

# Characterisation of Different Materials and Constructive Techniques of Heritage Bridges in Northern Italy



***Structural Faults + Repair-2018 &  
European Bridge Conference-2018  
Edinburgh, May 15<sup>th</sup>-17<sup>th</sup>, 2018***

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**THEME 1 - Extending the Life of Bridges: Investigation & Repair**

# The Path of Knowledge

## SURVEY

- ❖ survey of the building, cracks and deformation patterns

## HISTORY

- ❖ interpretation of the historical evolution of the construction

## IDENTIFICATION

- ❖ structural identification of the building and of its construction details

## PROPERTIES

- ❖ evaluation of mechanical properties of materials and their deterioration

## SOIL

- ❖ evaluation of soil-foundation relationship

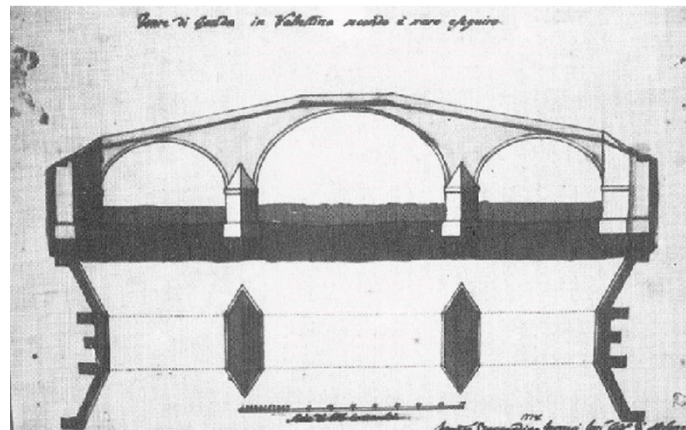
Introduction

**Italian current regulatory framework:** Structural Code for Constructions (D.M. 14/01/2008-rev. D.M. 17/01/2018) - Guidelines for Assessment and Reduction of Seismic Hazard of Heritage Buildings (D.P.C.M. 09/02/2011)

# Ganda Bridge in Morbegno



Johanne Antonio Amadeo  
(1447-1522) bas-relief medallion  
on the facade of Milan Duomo

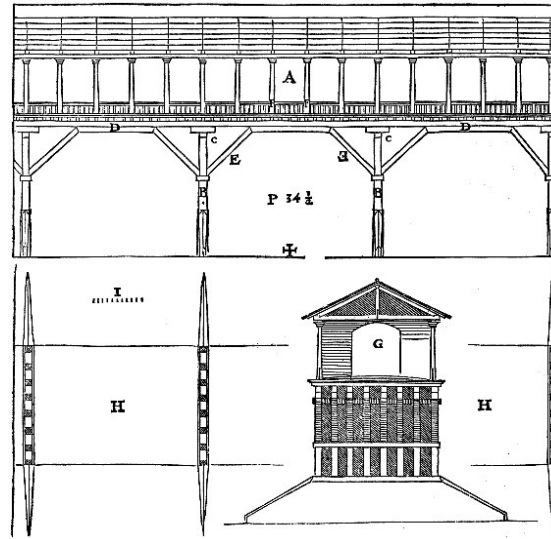
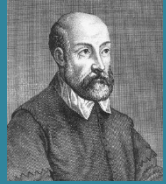


Survey of the bridge at the end of the re-  
construction by F.B.Ferrari (1788)

- 1489, first mention about the necessity to build a bridge
- Johanne Antonio Amadeo, chief architect of Duke of Milan, was entrusted for the construction
- 1497-1499 first construction of the bridge
- 1772 a river flood strongly damaged the bridge, Francesco Bernardino Ferrari was entrusted with the reconstruction
- 1778, the reconstruction was completed
- completed in Last maintenance works after 1987 flood



# Palladio's Bridge (Alpini Bridge) in Bassano



Andrea Palladio  
(1508-1580) *Four Books of Architecture*  
Book III Chap. IX



- 1209 first mention
- 1524 it began the construction of a stone bridge that fell during a flood two years after
- 1569 Andrea Palladio designed the new bridge
- 1748 a river flood damaged the bridge that was rebuilt faithfully by Bartolomeo Ferracina
- 1945 partially destroyed during a partisans attempt and in 1947
- Last maintenance works in 1966 and 1990

# Diagnostic, Survey and Monitoring

## GANDA BRIDGE SURVEYS

- geometric survey with laser-scanner technique;
- analysis of historical documents
- crack pattern and deformation survey;
- visual analysis of the state of conservation of the structure;

## DIAGNOSTICS

- ultrasonic tomography to determine extensive information about struct. stratigraphy
- coring and video inspection to determine punctual information about structural stratigraphy

## ASSESSMENT

- structural assessment both regarding static and seismic field

## BASSANO BRIDGE SURVEYS AND MONITORING

- geometric survey with laser-scanner technique;
- survey of the river bed;
- monitoring of vertical settings;

