USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS: CONCEPTIONS AND MISCONCEPTIONS IN THE EARLY 20th CENTURY

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INTRODUCTION

GEOGRAPHICAL AREA: ITALIA

CHRONOLOGICAL PERIOD: 1900 - 1945

YEAR 1900: FIRST LESSONS ON REINFORCED CONCRETE STRUCTURES IN ITALY (CAMILLO GUIDO - REGIA SCUOLA DI APPLICAZIONE DI TORINO).

YEAR 1945: END OF WORLD WAR II. BEGINNING OF THE AFTER-WAR RECONSTRUCTION.

APPROACHES:

- RESTORATION THEORIES
- TECHNICAL AND SCIENTIFICAL DEVELOPMENTS IN BUILDING CONSTRUCTION
- SOCIAL HISTORY
USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS

ORIGINS OF THE DEBATE AT THE END OF XIX CENTURY

ACHIEVEMENT OF THE “SCIENCE OF ENGINEERS”
- Scientific approach to structural design and safety assessment
- Modern “frame” conception of structures
- Structure as “skeleton” of the building
- New materials and building technologies (steel and cast iron)

ACHIEVEMENT OF “HISTORICAL-PHILOLOGICAL” RESTORATION THEORIES
- Scientific approach to restoration
- Monument as an artwork
- Monument as a document
- Conservation
- Structure vs. architecture
- Strengthening of structure to conserve architecture
- Restoration vs. consolidation
- Will of declaring modernity of the interventions

ROLE OF RESTORATION THEORIES – 1

PHILOLOGICAL RESTORATION THEORY
PRINCIPLE OF “CONSERVATION” (Boito 1893)

Historical buildings are “documents” (Boito 1893) or “stone archives” (Leon 1933), rather than works of art. The objective of restoration is to guarantee their permanence in time ensuring their historical authenticity.

Two ideas relevant to the question derive from this principle:

- The conservation of a monument is a purely technical problem.
- Restoration interventions should be recognizable (falsification is not admitted).
THE “SKIN” AND “BONES” ANALOGY

“The skeleton should be strengthened, keeping intact the skin with its flesh below and its muscles: the sun-bronzed skin, gathered, chapped, full of injuries, but nevertheless charming as the soft and rose skin of young ladies”

Camillo Boito - 1893

THE “SURGEON” ANALOGY

-[…] The restorer’s art is like that of the surgeon. It would be better - and who doesn’t see it? - if the fragile human body never needed probes, scalpels, and knives; but not everyone believes it is better to see a relative of friend die rather than cutting off a finger or giving him a wooden leg”.

Camillo Boito - 1893
**TWO ANALOGIES AND A POEM**

**RICONOSCIBILITA’ DEGLI INTERVENTI**

Serbare io devo ai vecchi monumenti
L’aspetto venerando e pittoresco;
E se a scansare aggiunte e compimenti
Con tutto il buon volere non riesco,
Fare devo così che ognun discerna
Essere l’opera mia tutta moderna.

(Camillo Boito-1893)

**MODERN INTERVENTION**

I must preserve in old monuments
The venerable and picturesque aspect;
And if to avoid additions or extensions
I must make sure everyone can see
That my work is all modern

(Camillo Boito-1893)

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**THE EFFECT OF THE TWO LATTER IDEAS WAS:**

**“ORTHOPEDIC” INTERVENTIONS**

(This adjective is often used with a positive meaning by the restorers of that epoch), characterized by the introduction of new structural elements within or alongside historical masonry structures.

Reinforced concrete was used to build “wooden legs” (Boito 1893), “crutches” to keep monuments “on their feet” (Giberti 1928).
The experts have agreed on various communications relative to the use of modern material for the consolidation of ancient buildings; and approve the judicious use of all the resources of modern techniques, and more especially of reinforced concrete. They express the opinion that ordinarily these means of reinforcement must be disguised so as not to alter the aspect or character of the building to be restored; and they recommend their use especially in cases in which they allow one to preserve the elements on the spot avoiding the risks of destruction and rebuilding”.

Athens Charter (1931, point IV)
MAIN TECHNICAL AND SCIENTIFIC FACTORS INDUCING TO USE REINFORCED CONCRETE IN RESTORATION:

- LACK OF KNOWLEDGE AND MODELLING APPROACHES TO MASONRY STRUCTURES
- STRUCTURAL "EFFECTIVENESS" OF REINFORCED CONCRETE
- PLASTICITY OF REINFORCED CONCRETE (INTENDED AS ABILITY TO BE SHAPED).

