La ferrovia Torino - Ceres:
un'interconnesione verso il futuro

TORINO 13 febbraio 2025

Progetto BRIDGE|50 – ideazione, sviluppo, obiettivi

Prof. Ing. Fabio Biondini
Politecnico di Milano
fabio.biondini@polimi.it | https://biondini.faculty.polimi.it

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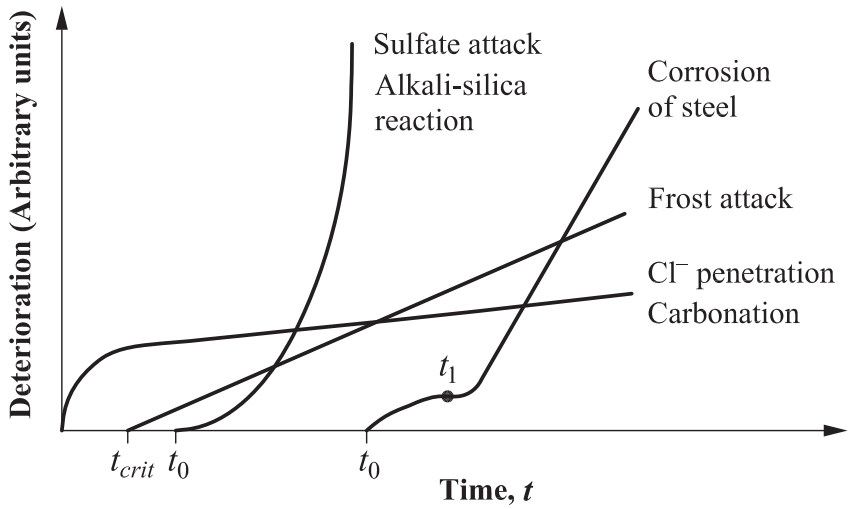
Structural Aging and Deterioration



(Clifton & Knab 1989; Ellingwood 2005)

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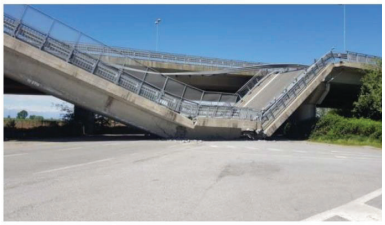
Progressive Collapse under Corrosion

Silver Bridge
Ohio, 1967
stress corrosion and corrosion fatigue

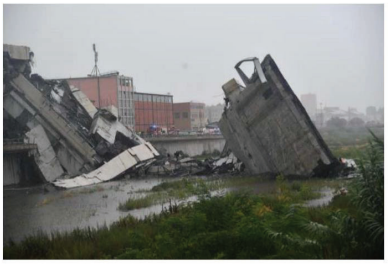
Mianus River Bridge,
Connecticut, 1983
rust formation and fatigue cracks

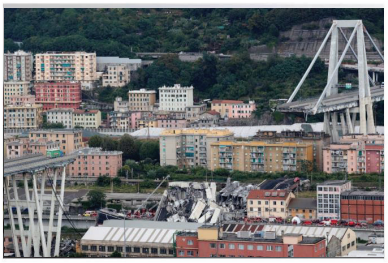
Recent Bridge Failures in Italy



Cavalcavia La Reale
18 aprile 2017
Fossano (CN, Piemonte)

Cavalcavia 167 - A14
9 marzo 2018
Ancona (AN, Marche)





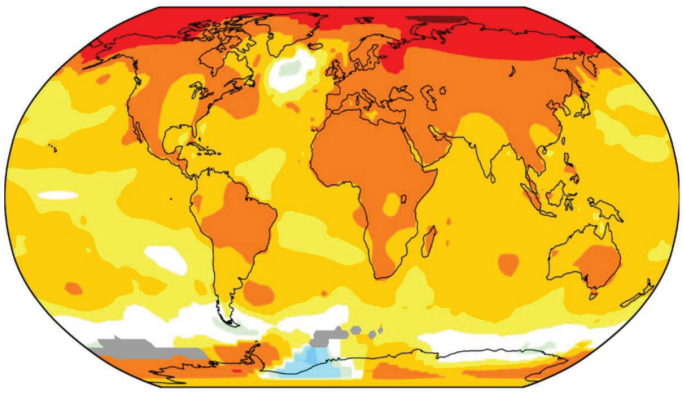
Viadotto Morandi
14 agosto 2018
Genova (GE, Liguria)

Stressors, Loading, Exposures

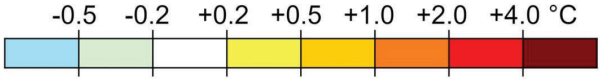



Climate Change Effects

Temperature change in the last 50 years



2011-2020 average vs 1951-1980 baseline



- ❑ **INCREASE CLIMATIC LOADS AND ALTER ENVIRONMENTAL CONDITIONS**
- ❑ **ACCELERATE AGING AND STRUCTURAL DETERIORATION PROCESSES**
- ❑ **EXACERBATE OCCURRENCE OF EXTREME EVENTS**
- ❑ **POTENTIAL CATASTROPHIC IMPACT ON STRUCTURAL SAFETY**

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- "There are more than 617,000 bridges across the U.S. Currently, 42% of all bridges are at least 50 years old, and 46,154, or 7.5% of the nation's bridges, are considered structurally deficient, meaning they are in "poor" condition. Unfortunately, 178 million trips are taken across these structurally deficient bridges every day."
- "A recent estimate for the nation's backlog of bridge repair needs is $125 billion."