## WOODEN TRUSSESS

- visual analysis of the state of conservation of the structure;
- instrumental analysis aimed at determining the structural degradation
- samples of wood and consolidating materials;

## MASONRY ABUTMENTS

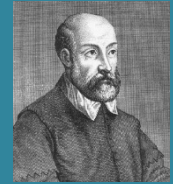
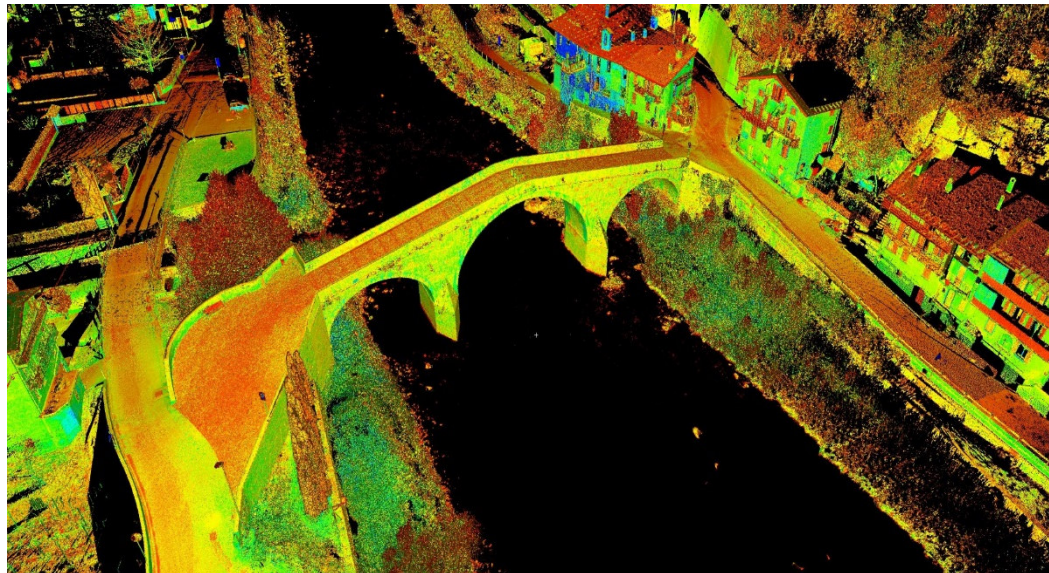
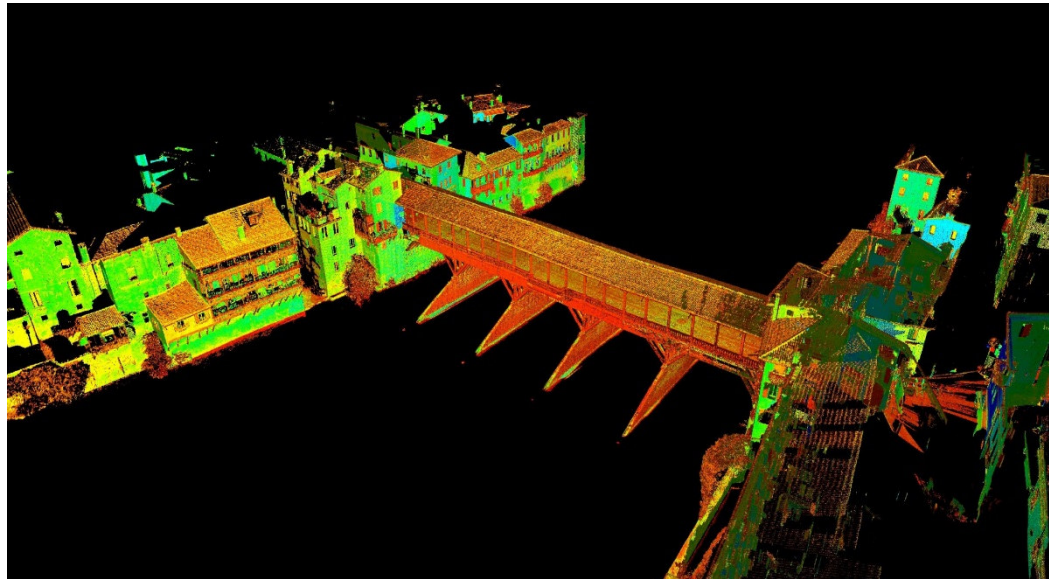
- corings and video inspections to identify geometrical characteristics
- flat jack tests to detect mechanical characteristics