IMPULSE OF EARLY XX CENTURY GREAT ITALIAN EARTHQUAKES

ENGINEERING SCIENCE AND MASONRY STRUCTURES - PHASES OF DEVELOPMENT:

1. IN THE GROWING BUILDING SCIENCE, SOME ATTEMPTS ARE PERFORMED TO DEFINE A THEORY FOR MASONRY ARCHES (KINEMATIC APPROACH).
   
   1712: De La Hire publishes his studies on the cinematic collapse of arches

2. THE DEVELOPMENT OF THE ELASTICITY THEORY INDUCES SCIENTISTS TO APPLY IT TO MASONRY STRUCTURES.
   
   1852: Poncelet publishes the “Examen critique et historique des principales théories ou solutions concernant l'équilibre des voûtes”, advancing the hypothesis that the elasticity theory may be applied to the masonry arch.

3. AWARENESS OF THE INAPPLICABILITY OF THE ELASTICITY THEORY TO MASONRY STRUCTURES – ABANDONING OF THE STUDIES.
   
   1913: Sejournè publishes the “Grand voûtes” and states that elasticity theory is inapplicable to masonry structures.
“At the moment, for the calculation of masonry vaults, we don’t have a theory better than the elasticity one. We should accept it not because it is true, but because vaults, designed with it, bear up. We accept it only temporarily, with reservations, until when further experimental evidences will lead to more reliable theories.”

G. Sejournè - 1913

BETWEEN ~1900 TO ~1950 SCIENTISTS RENOUNCE TO STUDY MASONRY STRUCTURES!

NO STUDIES AND NO THEORIES UNTIL HEYMANN (1966)!

“[…] in giving compactness to crumbling walls (with injections of liquid concrete), in creating organs able to resist the bending and shearing actions, […] in rigidly connecting the various parts of a building (with tie rods or with an elastic framework), etc. . .”.

Gustavo Giovannoni - 1932

MOREOVER, REINFORCED CONCRETE IS CONSIDERED AS THE TECHNIQUE THAT BEST RESPONDS TO THE CRITERION OF THE “BEST PERFORMANCE WITH THE LEAST MATERIAL” (Lopez Otero 1933), DEEMED AS DECISIVE IN RESTORATION BECAUSE IT ALLOWS TO MAKE THE REINFORCEMENT ELEMENTS “ALMOST INVISIBLE”.

THE STRUCTURAL EFFECTIVENESS OF R.C.

THE RESISTANCE TO TRACTION AND BENDING ACTIONS MARKS THE DIFFERENCE BETWEEN HISTORICAL MASONRY AND REINFORCED CONCRETE. THE NEW MATERIAL IS THUS USEFUL:
PLASTICITY OF R.C.

PLASTICITY IS DEEMED USEFUL IN RESTORATION WORK BECAUSE:

- IT ALLOWS ONE TO EASILY LINK THE NEW REINFORCING STRUCTURE TO THE ANCIENT STRUCTURES (Giovannoni 1931).

- IT ALLOWS ONE TO BUILD INVISIBLE STRUCTURES, HIDDEN IN THE MASONRY VOLUMES (Gavini 1923).

IMPULSE OF GREAT ITALIAN EARTHQUAKES

MESSINA AND REGGIO CALABRIA EARTHQUAKE - 1908
USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS
THE ROLE OF TECHNIQUE AND ENGINEERING SCIENCE

IMPULSE OF GREAT ITALIAN EARTHQUAKES

SORA AND AVEZZANO EARTHQUAKE - 1915

ROLE OF MESSINA AND REGGIO CALABRIA EARTHQUAKE

THE FIRST ITALIAN SEISMIC REGULATIONS (D.R. no. 193 of April 18, 1909) WERE DRAWN UP TWO YEARS AFTER THIS EARTHQUAKE. THIS CODE:

- POINTED OUT THE ROLE OF FRAMED STRUCTURES IN EARTHQUAKE RESISTANT DESIGN
- EXPLICITLY SUGGESTED REINFORCED CONCRETE AS A BUILDING MATERIAL
- RELEVANT ROLE FOR THE USE REINFORCED CONCRETE IN CONSOLIDATION WORKS.
ROLE OF MESSINA AND REGGIO CALABRIA EARTHQUAKE

Title III OF THE CODE, RELATIVE TO “REPAIRS” TO ORDINARY BUILDINGS, AMONG THE VARIOUS PROVISIONS STATES THAT:

“Buildings damaged and not built with the framed or “baraccato” system, rising above the ground floor […] must be strengthened with stanchions in wood, iron or reinforced concrete, fixed solidly into the foundations, continuous up to the top of the building and bound to one another by tie-rods at the offset floor of foundation, and to those of the roof and the eaves, in such way as to form a cage-like bracing.”