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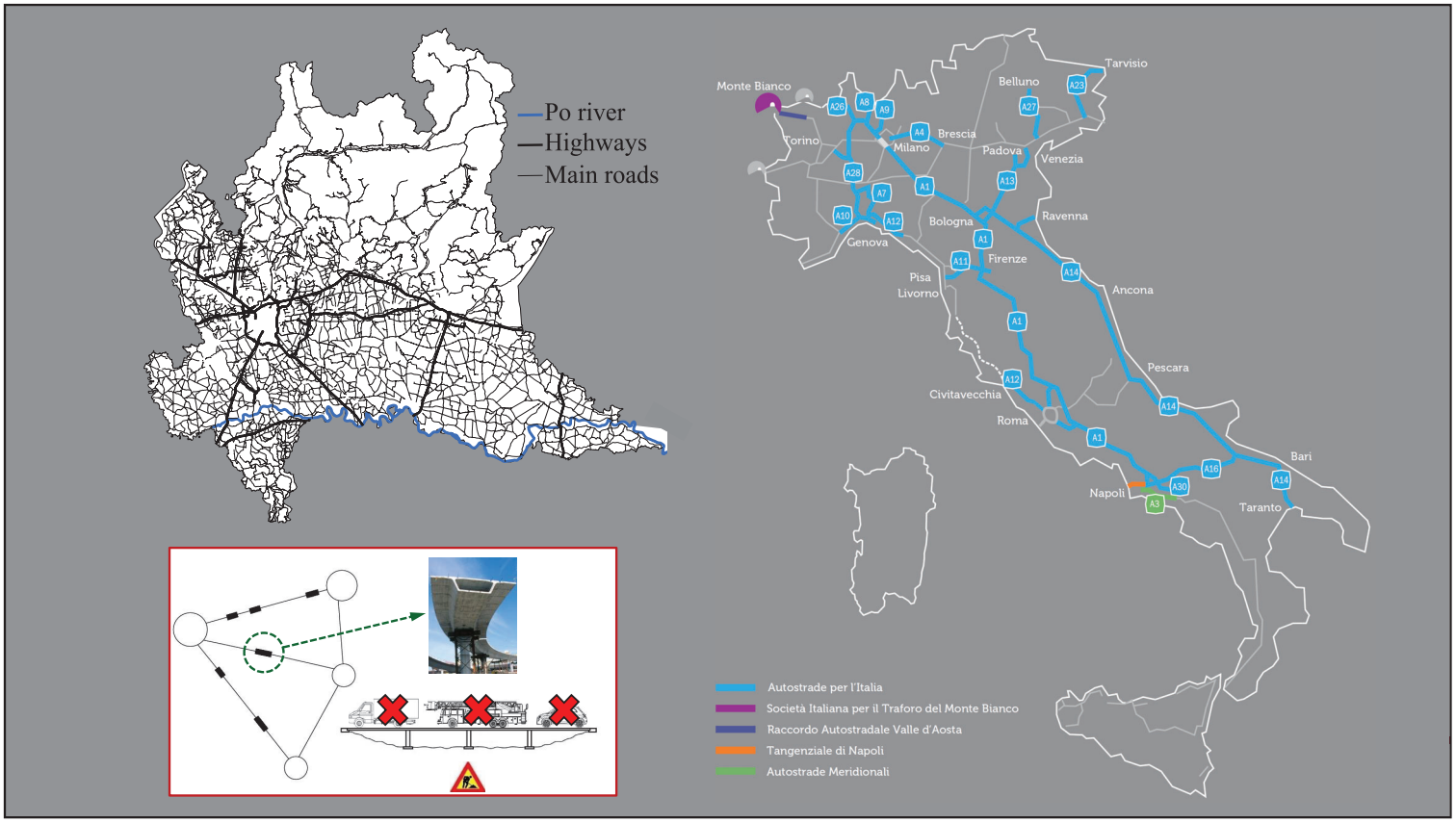

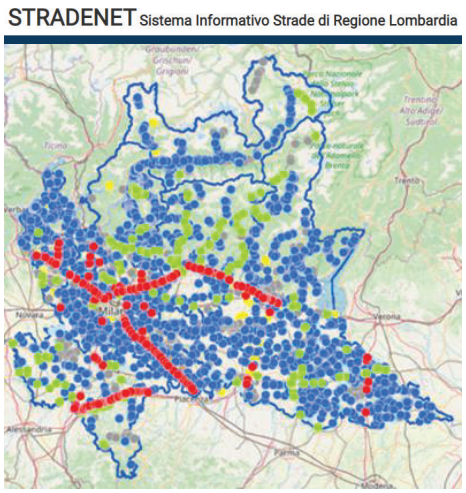

The Lombardy regional road network includes about **10,000 bridges**.

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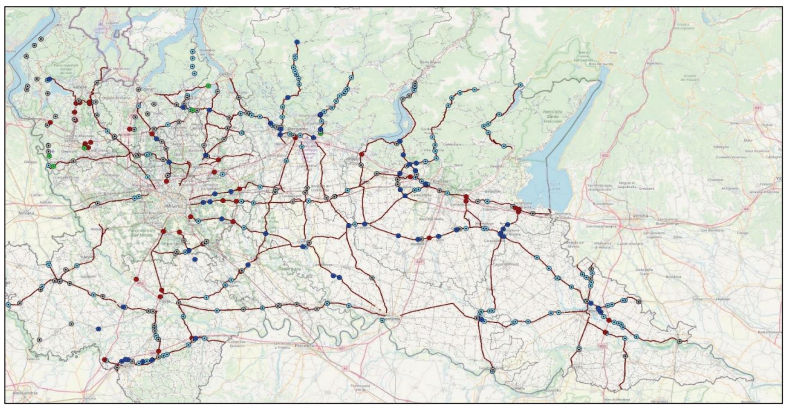
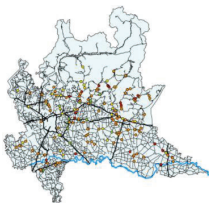
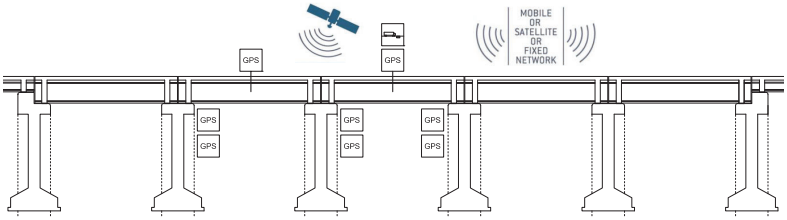
Regione Lombardia
POLITECNICO MILANO 1863

RL-PoliMi: about 400 bridges, including SHM of 9 bridges







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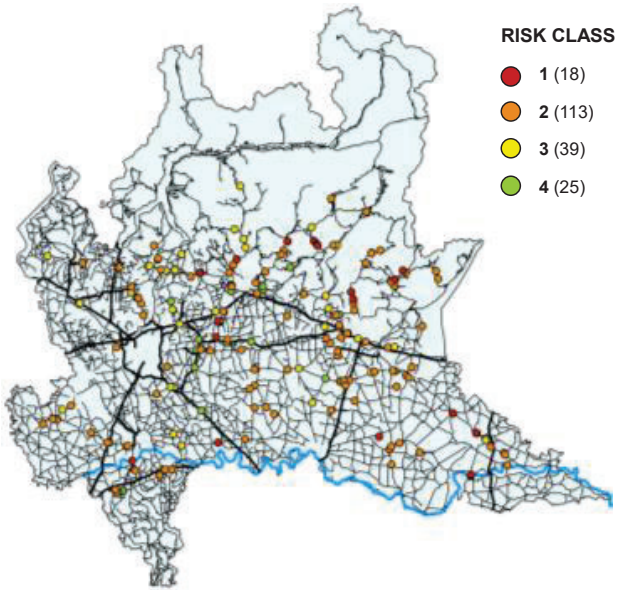
Risk Maps