# Geometrical Survey with Laser-scanner



Execution of  
three-dimensional scans -  
Point cloud model



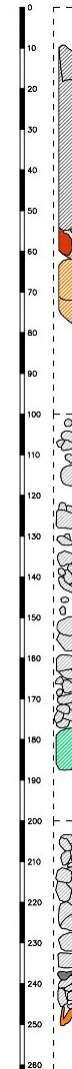
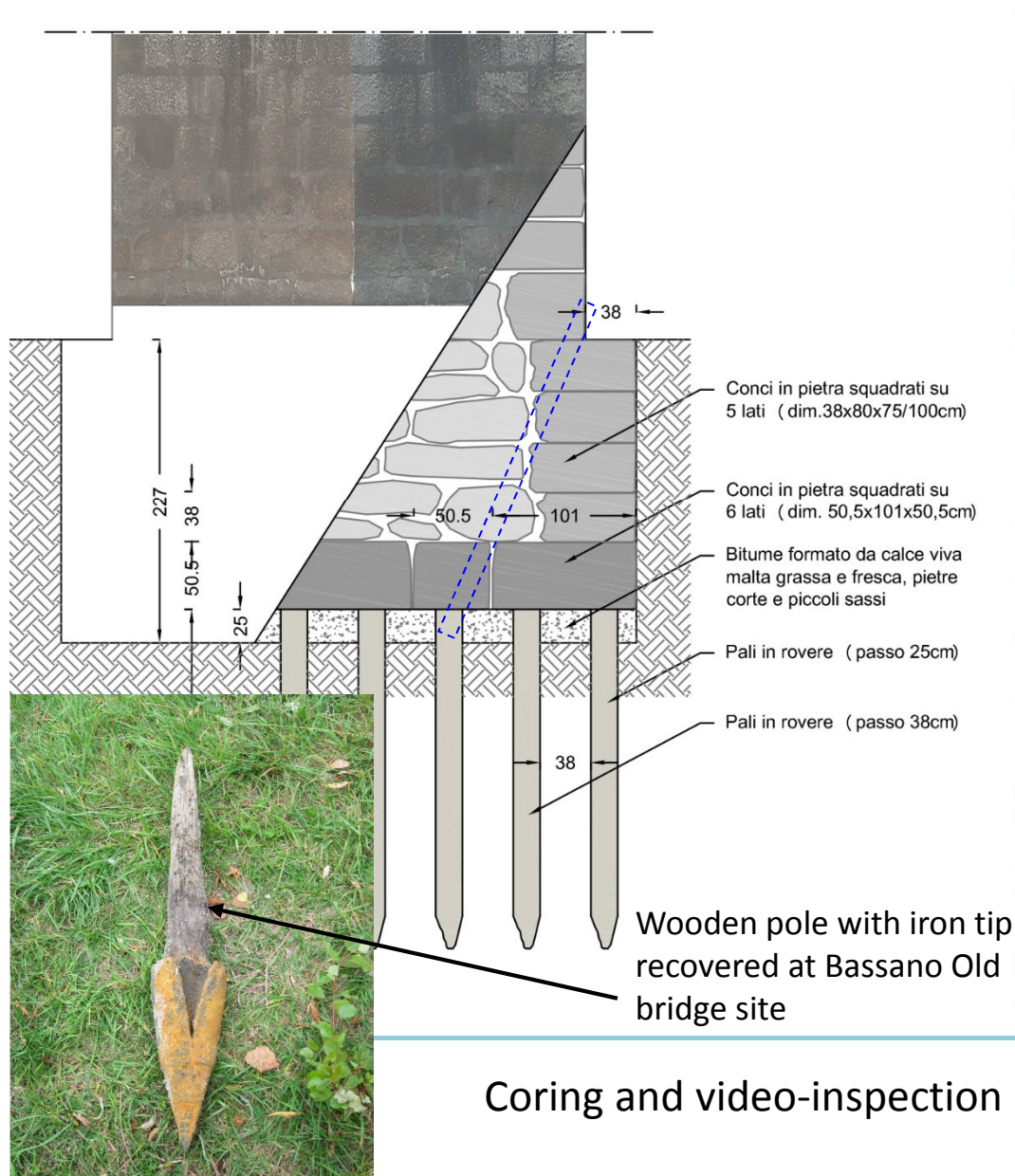
Surveys

