



SAFE CERTIFIED STRUCTURE

Derisking
Infrastructure:
Assessing Risk,
Preventing Disasters,
Optimizing Maintenance
and Total Cost
of Ownership

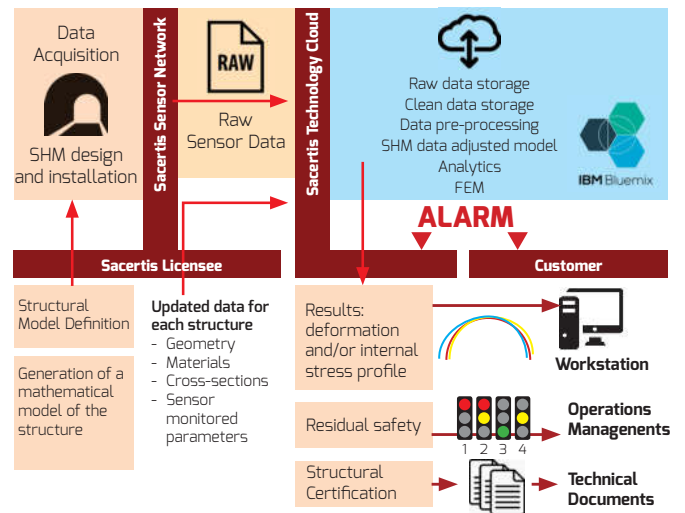
Monitoring, Analyzing,
Modeling, Certifying
the Quality, Robustness
and Resilience of
any Construction
to enhance People Safety
and optimize Lifetime
Asset Management

DERISKING INFRASTRUCTURE

System Overview

Sacertis delivers clients with a system to assess in real time the residual safety of any structure

Sacertis System Architecture

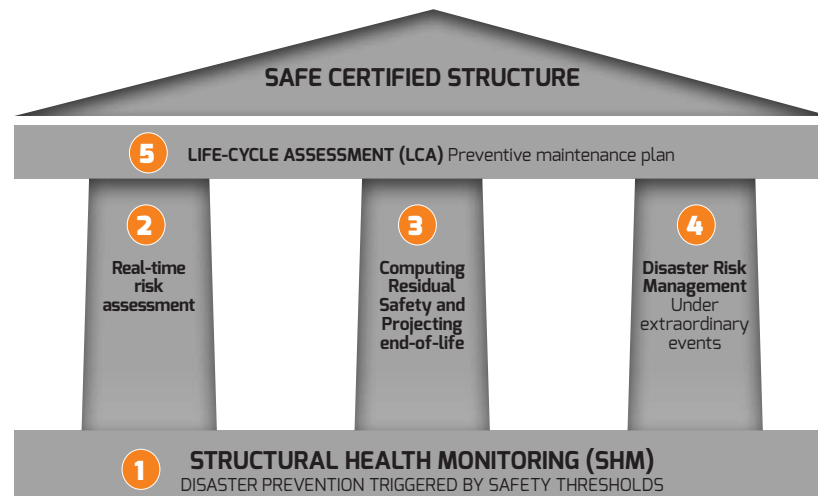


- **Structural Health Monitoring (SHM)** systems are a **high quality sensor network** to monitor critical structural parameters
- SHM is connected to the **cloud** for real time data acquisition, storage and processing
- Data are collected in the cloud, where the **real-time measurements** of the key structural parameters are analysed and compared with the results expected by the mathematical model of the structure to **detect in an early phase any weakness in the quality of the construction and compute its residual safety margins**
- When **critical** values are met, **emergency** calls to the safety decision makers are automatically activated
- SHM can be combined with advanced structural models to develop an in-depth Critical Event Risk Analysis. The resulting **SHM calibrated fragility** functions provide both the probability of exceeding different damage conditions, and the residual reliability of the structure under different levels of stress for predictive and post-event assessments.
- Detailed **structure life-cycle analysis and synthetic management tools** allows the efficient allocation of resources for maintenance and repair

The Integration of SHM, advanced structural models and risk analysis with the real-time updating of structural models by the sensor network constantly controls the risk profile and the residual safety of the monitored structure



