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Structural Monitoring Of Viaducts of Milano Serravalle network

An application of modern AI-based technologies to create a digital twin to evaluate the safety level of structure under traffic

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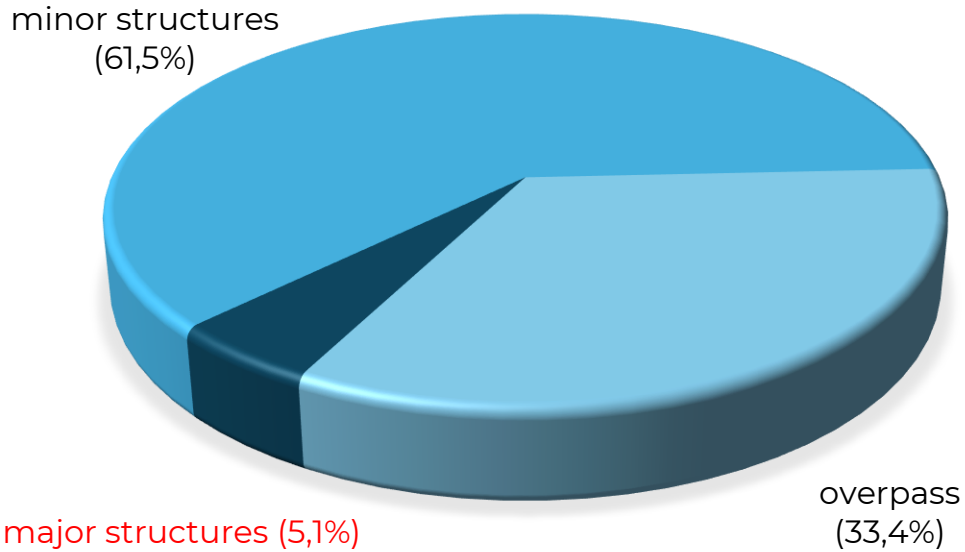
MSMT STRUCTURES CLASSIFICATION



TARGET OF MONITORING SYSTEM

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- Along the network managed by Milano Serravalle over 400 structures are included in the surveillance program based on periodic visual inspections and local non-destructive tests.
- More recently Serravalle has designed and realized a structural health monitoring system that allow to verify, from remote and almost in real time, the safety level of the main viaducts present in the network.
- The system has been co-financed through the PNRR (Recovery and Resilience Facility)
- The system is still in the testing phase (learning curve) and it's expected to be completed by the end of 2024.

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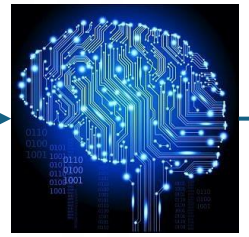
Monitored structures

	STRUCTURE	LENGH [m]	# SPANS
1	viadotto dei parchi - Nord (A51)	2.920,19	121
2	viadotto dei parchi - Sud (A51)	3.064,19	126
3	Forlanini Nord (A51)	371,00	8
4	Forlanini Sud (A51)	376,00	8
5	ghisolfa M1 (A50)	72,00	3
6	ghisolfa M2 (A50)	101,00	3
7	ghisolfa M3 (A50)	123,00	4
8	ghisolfa M4 (A50)	56,00	2
9	ghisolfa M5 (A50)	123,00	4
10	ghisolfa M6 (A50)	126,00	4
11	piazza Maggi - La Spezia (A7)	131,02	4
12	piazza Maggi - Schiavoni (A7)	124,30	4
13	Scrivia (A7)	282,00	11
14	Tortona (A7)	217,79	8
15	Po sud (A7)	831,84	12
16	Po nord (A7)	762,41	11
17	Ticino (A7)	251,70	6
18	sovrappasso SS35 (A52)	300,00	5
	TOTAL	10.233,44	344

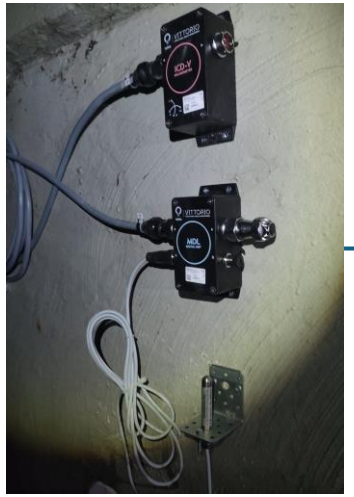
SYSTEM ARCHITECTURE

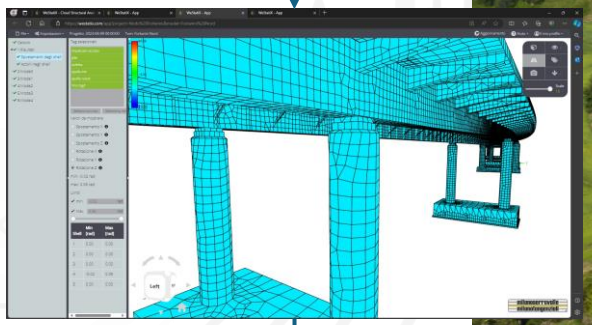
Artificial Intelligence

Data transfert to cloud



Sensors





Digital Twin (continuously update & simulation)

Monitoring Dashboard

Digital Twin (continuously update & simulation)