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# Foundations



depth 30cm



depth 90cm



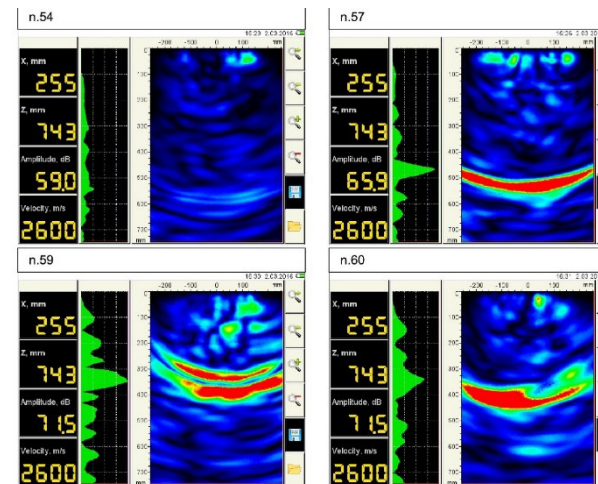
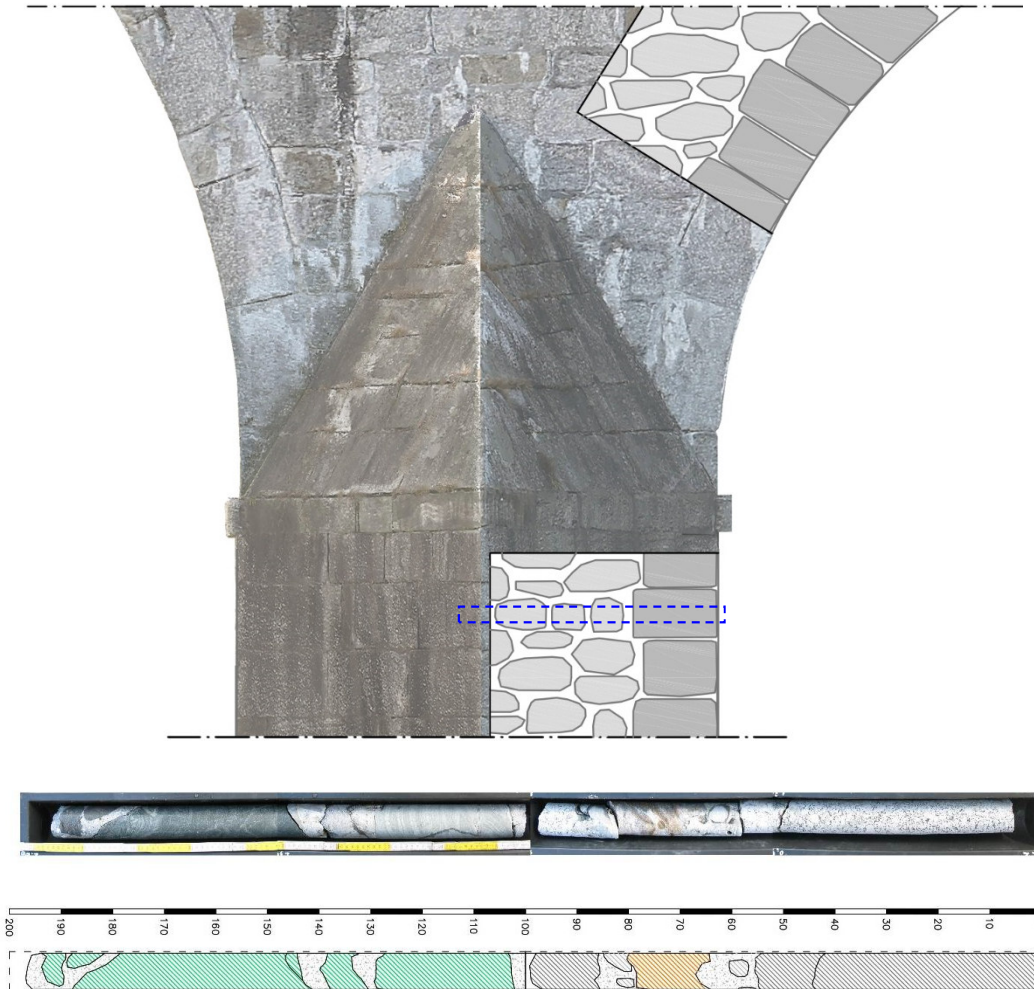
depth 170cm



Coring and video-inspection of the foundation of the left pier

Analysis

# Arch and Piers

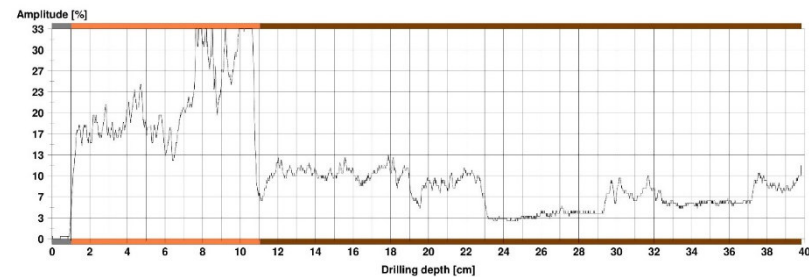
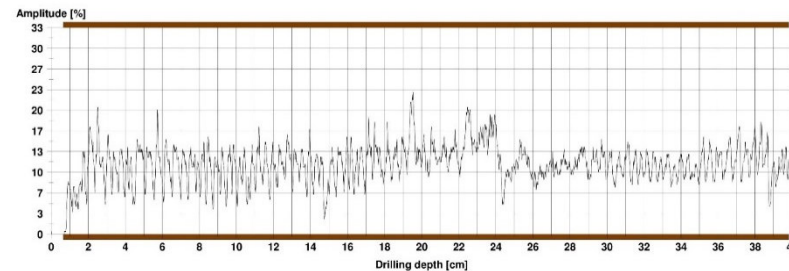
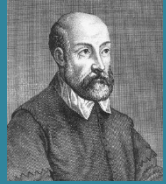