D.R. no. 193 of April 18, 1909 – Title III

WHILE FOR MONUMENTAL BUILDINGS:

“[…] the path to be followed for consolidation alone will be established case by case.”.

DOUBTS

EARLY DOUBTS

COMPATIBILITY

INTENDED IN MOST CASES FROM THE AESTHETIC AND ARCHITECTURAL POINT OF VIEW, RATHER THAN STRUCTURAL

“It is a singular paradox that modern architecture, through the widespread use of materials to be poured and reinforced, breaking completely with the ancient and traditional systems of building, has so strongly helped the preservation of our ancient monuments, to which it is, in its principles, radically foreign and which, in the future, it is destined to replace”.

Leon, La Restauration des Monuments en France (1933)
EARLY DOUBTS

COMPATIBILITY
INTENDED IN MOST CASES FROM THE AESTHETIC AND ARCHITECTURAL POINT OF VIEW, RATHER THAN STRUCTURAL

“It’s easy to understand the worries that the application of such a building system in Medieval buildings may stir; it means introducing in their extremely elastic structures elements that are essentially rigid and likely to alter their equilibrium”.

Paquet, Le Ciment Armé dans la Restauration des Monuments Anciens (1933)
**EARLY DOUBTS**

**COMPATIBILITY**

INTENDED IN MOST CASES FROM THE AESTHETIC AND ARCHITECTURAL POINT OF VIEW, RATHER THAN STRUCTURAL

“[…] Even if scientific and technical studies, as well as special legislative requirements, had made anti-seismic design based on framed structures compulsory in Italy, serious difficulties arise when these schemes, made up of frameworks that are all integral of elastic materials, are used again for the reinforcement or renovation of ancient monuments whose organisms are in total contrast with them”

Gustavo Giovannoni - 1931

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**ENGINEERS AND CONSERVATION INSTITUTIONS**

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<tr>
<th>G. GIOVANNONI</th>
<th>CIVIL ENGINEER</th>
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<tr>
<td>Theorist and disciple of C. Boito</td>
<td>(REGIA SCUOLA DI APPLICAZIONE PER INGEGNERI DI ROMA - 1895)</td>
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<th>A. AVENA</th>
<th>CIVIL ENGINEER</th>
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<td>Head of the Regional Office for Monuments (1897-1912)</td>
<td>(REGIA SCUOLA DI APPLICAZIONE DI NAPOLI)</td>
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<td>Head of the Regional Office for Monuments in Venezia-Giulia and Veneto (1926-1952)</td>
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**CONSERVATION INSTITUTIONS AND NEW ENGINEERING SCHOOLS**

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<td>Head of the Regional Office for Monuments in Lombardia (1926-1952)</td>
<td>(POLITECNICO DI MILANO)</td>
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AN INSTITUTIONAL PROBLEM

WHO IS RESPONSIBLE FOR THE STRUCTURAL SAFETY AND THE DESIGN OF
STRENGTHENING INTERVENTIONS OF MONUMENTAL BUILDINGS?

CONSERVATION INSTITUTIONS    ?    COUNCIL OF CIVIL BUILDINGS

1920  
STRENGTHENING SYSTEM FOR MASONRY BUILDINGS DAMAGED BY VAULT THRUSTS

(Troya, O., Sistema iperstatico atto a consolidare fabbriche dissestate da spinte di volte, “Il Giornale del Genio Civile”, 1920, p. 301)

1921  
USES OF REINFORCED CONCRETE FOR THE CONSOLIDATION OF EXISTING STRUCTURES

(Troya, O., Consolidamenti, modificazioni e riparazioni con l’uso del cemento armato, “Il Giornale del Genio Civile”, 1921, p. 158)

FIRST ATTEMPTS (1900-1915)

1903-04: S. STEFANO BELL TOWER - VENEZIA  
CONSOLIDATION OF MASONRY WALLS AND FOUNDATIONS WITH CONCRETE INJECTIONS  
(DESIGN BY C. CASELLI AND C. ANTONELLI)