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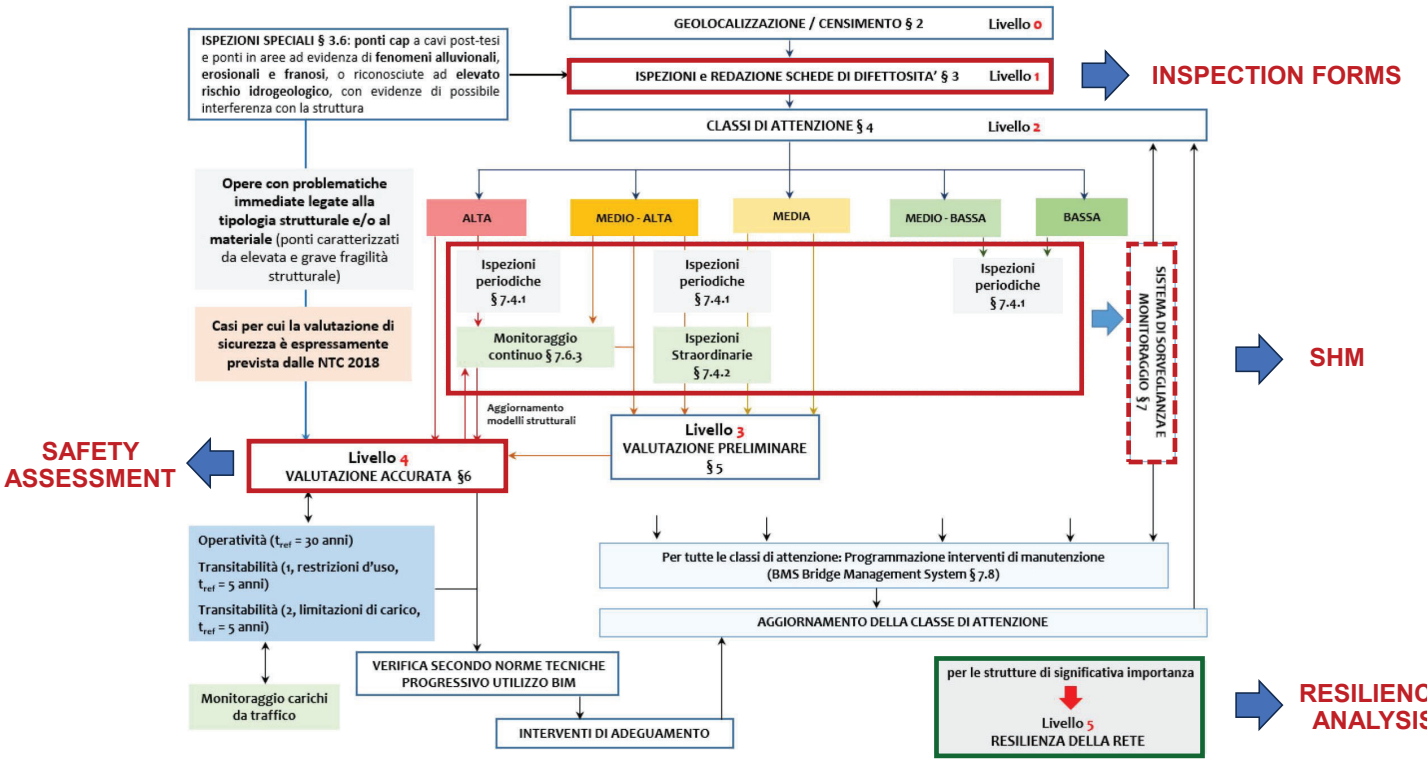
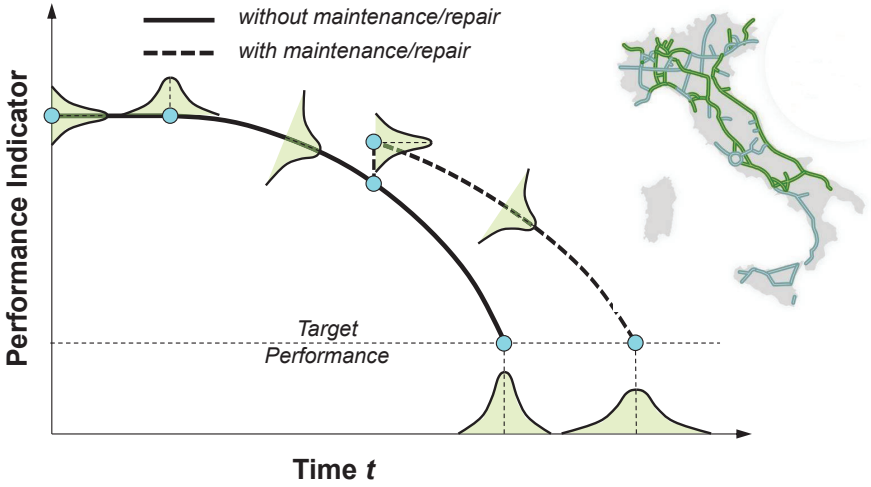
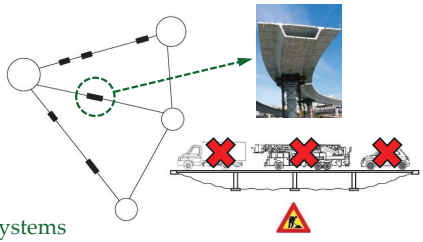
2020 ITALIAN GUIDELINES ON RISK CLASSIFICATION AND MANAGEMENT OF BRIDGES



Life-Cycle Performance under Uncertainty

Paradigm Shift: Time is the new Variable, Infrastructure is the new Scale !





Biondini, F., Frangopol, D.M., 2016. Life-Cycle Performance of Deteriorating Structural Systems under Uncertainty: Review, *Journal of Structural Engineering*, ASCE, 142(9), F4016001, 1-17.

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ASCE JSE Survey

Life-Cycle Performance of Civil Structure and Infrastructure Systems: Survey

F. Biondini and D.M. Frangopol

ASCE Journal of Structural Engineering

Vol. 144, No. 1, 2018

- **Life-cycle-oriented computational models are well established** for some of the most detrimental damage processes, such as **corrosion and fatigue**, and are rapidly becoming available for a wider spectrum of deterioration mechanisms.
- However, **deterioration models are very sensitive** to change of the **key damage parameters**. Robust validation and accurate calibration are difficult tasks because of limited availability of data.
- Further efforts in this direction, aimed at **gathering new data** from both **existing structures and experimental tests**, are crucial for a successful implementation of life-cycle frameworks.

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Experimental Testing on Existing Structures

BRIDGE|50 Research Project

Lombardi

SCR PIEMONTE
SOCIETÀ DI COMMITTENZA

POLITECNICO MILANO 1863

POLITECNICO DI TORINO 1859 1906

TNE Torino Nuova Economia

REGIONE PIEMONTE

TORINO METROPOLI

CITTA' DI TORINO

despe
ENGINEERED SPECIAL DEMOLITIONS

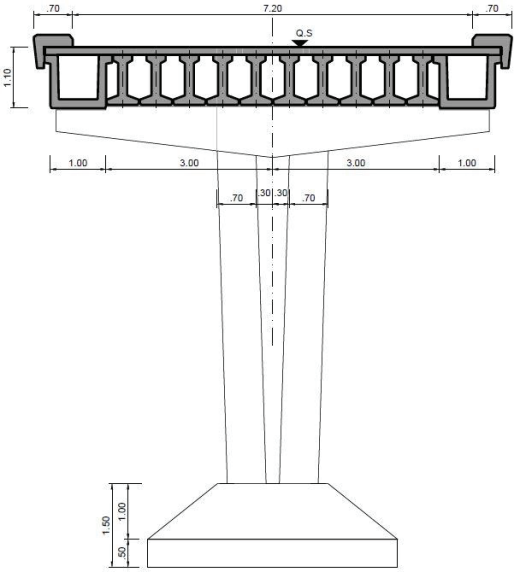
ITINERA

Quaranta Group

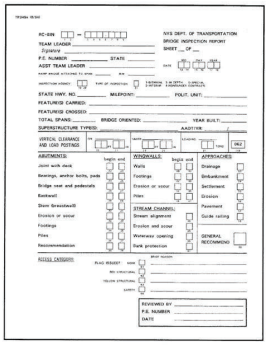
PERINO PIERO s.r.l.

Biondini, F., Manto, S., Beltrami, C., Tondolo, F., Chiara, M., Salza, B., Tizzani, M., Chiaia, B., Lencioni, A., Panseri, L., Quaranta, L., 2021. BRIDGE|50 Research Project: Residual Structural Performance of a 50-Year-Old Bridge. *Tenth Int. Conference on Bridge Maintenance, Safety and Management* (IABMAS 2020-2021), April 11-15, 2021, Sapporo, Japan.