Coring and video-inspection of the masonry of the right pier  
Tomographic tests performed with positioning techniques by ropes

Analysis



# Wooden Trusses



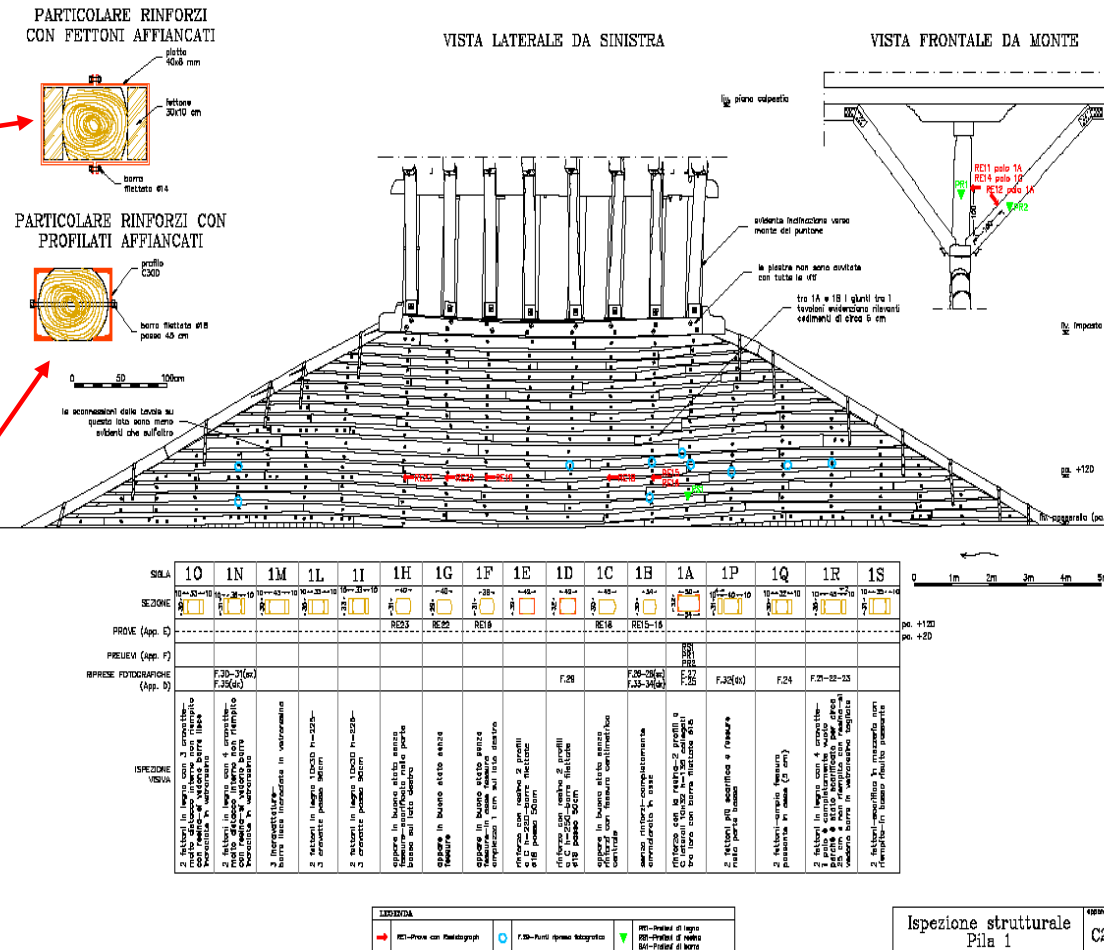
Micro drilling tests (with Resistograph)  
on the wooden trusses and wood  
sampling by means of Pressler auger

Analysis



Pole of the spurs reinforced with two lateral planks, connected with metal rods (1N)

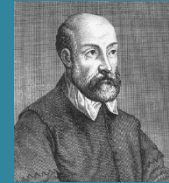
Pole under the deck reinforced with steel elements, connected with threaded metal rods (1D)



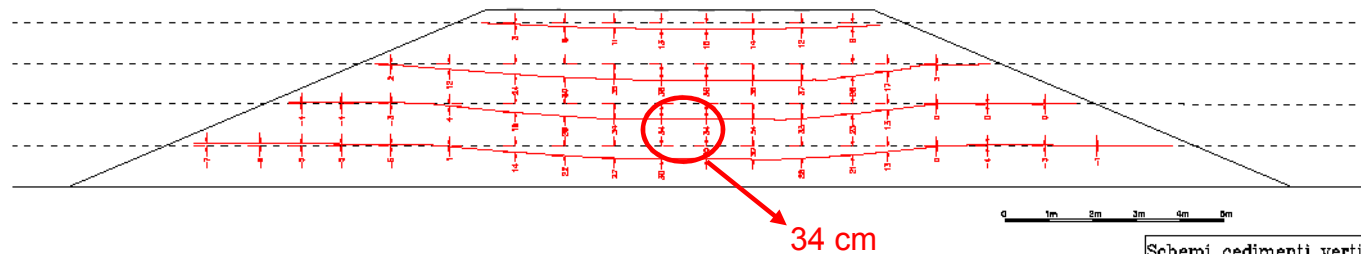
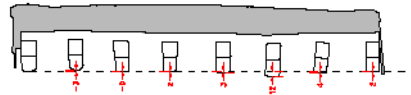
Information from inspection represented on the face of the piers