1909: TOWER - VEZZANO LIGURE  
CONSOLIDATION OF MASONRY WALLS WITH CONCRETE INJECTIONS  
(DESIGN BY A. D’ANDRADE)

1909: GALLIANO BASILICA - COMO  
CONSOLIDATION OF MASONRY STRUCTURES WITH CONCRETE INJECTIONS  
(DESIGN BY A. ANNONI)

1908: CATHEDRAL OF COMO  
STRENGTHENING OF THE OVERTURNING FACADE WITH THE INTRODUCTION OF TRASVERSAL CONCRETE BEAMS  
(DISEGN BY A. ANNONI)

NEW STRUCTURAL CONCEPTION
USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS

THE TECHNIQUE OF INTERVENTIONS (1920-1945)

TYPES OF R.C. STRENGTHENING INTERVENTIONS

- USE OF CONCRETE AS A BINDER

- USE OF REINFORCED CONCRETE TO INCREASE THE RESISTANT SECTION OF STRUCTURAL ELEMENTS AND GIVE THEM RESISTENCE TO TRACTION.

- USE OF REINFORCED CONCRETE TO CREATE ELEMENTS RESISTANT TO TRACTION WITHIN MASONRY

- USE OF REINFORCED CONCRETE FOR THE BUILDING OF NEW LOAD BEARING STRUCTURES INSIDE MASONRY

CASE STUDY 1: THE TOWER OF SANT’ANTONINO IN PIACENZA

THE STRUCTURAL PROBLEM:
HIGH COMPRESSIVE STRESSES AT THE BASE OF THE TOWER

1893

NEED OF REOPENING THE ORIGINAL BIFORAS

NEED OF A STRUCTURAL INTERVENTION

INCREASING STRUCTURAL DAMAGE
THE REPORT BY C. GUIDOTTI (1909):

PROPOSALS FOR CONSOLIDATION OF INTERNAL COLUMNS

- SUBSTITUTION OF THE ORIGINAL BRICK COLUMNS WITH NEW STONE COLUMNS (UNSTITCH-STITCH OPERATION).
- PLUGGING, WITH BRICK MASONRY, OF THE EIGHT MINOR INTERCOLUMNS AT THE BASE OF THE TOWER
- ENLARGEMENT OF THE COLUMN SECTION

“[…] In agreement with the Regional Office of Monument, I propose finally the intervention more respectful toward the monument, that is the reconstruction of the columns in granite”.

THE FIRST REPORT BY E. RIGHETTI (April 27th, 1911):

- UNITING ALL THE FOUNDATIONS OF THE COLUMNS AND THE PILASTERS WITH A CONTINUOUS MASONRY FOUNDATION.
- SUBSTITUTION OF THE BASE OF THE ARCHES WITH STONE BLOCKS.
- CONSOLIDATION OF THE COLUMNS

“Now in as much as one tries to avoid the use of iron in works of restoration for ancient buildings, especially if of monumental or artistic nature, due to its tendency to rust and because it does not comply with the character of such buildings, but since one is dealing with consolidation, as an internal structure, today that it is widely used together with concrete”.
WHY THE IRON-CONCRETE SOLUTION WAS NOT ACCEPTED?

**THE SECOND REPORT BY E. RIGHETTI (June 23rd, 1911):**

**DURABILITY PROBLEMS**

“[…] still no experience had been made “in relation to the duration of the behaviour of iron with concrete, to be able to use it in total safety in sheathing and as strengthening for columns”

**THE JUDGEMENT OF THE REGIONAL OFFICE OF MONUMENTS:**

**INCOMPATIBILITY PROBLEMS**

“The use of a heterogeneous material would introduce a non-homogeneous element in the internal structure of the church”.

**THE JUDGEMENT OF THE FINE ARTS (February 13rd, 1912):**

“I am totally convinced that it is criminal to apply in a work of consolidation of a monumental building, like the one in question, a new building system, which having been applied for only twenty years, does not give us assurance of long duration and good results”

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**THE REPORT BY U. ARATA (1918):**

- SUBSTITUTION OF THE ORIGINAL BRICK COLUMNS WITH NEW STONE COLUMNS (UNSTITCH-STITCH OPERATION).
- INTRODUCTION OF A NEW STEEL STRUCTURE, ABLE TO DIRECT THE LOADS TOWARD THE CORNER PILLARS OF THE TOWER.
- CONSOLIDATION OF THE FOUNDATION SYSTEM

**CONCRETE INJECTIONS** + **R. CONCRETE JACKETING**
THE PROJECT OF “GENIO CIVILE” (1923-26):

- BUILDING OF AN INTERNAL REINFORCED CONCRETE FRAME, SUBSTAINING THE OLD MASONRY STRUCTURE.
- STRENGTHENING OF THE COLUMNS THROUGH REINFORCED CONCRETE RINGS.
- CONSOLIDATION OF THE FOUNDATION SYSTEM THROUGH REINFORCED CONCRETE JACKETING.