Corso Grosseto Viaduct (Turin, Italy)

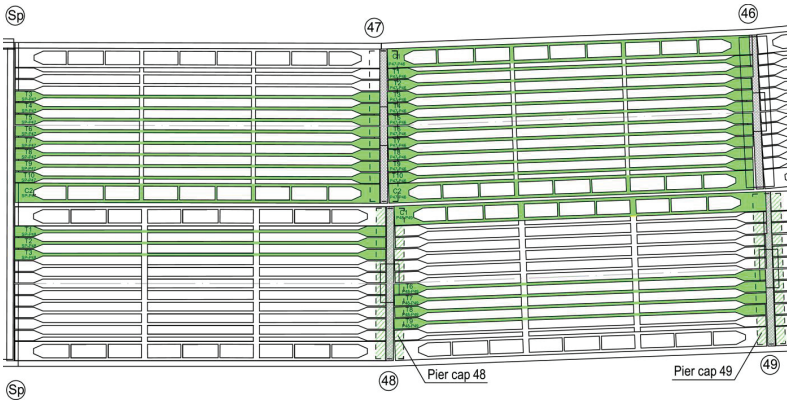


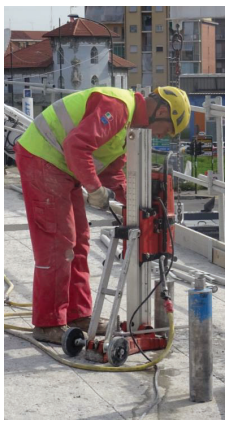
Bridge Inspection

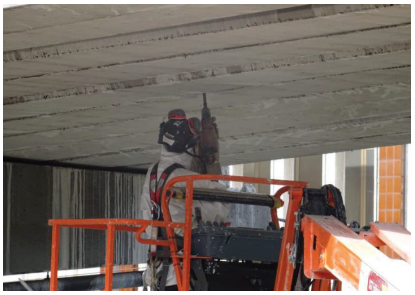



Appendix C

Bridge routine surveillance inspection report


Sp
47
46
Pier cap 48
Pier cap 49
48
49
Sp











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Testing Site




- 25 I-shaped deck beams
- 4 U-shaped box beams
- 2 pier caps

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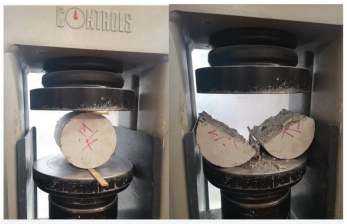
Dismantling

Visual Inspection

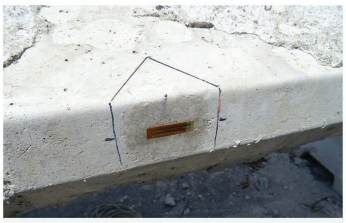
Testing site

NDT

Carbonation Testing



Laboratory tests

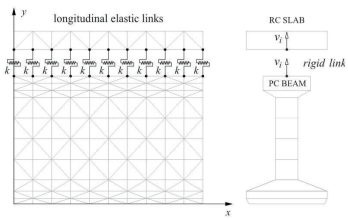


Residual Prestressing

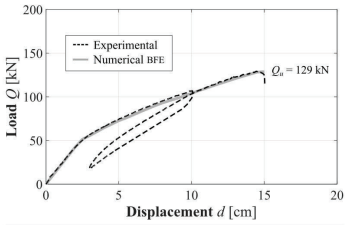
Full-Scale Load Test

Cracking Assessment

Digital Modeling

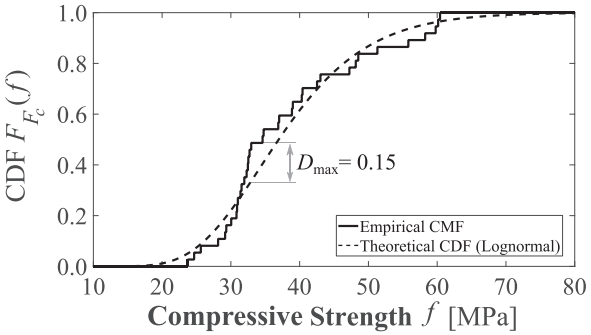


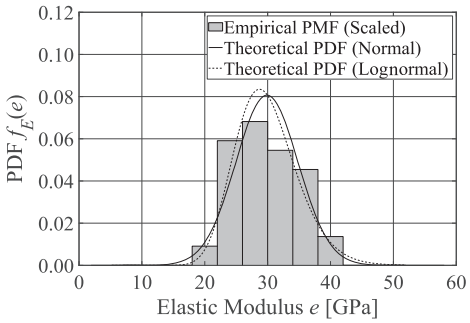
Structural Modeling

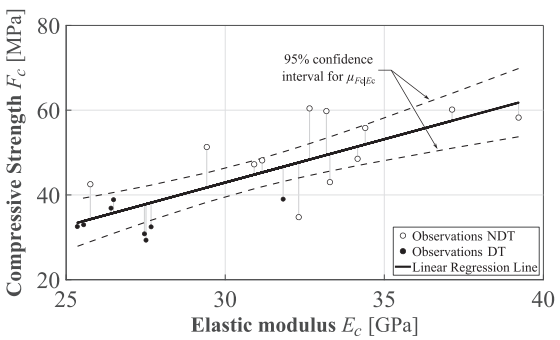


Numerical Validation

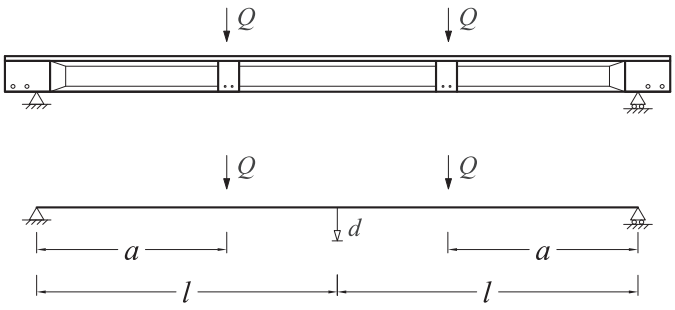
Statistical Data Processing







Full Scale Load Tests



$l = 9.58$ m $\alpha = a/l$ $\alpha \in [0; 1]$

Savino, P., Tondolo, F., Sabia, D., Quattrone, A., Biondini, F., Rosati, G., Anghileri, M., Chiaia, B., 2023. Large-scale experimental static testing on 50-year-old prestressed concrete bridge girders, *Applied Sciences*, 13(834), 1–22, 2023.