# Deformations Pattern Survey



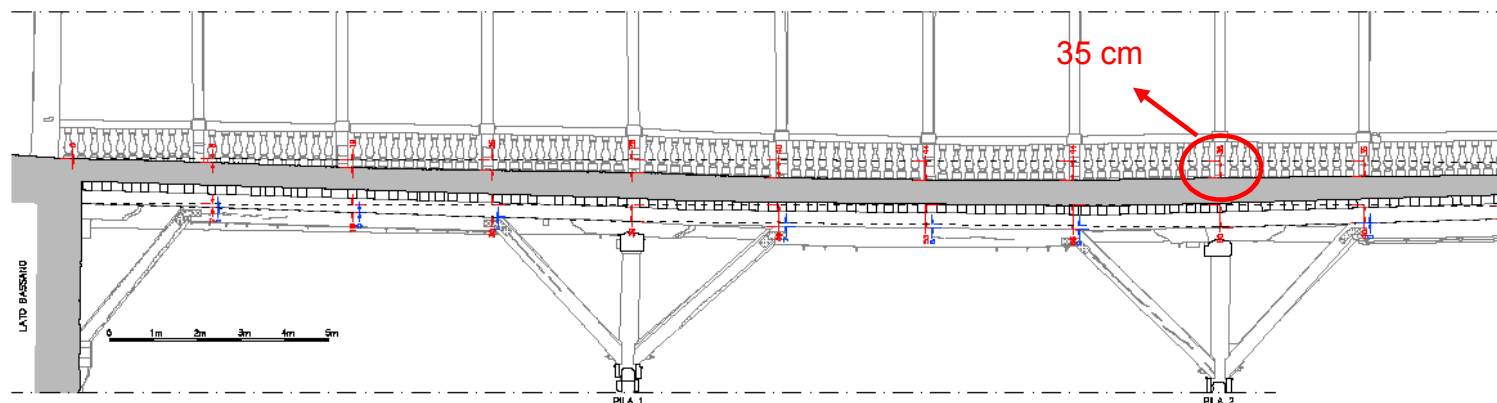
VISTA LATERALE DA SINISTRA-PILA 2



Schemi cedimenti verticali  
Pila1-Pila2

|    |
|----|
| G2 |
|----|

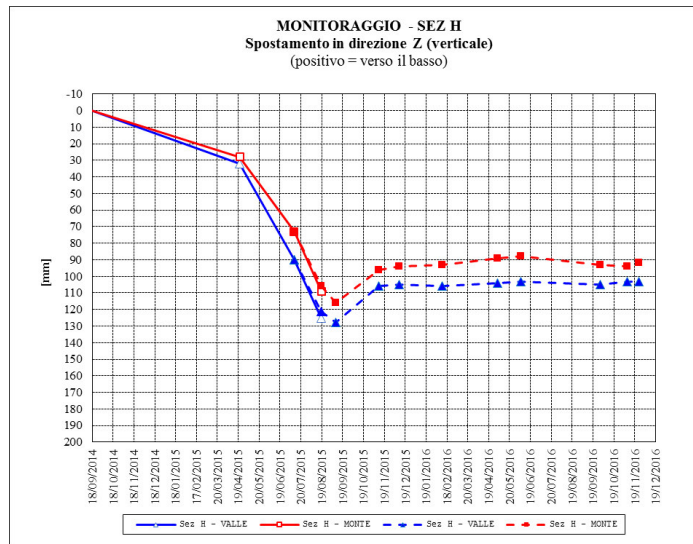
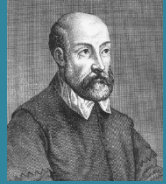
SEZIONE LONGITUDINALE