Scalable Offering for all Needs



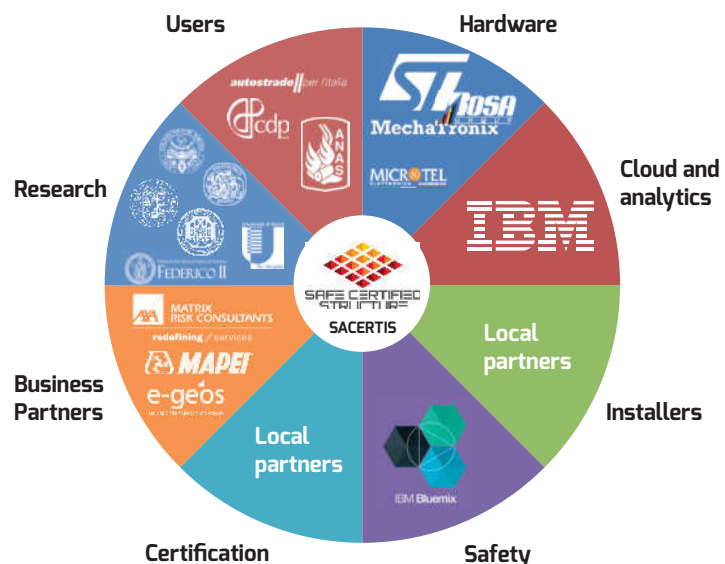
- 5** **Develop a framework** for full Structure Life-Cycle Analysis and Management, (efficient allocation of resources for inspection, maintenance and repair)
Deliverable: life-cycle costs assessment and management instruments to minimize total life cost or to extend the residual service life of the structure
- 4** **Combine the SHM** with advanced structural models to develop the in-depth Critical Event Risk Analysis, both in a predictive approach and after critical events
Deliverable: SHM data calibrated fragility curves show the quantitative risk estimation and the probabilistic assessment of the residual strength after critical events
- 3** **Combine the model** with deep learning and analytical tools to diagnose the weaknesses of the structure and project its residual safety and end-of-life expectation
Deliverable: Diagnosys of the identified weakness (what, where and residual safety)
- 2** **Develop Analytical Structural Models** and verify the compatibility between the results expected by the model and the SHM retrieved data
Deliverable: linear analytical models gauged on SHM data and compatibility report of the results expected by the model versus the experimental data
- 1** **Install a Structural Health Monitoring (SHM)** system on the structure monitor its real time evolution and provide disaster prevention tools
Deliverable: report of eventual changes of relevant structural parameters and alarm when critical thresholds are met

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INCREASING LEVEL OF ANALYSIS AND ASSESSMENT TOOLS

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A complete ecosystem



Derisking Infrastructure

The Sacertis approach perfectly fits into the traditional RM process

Advanced processing algorithms

Provide the identification
of the weak points
in the structure

Identify

Quantify

Comparison

With the mathematical
model provides the
evidence of the quality of
the Construction

Risk analysis

Based on data retrieved
from structural
monitoring computes
the residual safety
margin of the structure

Analyse

**Risk
Management
cycle**

Control

SHM

Provides evidence
of the real behaviour
of the structure

Treat

**Transfer risk
to the market**

**Technical
treatment**

Either decision requires risks to be known,
analyzed and properly managed

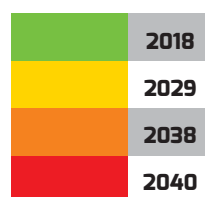
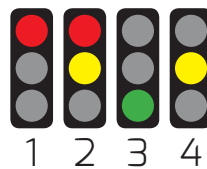
Managing and transferring risk

Getting the most from the existing
infrastructure by managing ageing and
natural disaster. Quantitative risk analysis
based on real time measurement of critical
parametres combined with advanced
analytics extends the residual lifetime
of the structure and reduces total asset
lifetime cost.