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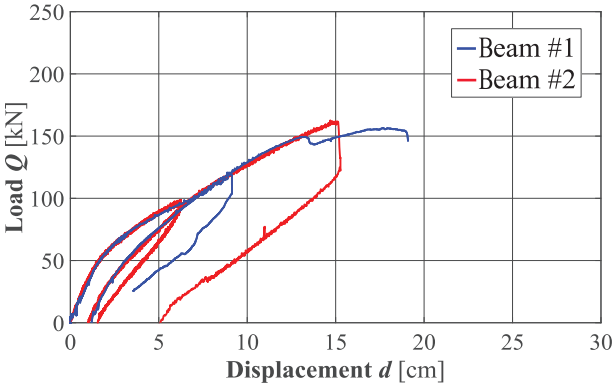
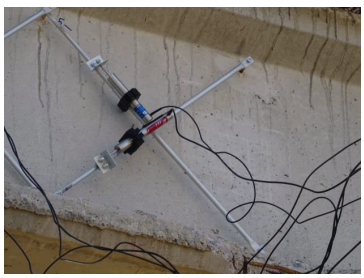
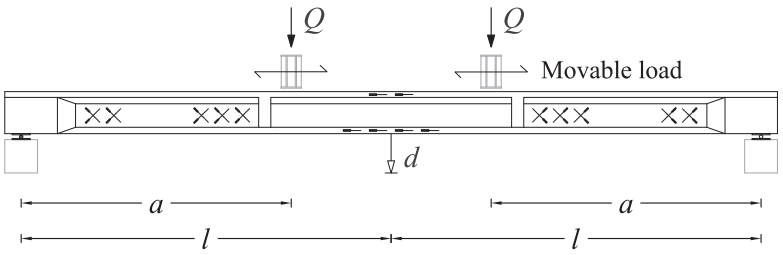
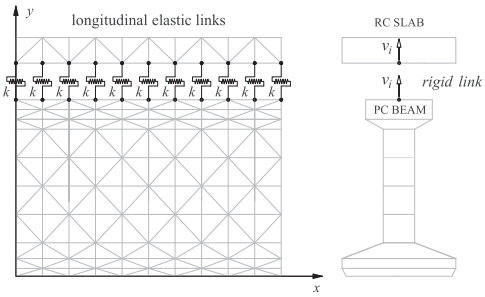
Load Tests (*in progress*)

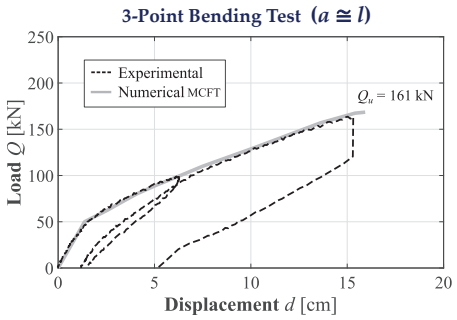


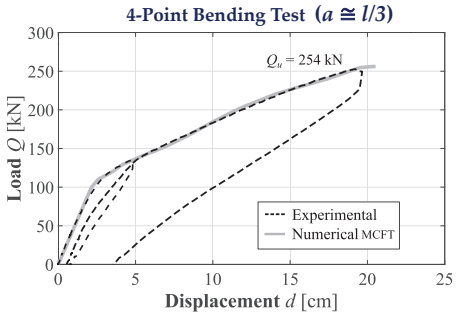


Model Validation







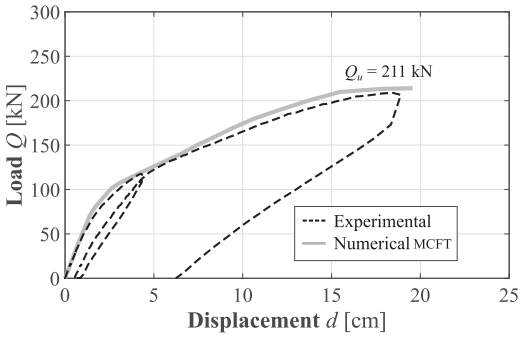


Anghileri, M., 2022. *Life-Cycle Performance of RC/PC Bridges: Computational Modelling and Experimental Validation*. PhD Thesis, Politecnico di Milano.

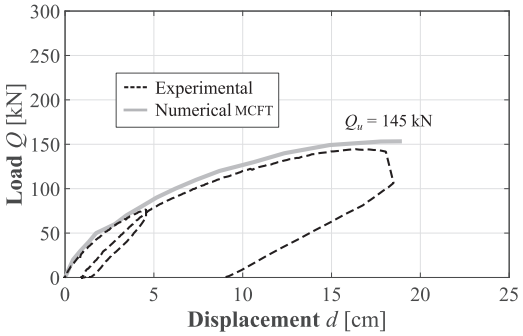
Anghileri, M., Biondini, F., 2025. Validation of life-cycle-oriented computational methods for nonlinear analysis of RC/PC structures based on experimental tests, *Structure and Infrastructure Engineering* (In press).

PC Deck Beams under Artificial Damage

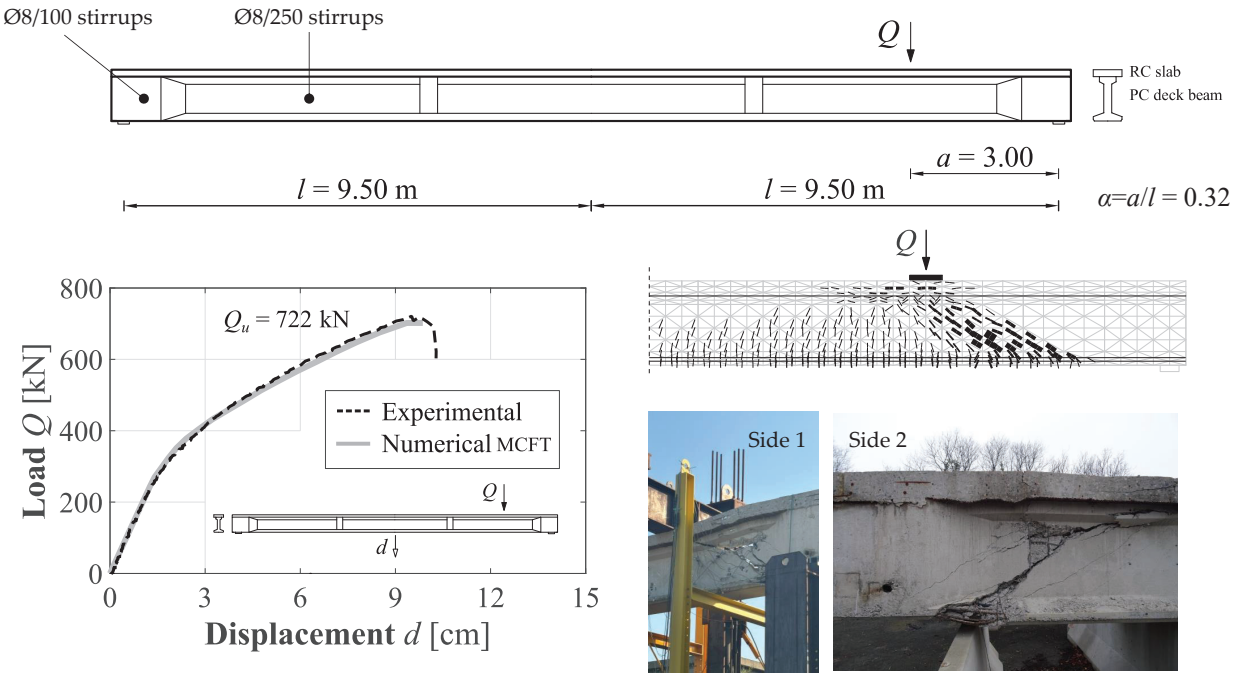
core drilling of concrete at top slab and bottom beam flange
+ cut of 4 strands