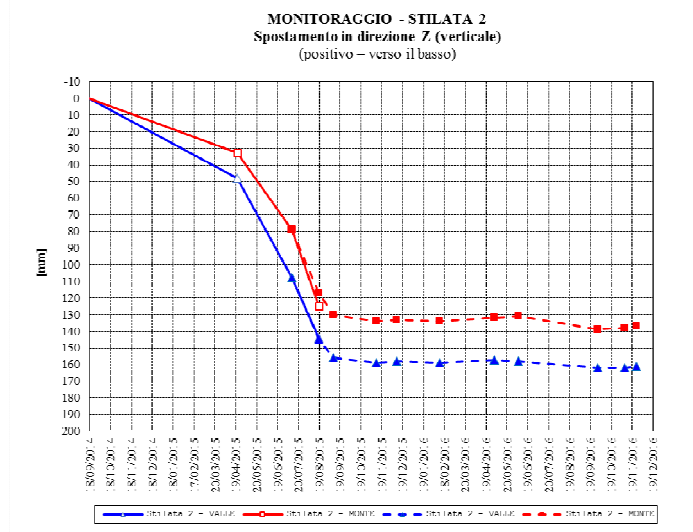
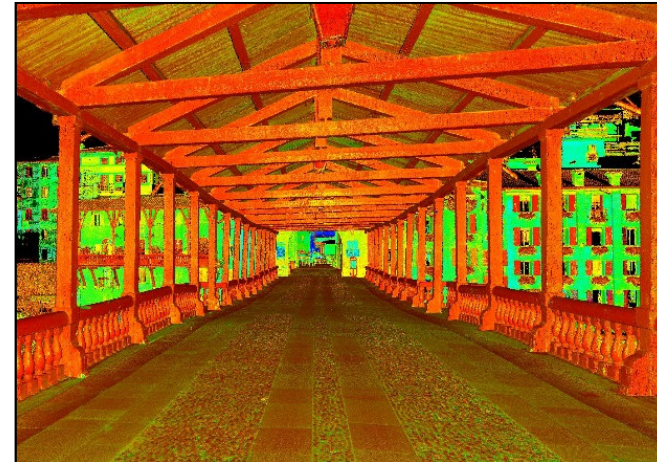
Settlements within pier measured on the basis of planks deformations  
Settlement of the piles measured on the basis of deck deformations

Surveys

# Monitoring



Laser scanner measurement



Topographic targets measurement



Monitoring

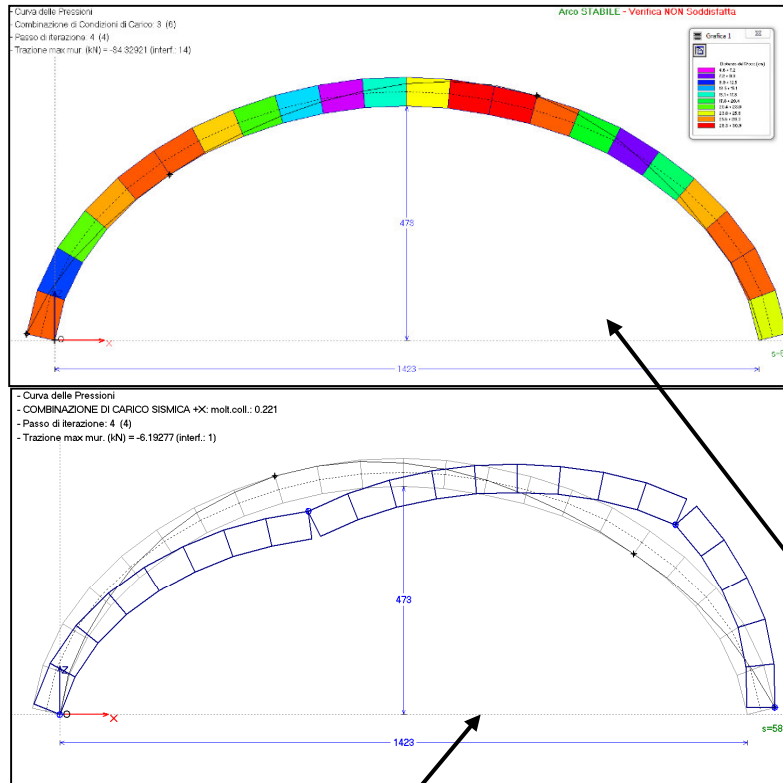
Monitoring was started by scans thought Scanner HDS 7000 Leica Geosystems, and continued by topographic targets surveyed thought Leica TCRA 1201 “total station”



# Modelling and Structural Calculations



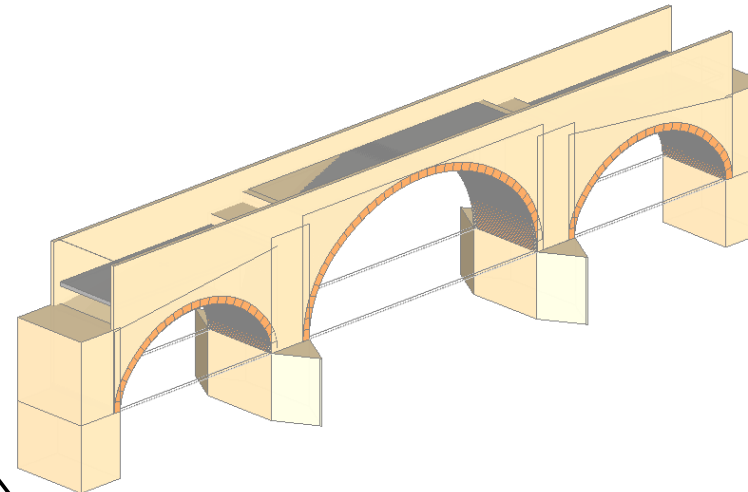
## 2D MODEL: LIMIT ANALYSIS



### SEISMIC ANALYSIS

- Curve of pressure;
- Kinematic limit;
- Seismic risk indicator.

