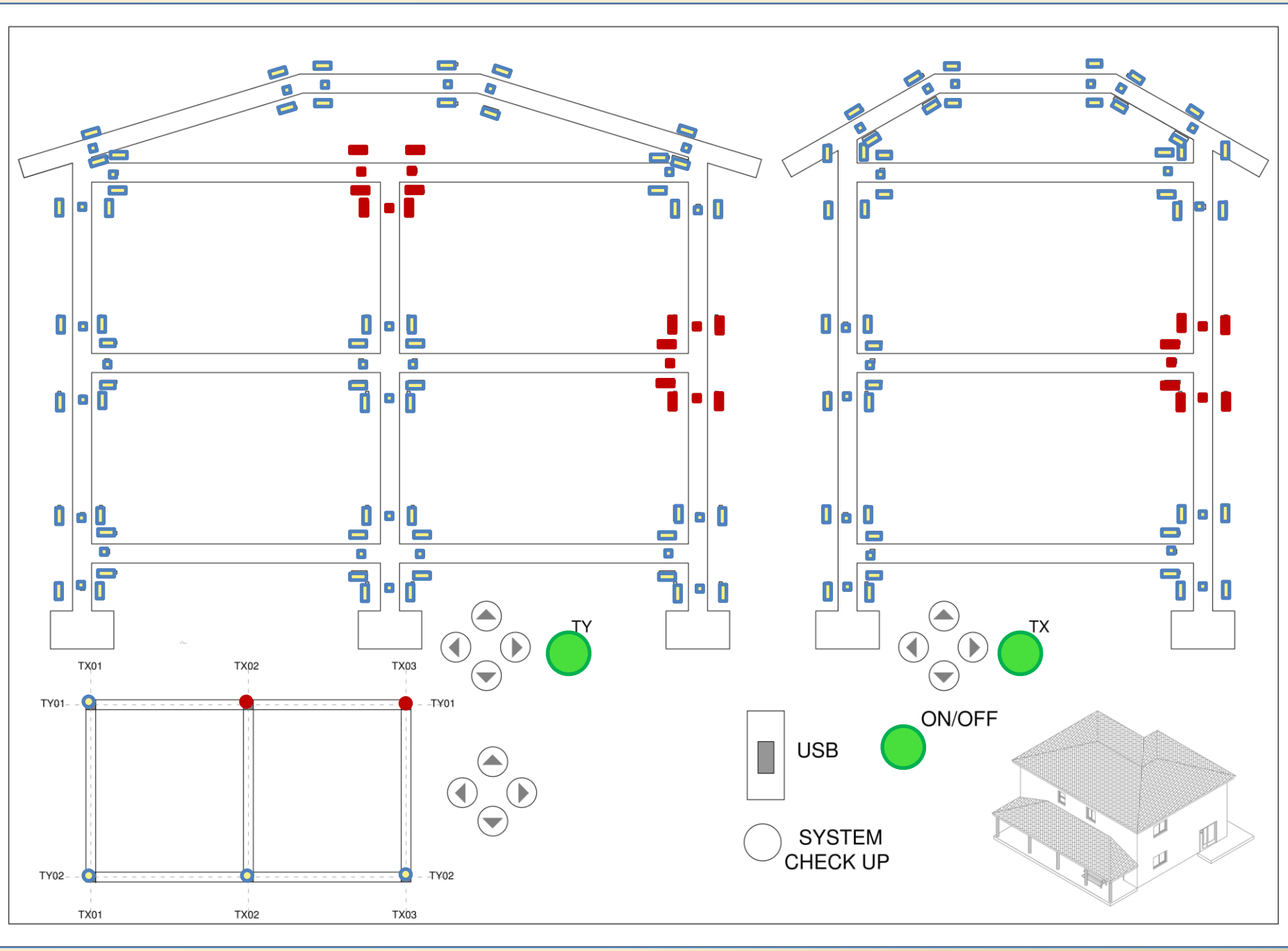
Arduino’s like platform

(Arduino, invented and designed by italian electronic engineers at Ivrea, Italy)

Diffused embedded sensors in order to check the local stress in most critical zones



Imaginary control panel in the basement of every house


TY
TX
TX01
TX02
TX03
TY01
TY01
TY02
TY02
TX01
TX02
TX03
USB
ON/OFF
SYSTEM
CHECK UP

CONCLUSION

- Objectives:
  - to permanently assess the condition of the concrete and the risk of carbonation and corrosion for the reinforcing bar
  - to define and realize affordable devices in order to achieve a lifelong health of the structure
  - to realize a tailored network in order to collect all these data and elaborate it

. Difficulties (at the moment):
  - control only on the surface
  - random and point measurement
  - to see the rusty bar without remove the cover
  - necessary to perform on site measurement
  - necessary to collect and elaborate large number of measurements.

To control the building as we control our car

SMART BUILDING -> *SAFE BUILDING*

Thank you!