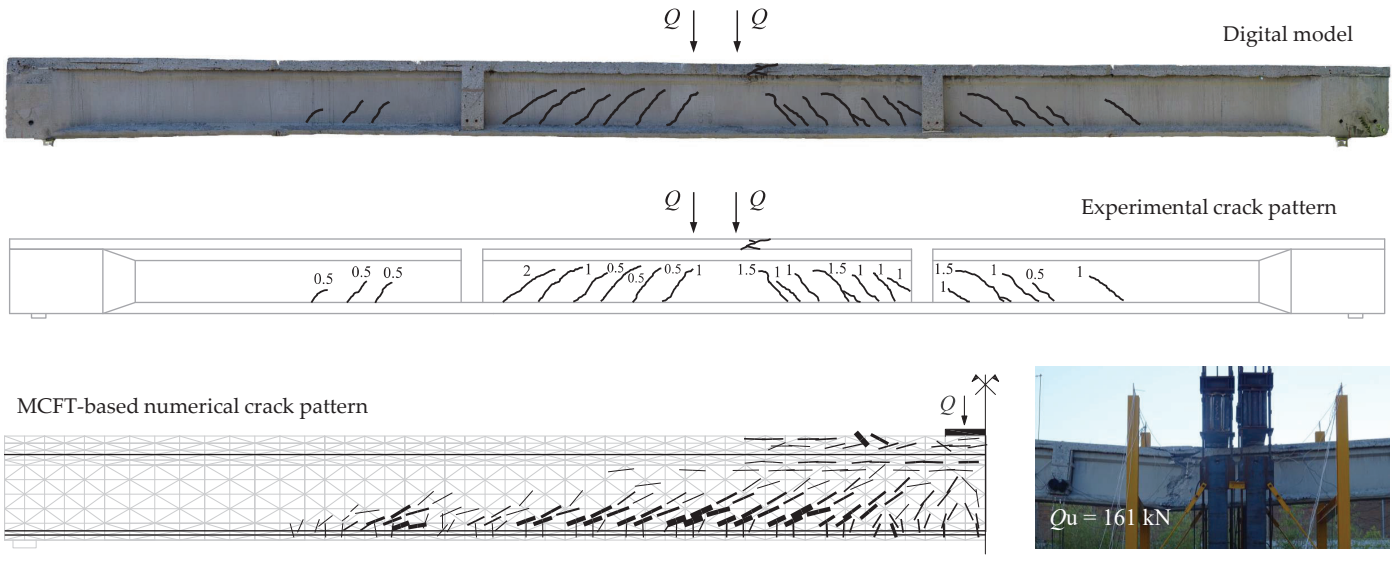
concrete cover removal
+ cut of 8 strands



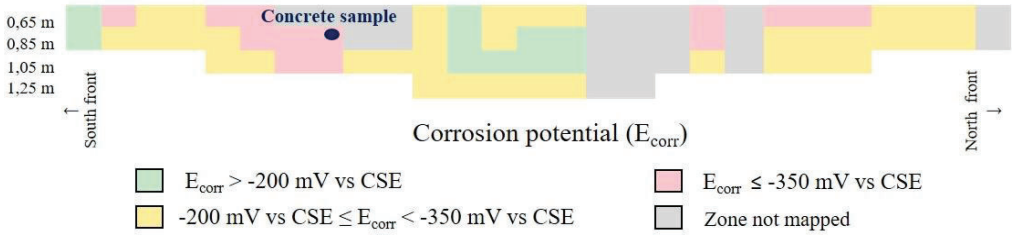
PC Deck Beam under Shear Failure



Model Validation | Cracking Pattern

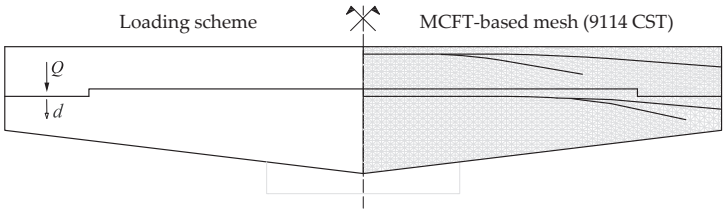


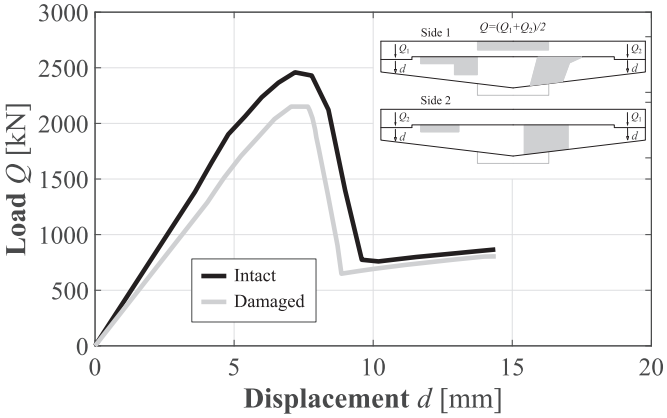
Corrosion Assessment



Carsana, M., Redaelli, E., Biondini, F., 2023. Field and laboratory tests for corrosion assessment of existing concrete bridges, **Keynote paper**, Eighth International Symposium on Life-Cycle Civil Engineering (IALCCE 2023), July 2-6, 2023, Milan, Italy. In: "Life-Cycle of Structures and Infrastructure Systems", F. Biondini, D. M. Frangopol (Eds.), CRC Press, London, UK, 45-56 (Open Access).

Model Validation | Pier Caps (*in progress*)





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Research Needs and Activities

- An effort is ongoing in the structural engineering community to promote further advances on **life-cycle design of deteriorating structures and infrastructure systems under uncertainty** and to **incorporate life-cycle concepts** into **risk-based design codes and standards** considering the potential impact of **climate change**.

INTERNATIONAL ASSOCIATION FOR BRIDGE MAINTENANCE AND SAFETY
http://www.iabmas.org

IABMAS Italy Group
http://www.iabmas-italy.it

iaLcce
International Association for Life-Cycle Civil Engineering
http://www.ialcce.org

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS
http://www.asce.org

Former SEI/ASCE Technical Council Life-Cycle Performance, Safety, Reliability and Risk of Structural Systems (2008-2023)

Task Groups:

TG1. Life-Cycle Performance of Structural Systems under Uncertainty

TG2. Reliability-Based Performance Indicators for Structural Systems

TG3. Risk Assessment of Structural Infrastructure Facilities and Risk-Based Decision Making