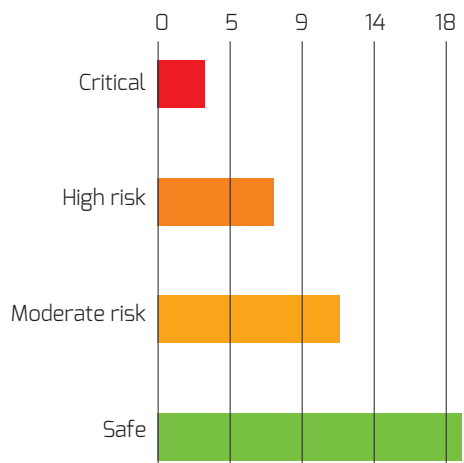
Real time monitoring and risk assessment
combined with impact evaluation (including
cost of interruption) is the state-of-the-
art risk management procedure and the
condition to meet in order to transfer risks to
the market (insurance)

**Sacertis provides fact based risk
assessments for single structures
and for whole asset portfolios**

For each asset
Actual and projection



For the whole portfolio



An extensive field trial

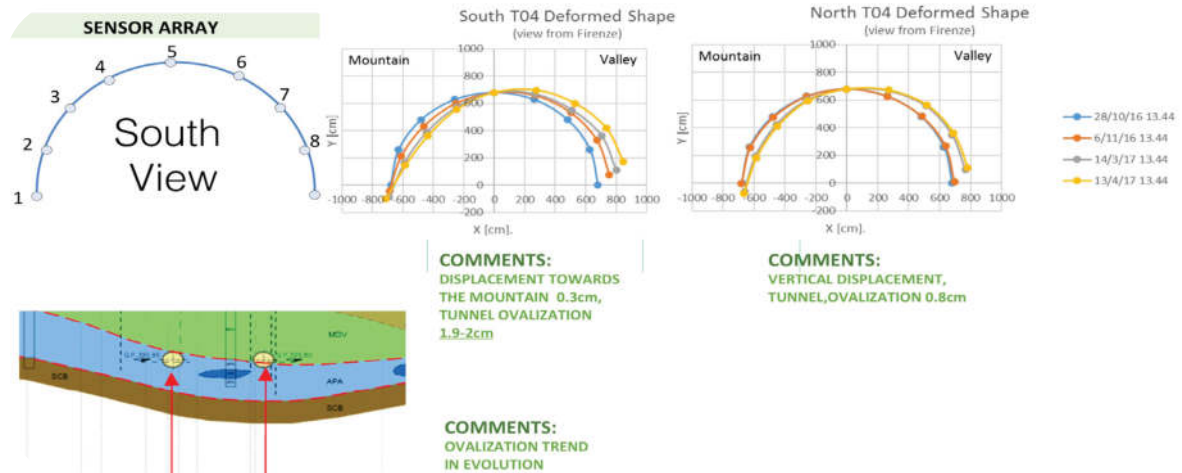


Several Structures covering many different applications:

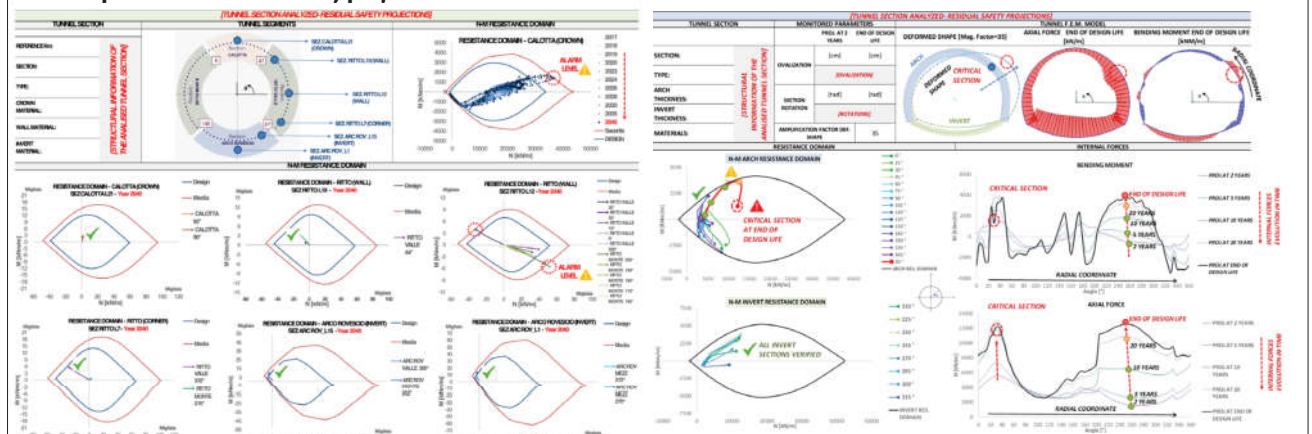
- One heavily damaged and one critical concrete bridge
- Bridge prestressing tendons
- Two one-km-long critical highway tunnels
- One high rise concrete double tower
- Several landslides
- One historical building
- Wind towers