THE RESTORATION OF THE TOWER OF SANT’ANTONINO WAS THEN CARRIED OUT IN 1990’s

USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS

CASE STUDY 1: THE TOWER OF SANT’ANTONINO IN PIACENZA - 6

1929:
AFTER THE DEMOLITION OF SOME LOW HOUSES AROUND THE TOWER, A SEVERE STRUCTURAL DAMAGE WAS ASSESSED (DEEP VERTICAL CRACKS AT THE BASE).

CAUSES:
- RAISING OF THE TOWER IN 1874
- LOW QUALITY OF THE MATERIALS

COMMISSION:
- G. MORETTI
  ARCHITECT AND HISTORIAN
- E. BECCARIO
  HEAD OF “GENIO CIVILE” OF MILAN
- C. CALZECCHI
  REGIONAL OFFICE FOR MONUMENTS
- A. DANUSSO
  POLITECNIC OF MILAN

CASE STUDY 2: THE BELL TOWER OF “CANONICI” IN MILAN - 1

STRUCTURAL PROBLEM:
HIGH COMPRESSIVE STRESSES AT THE BASE OF THE TOWER
**THE FIRST PROJECT BY A. DANUSSO (1929):**

- UNDERPINNING OF THE FOUNDATIONS THROUGH REINFORCED CONCRETE STRUCTURES.
- BUILDING OF A DOUBLE REINFORCED CONCRETE RING
- CONNECTION OF THE TWO RINGS WITH STEEL “DOUBLE-T” BEAMS.

**REALIZED IN 1930**

**THE SECOND PROJECT BY A. DANUSSO (1930):**

- PRELIMINARY PROPOSAL – THREE ALTERNATIVES:
  1) REBUILDING OF MASONRY STRUCTURES;
  2) INTRODUCTION OF NEW MASONRY PILLARS IN THE CORNERS;
  3) BUILDING OF AN “ORTHOPEDIC” R.C. STRUCTURE INSIDE THE TOWER

**JUDGEMENT OF THE COMMISSION:**

“The Commission judged that the last proposal is the more suitable for the integral conservation of the ancient building and that it is in agreement with the criteria and the feelings of modern technique”

**REALIZED BETWEEN 1930 AND 1932**
USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS

CASE STUDY 2: THE BELL TOWER OF “CANONICI” IN MILAN - 4

THE SECOND PROJECT BY A. DANUSSO (1930):

- INJECTIONS IN MASONRY STRUCTURES
  
  \[27.4 + 22.3 + 6.5 = 56.2 \text{ tons} \] INJECTED!

REALIZED BETWEEN 1937 AND 1939

CASE STUDY 3: THE CATHEDRAL OF SAN GAUDENZIO IN NOVARA - 1

1° PHASE: COSTRUCTION OF THE DOME

- 1882: 1st COMMISSION
  - C. PRATO
  - G. CURIONI
  - A. SACCHI

- "GENIO MILITARE" OF TURIN
  - REGIA SCUOLA DI APPLICAZIONE DI TORINO

- ARCHITECT– REGIA SCUOLA DI APPLICAZIONE DI MILANO

- MANY VERTICAL CRACKS OF INCREASING WIDTH (BOTTOM/TOP)

2) CRACKS IN THE LINTELS CONNECTING THE CIRCULAR COLUMNS

3) DAMAGE IN THE ORIGINAL FOUR BASE ARCHES AND BASE PILLARS.

IN 1883 A. ANTONELLI STRENGHTENED THE FOUNDATIONS AND THE BASE PILLARS OF THE STRUCTURE
AUGUST 29th, 1907: SUDDEN COLLAPSE OF THE SANCTUARY OF BOCA

SEPTEMBER 9th, 1907: 2nd COMMISSION
INGEGNERE CAPO DELL’UFFICIO TECNICO + DIRETTORE FABBRICA LAPIDEA

1) FAILURES IN THE UPPER SMALL DOME
2) SMALL CRACKS IN THE PLASTER ON THE LOWER STRUCTURES

CAUSES:
- WIND

1909: SLIGHT SEISMIC ACTIONS

“We need the help of a technical specialist” (!)