## 3D MODEL: MACRO-ELEMENTS ANALYSIS



### STATIC ANALYSIS

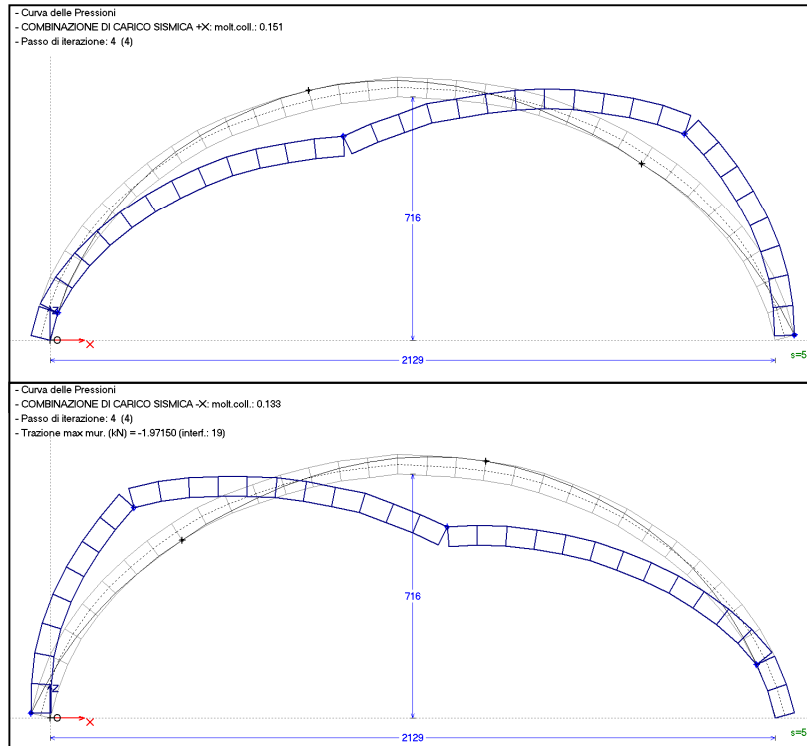
- Curve of pressure;
- Stability safety factor;
- Friction safety factor;
- Masonry compression strength.

Different models set up for limit analysis and macro-elements analysis

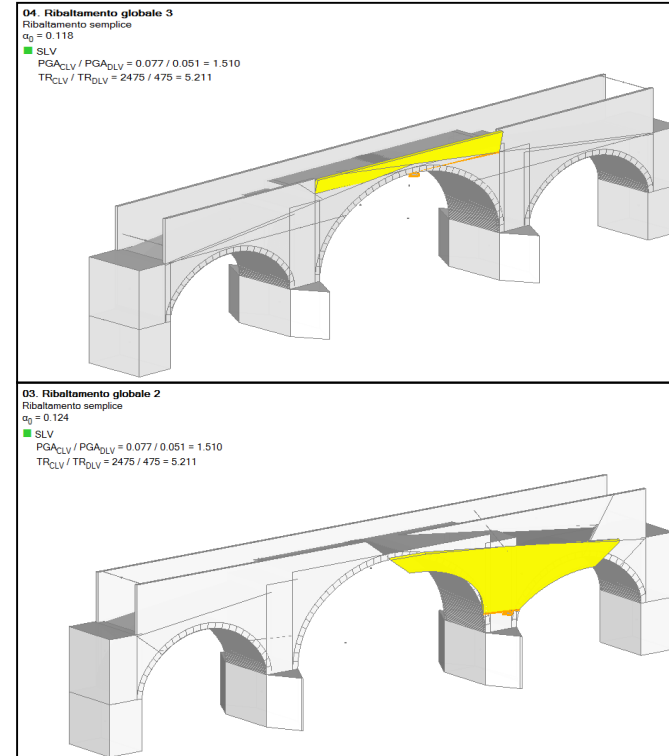
# Static and Seismic Assessment



## Kinematic analysis, Seismic risk indicators



## Macro-element analysis, Seismic risk indicators



Indicatori di Rischio Sismico I.R.:

- in termini di PGA:  $(PGA_{CLV} / PGA_{DLV}) = 0.077 \text{ g} / 0.051 \text{ g} = 1.510 \geq 1$
- in termini di TR :  $(TR_{CLV} / TR_{DLV}) = 2475 \text{ anni} / 475 \text{ anni} = 5.210 \geq 1$   
 $(TR_{CLV} / TR_{DLV})^{0.41} = (2475 \text{ anni} / 475 \text{ anni})^{0.41} = 1.968 \geq 1$
- in termini di  $V_a$ :  $>2475 \text{ anni}$

Seismic assessment of the bridge qualified as pedestrian walkway (3<sup>rd</sup> category)

Assessment



# THANK YOU FOR YOUR ATTENTION