Tunnel in central Italy

Deformations, forces and residual safety margins. 13 meter diameter tunnel: data have been collected before and after the fall of the last diaphragm. Below 1 mm displacements have been detected



Sacertis provides residual safety projections

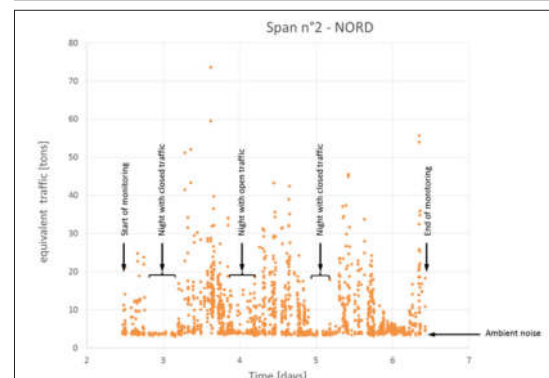
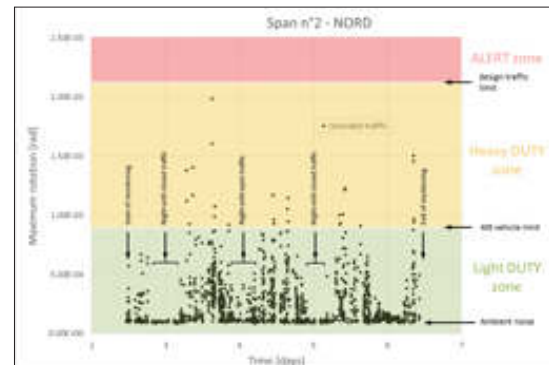


An important set of experimental results

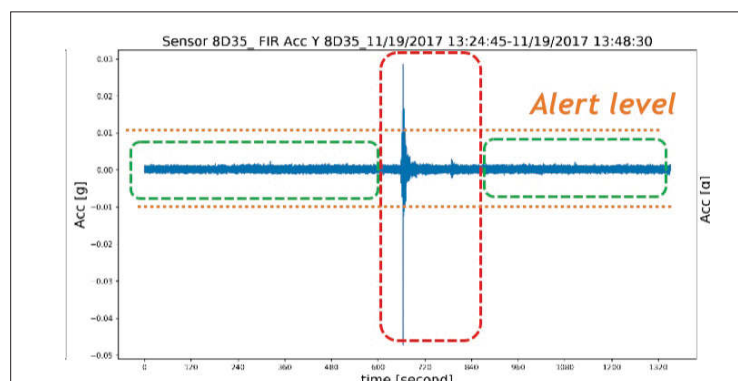
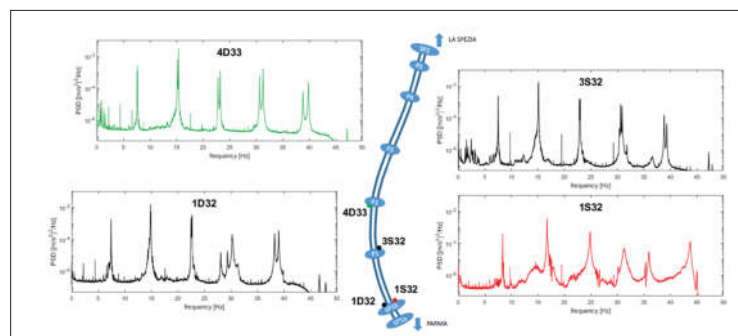
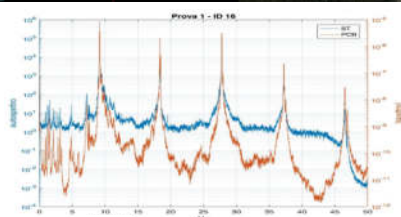
Damaged Bridge