CASE STUDY 3: THE CATHEDRAL OF SAN GAUDENZIO IN NOVARA

- 1927: ARTURO DANUSSO IS CALLED ON – WHY?
  - HE WAS A “LECTURER OF STRUCTURAL MECHANICS AT THE POLYTECHNIC OF MILAN”
  - HE WAS “A SPECIALIST AND PROFESSOR OF CALCULUS OF REINFORCED CONCRETE”

- 1927-31: FIRST INVESTIGATIONS BY DANUSSO
  - HE ASSESSES DAMAGE IN THE SMALL DOME

CAUSES:
- WIND-INDUCED VIBRATIONS
- CHEMICAL-PHYSICAL DEGRADATION OF MATERIALS

DANUSSO SUGGESTS THE RECONSTRUCTION OF THE SMALL DOME IN REINFORCED CONCRETE
USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS

CASE STUDY 3: THE CATHEDRAL OF SAN GAUDENZIO IN NOVARA - 4

1st PROJECT BY DANUSSO (1931-32)

PROJECT BY DANUSSO

CASE STUDY 3: THE CATHEDRAL OF SAN GAUDENZIO IN NOVARA - 5
"The objection that comes easily to mind is the following: but with this overload won’t the resistance and the stability of the lower structure be compromised? One could answer negatively with a clear conscience, because that is what the calculations made tell us”

Head of the Fabbrica Lapidea, 1931
AUGUST 13th, 1936: 2° PROJECT BY DANUSSO

USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS

CASE STUDY 3: THE CATHEDRAL OF SAN GAUDENZIO IN NOVARA

1932 STRENGTH.

1937 STRENGTH.

OCTOBER 1937: NEW ALARMS!
NEW CRACKS AND RE-OPENING OF OLD CRACKS IN THE FOUR ORIGINAL BASE PILLARS

INSTALLATION OF A MONITORING SYSTEM
THE INSTRUMENTS POINT OUT ON-GOING DISPLACEMENTS

CAUSES DETECTED BY DANUSSO:

FOUNDATION PROBLEMS

ANTONELLI’S BRAVERY

OCTOBER 28th, 1937: COLLAPSE IS ATTENDED!
• INVITATION TO LEAVE NEAR HOMES (90M)
• WOOD SHORING OF THE FOUR BASE ARCHES
• STEEL HOOPING OF THE BASE PILLARS
DAVERIO’S CRITICISMS (1938-39)

- THE ALARM OF 1937 WAS NOT JUSTIFIED:
  - MONITORING INSTRUMENTS ARE UNRELIABLE
  - SHORING STRUCTURES ARE NOT BEARING LOADS

- THE INTERVENTION CARRIED OUT IN 1930 TO 1937:
  - INCREASED THE WEIGHT OF THE BUILDING;
  - INCREASED THE STIFFNESS OF THE HIGHER PART OF THE STRUCTURE
  - CHANGED THE DYNAMICAL BEHAVIOUR OF THE STRUCTURE

- CRACKS FOUND IN THE BASE ARCHES WAS TO BE ATTRIBUTED TO:
  - THE MODIFICATION UNDERGONE BY THE STRUCTURE;
  - THE STRONG WIND OF THE OCTOBER 1938;
  - ARTIFICIAL HEATING OF THE CATHEDRAL.

“This is the monument to fear”
1932 STRENGTH.
1937 STRENGTH.
1939 STRENGTH.

1945-47: 4th PROJECT BY DANUSSO
BUILDING OF A BIG REINFORCED CONCRETE RING AT THE TOP OF THE INTERNAL DOME.

TODAY

CASE STUDY 3: THE CATHEDRAL OF SAN GAUDENZIO IN NOVARA

USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS

CONTEMPORARY EVIDENCES - 1

UMBRIA - 1997
USE OF REINFORCED CONCRETE IN PRESERVATION OF HISTORIC BUILDINGS

CONTEMPORARY EVIDENCES - 2

MOLISE - 2002

CONTEMPORARY EVIDENCES - 3

L’AQUILA CASTLE - 2009
S. MASSIMO CHURCH - L’AQUILA - 2009

S. MARIA DEL SUFFRAGIO - L’AQUILA - 2009