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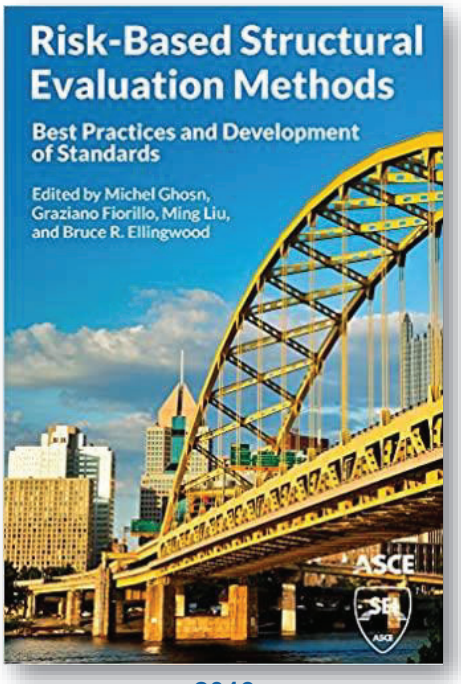
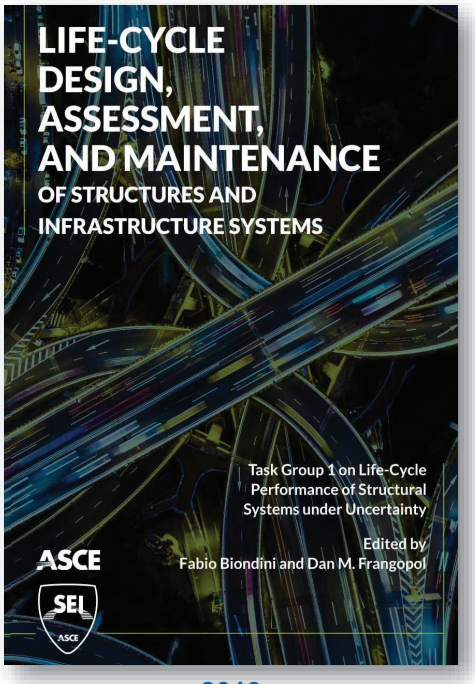
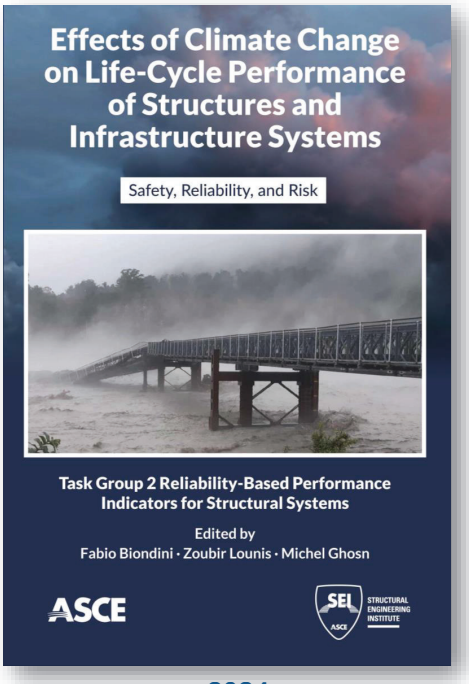
ASCE Books



2019



2019



2024

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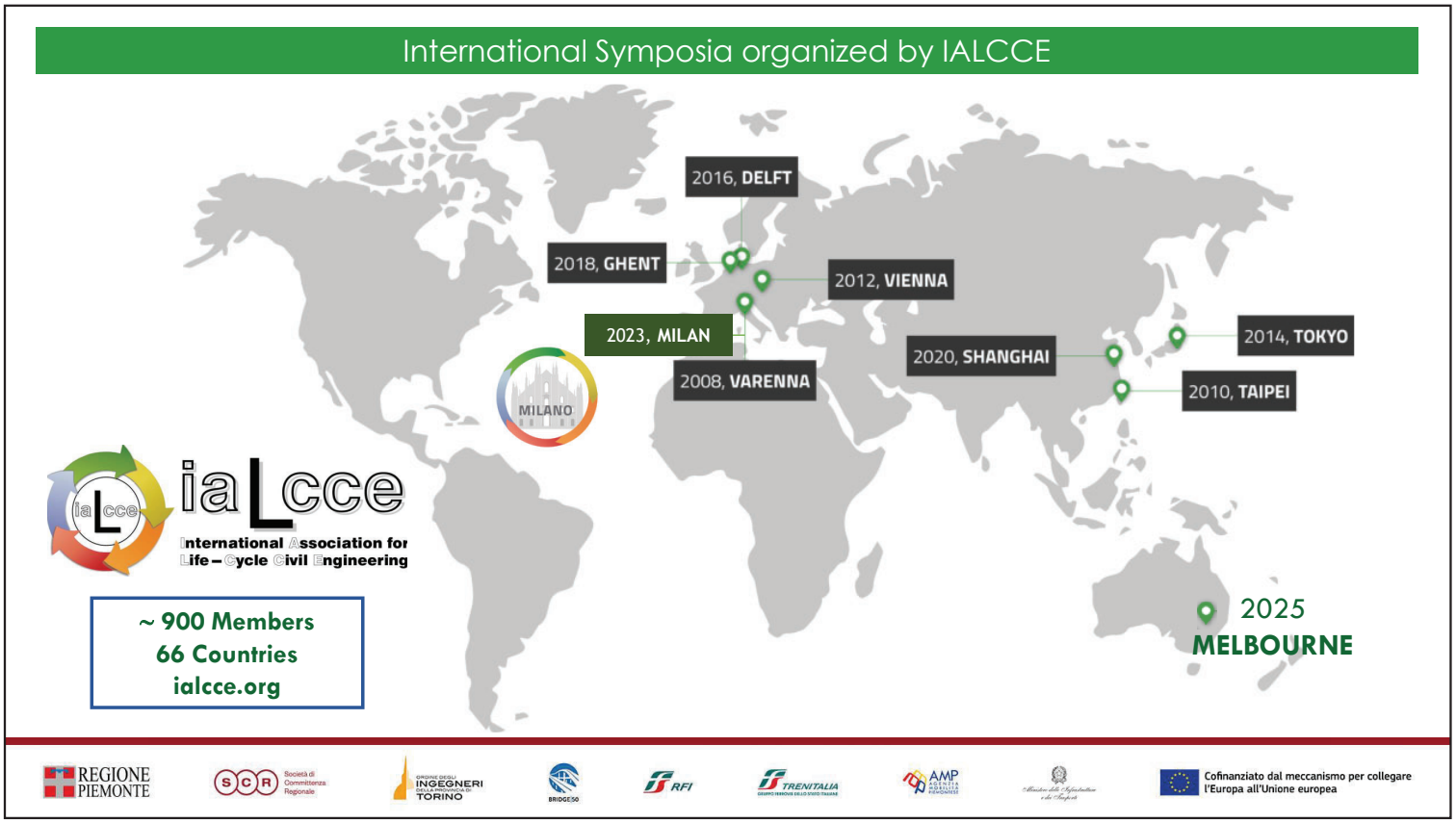

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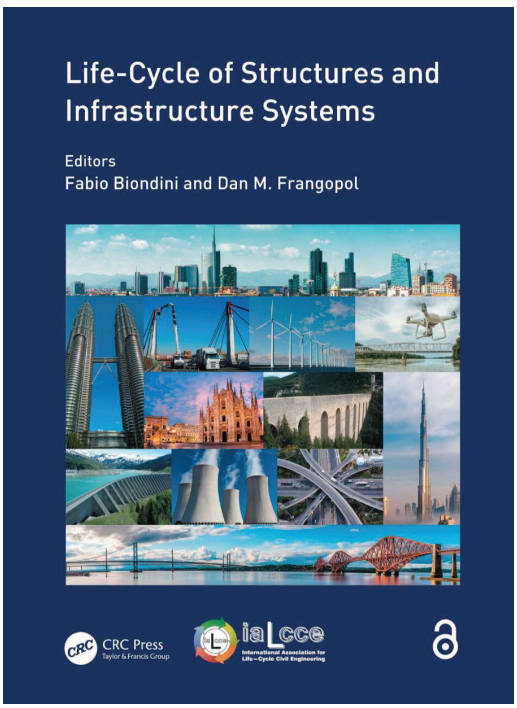

https://ialcce2023.org

Open Access

Biondini, F., Frangopol, D.M., (Eds.), 2023. *Life-Cycle of Structures and Infrastructure Systems*. CRC Press, Taylor & Francis Group, London, UK, 514 papers, 4240 pages, ISBN 9781003323020.