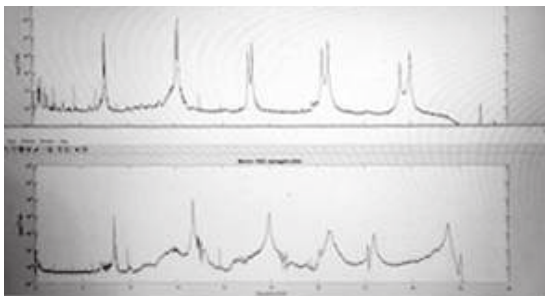
1.2 Km heavily damaged bridge.
Sacertis detects the traffic crossing the bridge at any given time and the relevant dynamic rotations of the beams



Bridge prestressed tendons: damages and earthquake resilience



System Components



A robust self-verification algorithm, based on advanced analytics and cross-checking of three different physical measures: tilt, vibration, stress.

Easy-to-install sensor boxes

- Sensor arrays (tilt, vibrations, stress, crack displacement, corrosion)
- Integrated on-board data processing and storage
- Mains, Battery, Photovoltaics or energy scavenging power supply
- Powerline, wireless or wireline data transmission systems
- Dedicated application for simple installation and configuration
- Plug & play installation



Gateway

- Storage and preprocessing of acquired data
- Data transmission to the cloud via wireless, wireline or fiber connection

Cloud infrastructure

- IBM Bluemix System
- Analytics and Cognitive processing
- Dashboard, alert generation, weak point identification

Residual Safety Computing and Projections

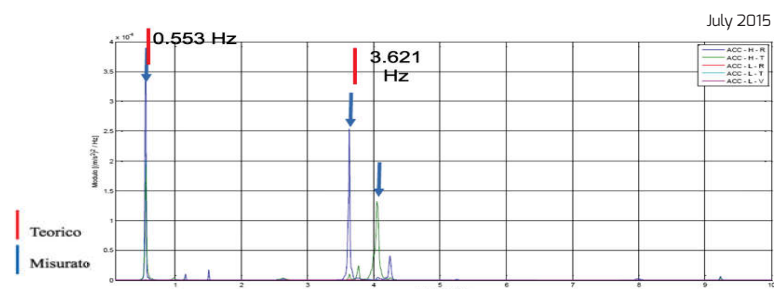
- Computing the forces applied to the structure
- Computing the Residual Safety
- Projecting the end-of-life



Wind Tower accelerometer



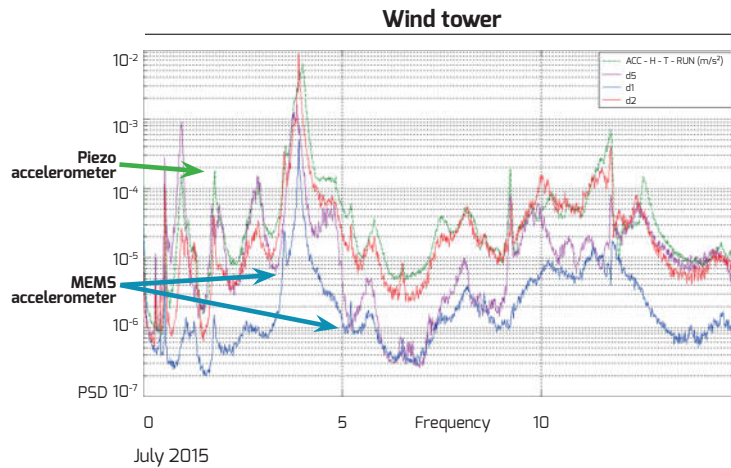
The normal vibration frequency measured on a wind tower perfectly matches the predictions of the Mathematical Model



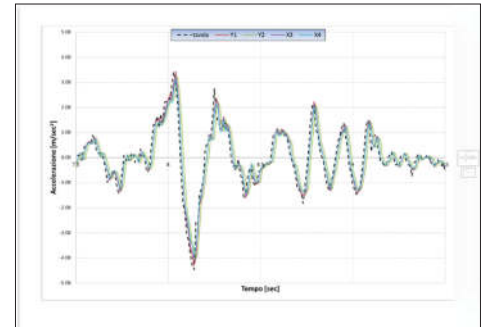
Proof of concept

Accelerometers and inclinometers

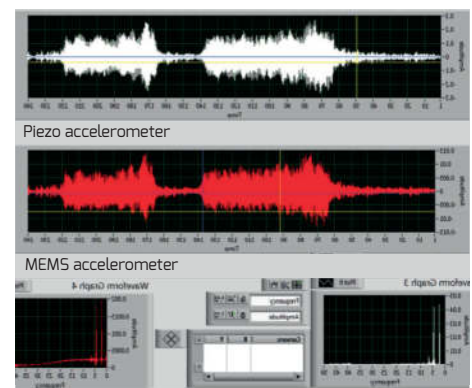
Sacertis accelerometers versus professional devices



Amatrice earthquake replication

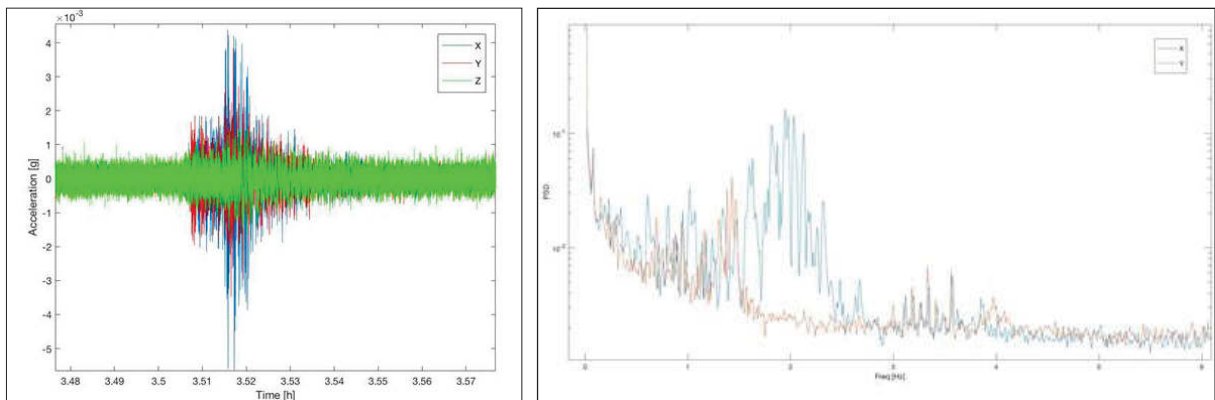


Stadium (San Siro rock concert)



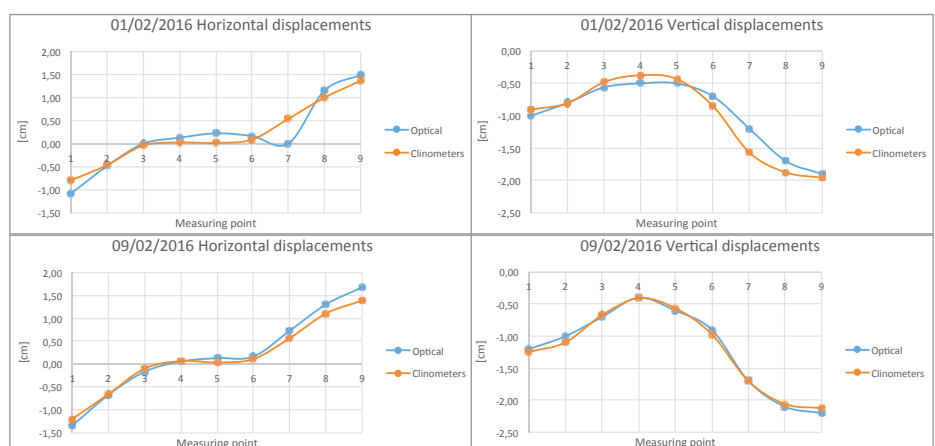
Amatrice earthquake recording in Bologna

August 2016



Sacertis inclinometers versus georeferenced measurement system

January 2016

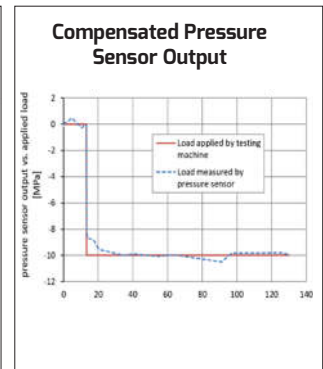
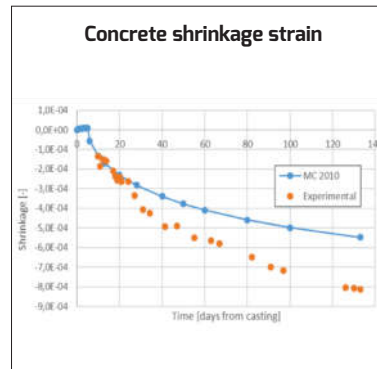