https://www.taylorfrancis.com/books/oa-edit/10.1201/9781003323020/life-cycle-structures-infrastructure-systems-fabio-biondini-dan-frangopol

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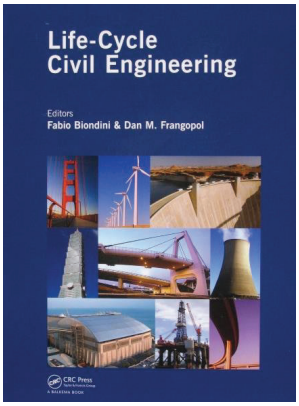

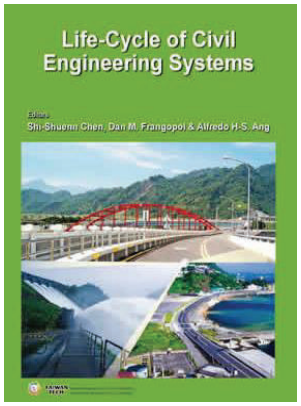

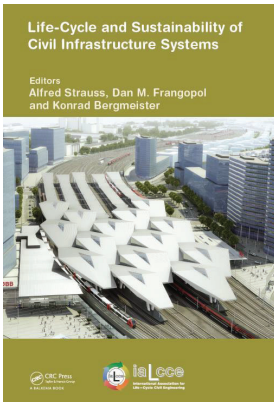

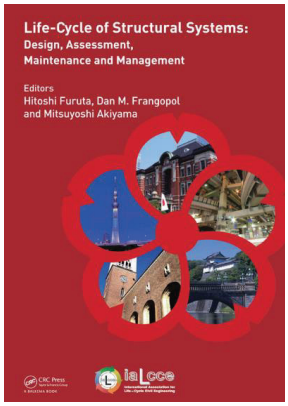

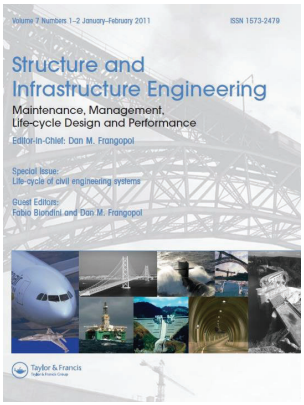

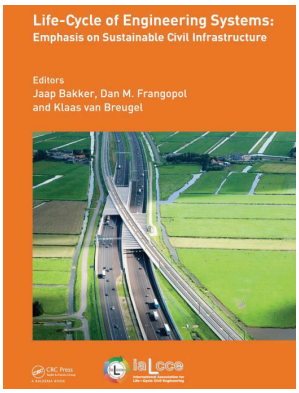

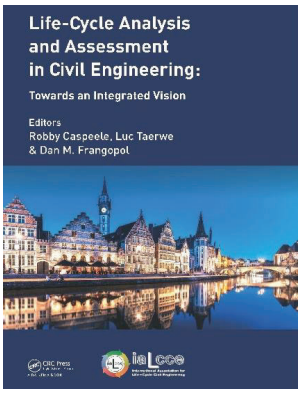

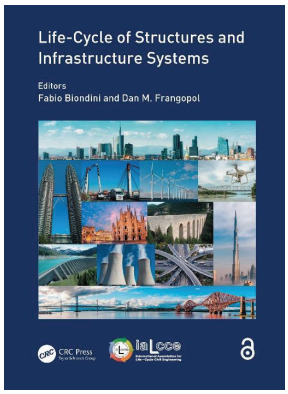

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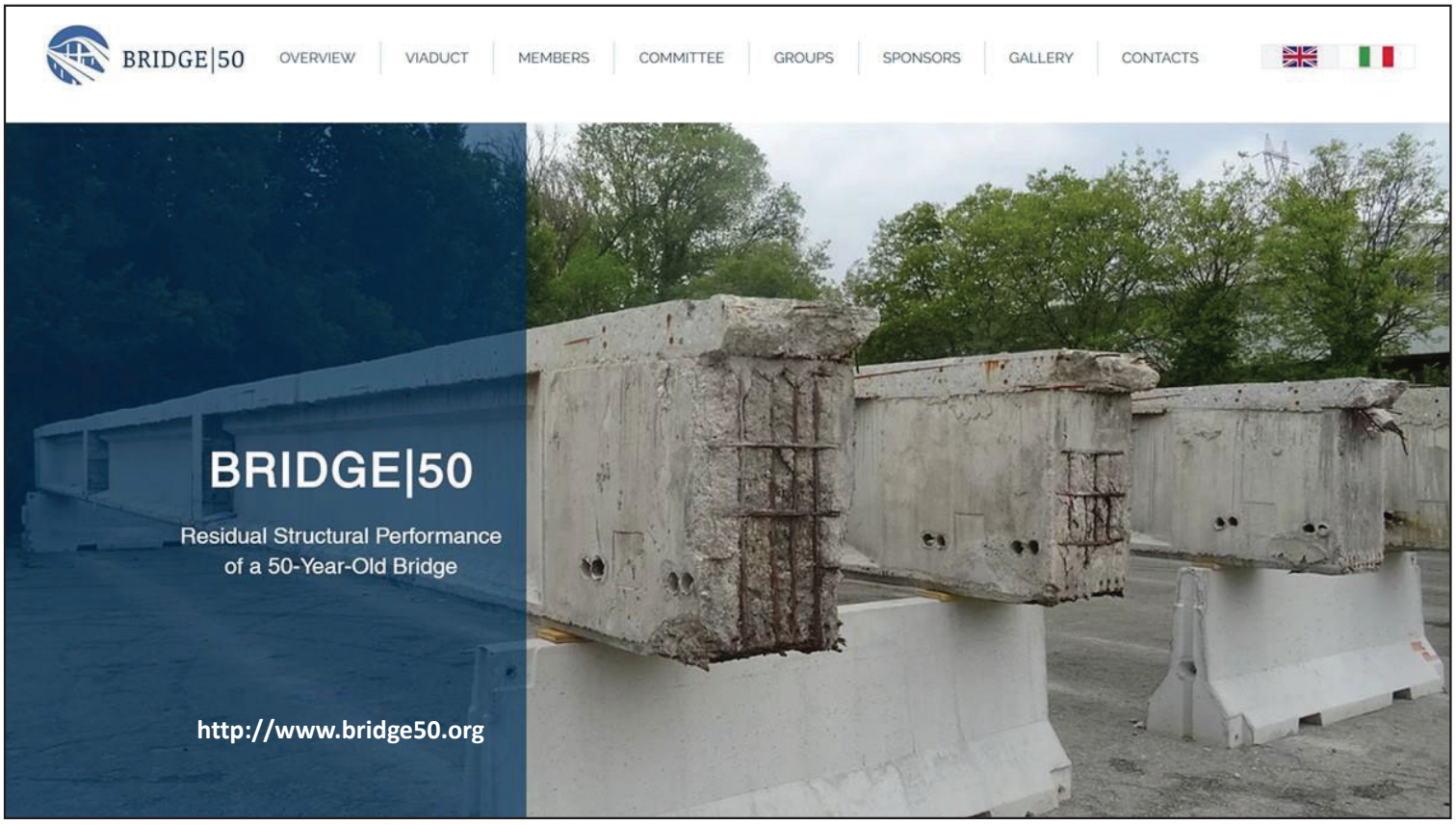

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