Average difference over 13 mt diameter - Along the x axis: 1.2 mm - Along the Y axis: 0.5 mm

Proof of concept Stress Sensor

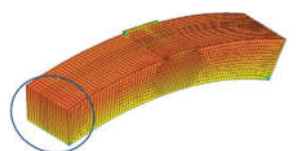
September 2016

Patented Stress Sensor

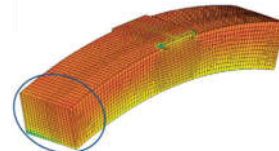


Tunnel segment three point beam test Tor Vergata

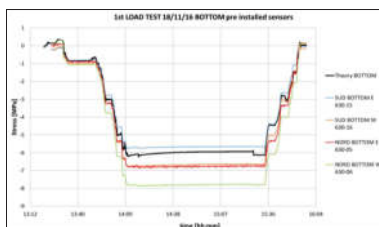
December 2016



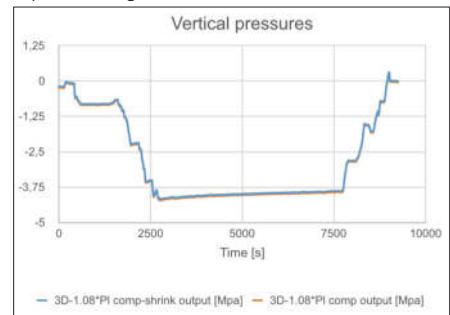
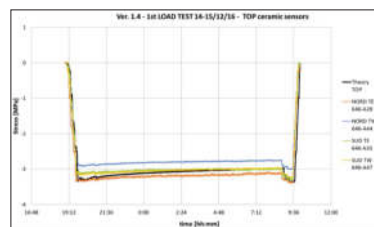
Main Compression Voltages: North Face Detail



Main Compression Voltages: South Face Detail

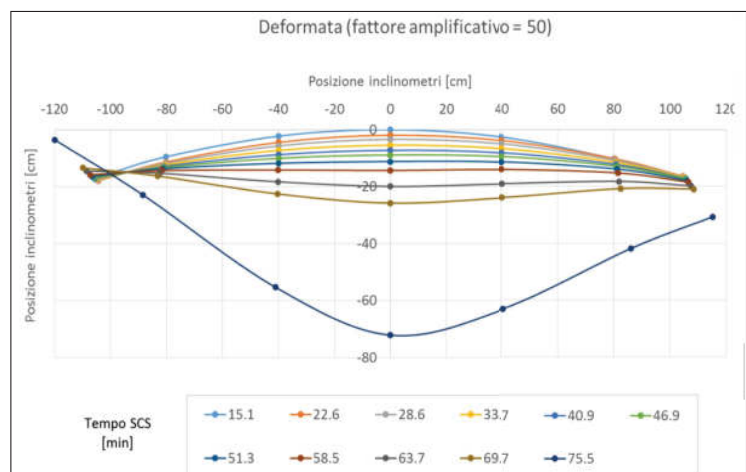


PRE INSTALLED



POST INSTALLED

Tunnel Segment Breakdown Test



Safe Certified Structure at a glance

- The combination of several easy to install sensors (accelerometer, tilt, stress, etc) working over different physical principles allows Civil Engineers to compute a **real time exhaustive picture** of the status of any monitored structure
- Several power supply and communication options provide flexibility of installation according to the characteristics of the single site
- **Cloud-based** data collection, advanced analytics and cognitive computing leveraging the state-of-the-art IBM Research knowledge
- **Risk Profiling** of the different structures: computing **residual safety**, projecting **end of life**, setting **data-based maintenance** priorities
- **Differentiated** business models for different customer needs
- Installed on several structures: bridges, tunnels, high rise buildings, wind towers.
- Further information extracted from data analytics open space for **innovative applications**