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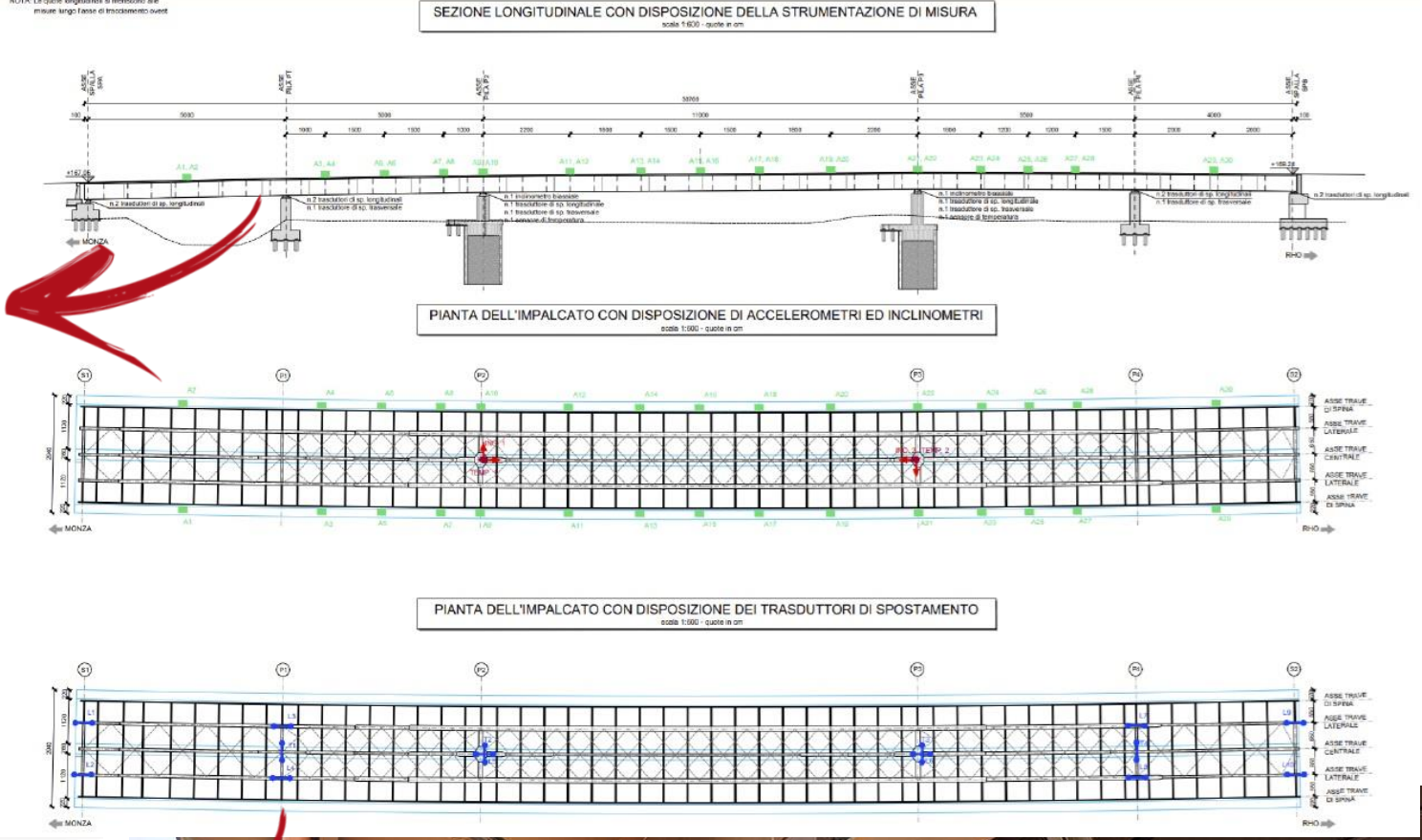
SENSORS NETWORK

TRI-AXIAL
ACCELEROMETERS
(sampling rate = 125 Hz)



BI-AXIAL INCLINOMETERS
(sampling rate = 1 Hz)

SINGLE-DIRECTIONAL DISPLACEMENT TRANSDUCERS
(SR= 1 Hz)

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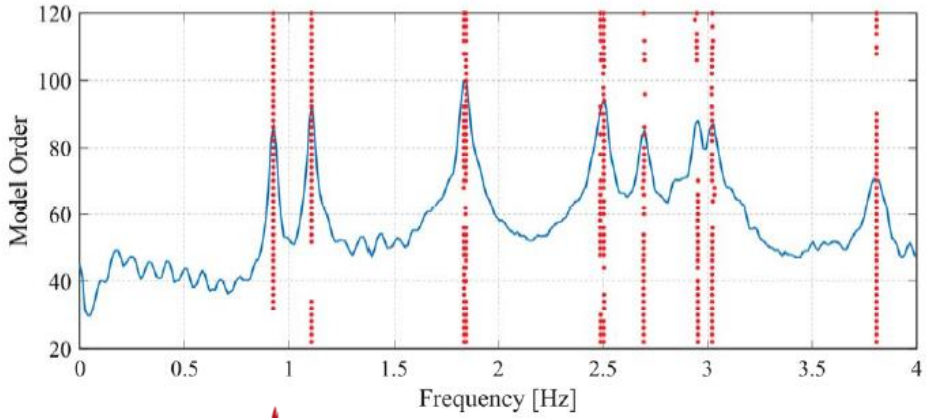
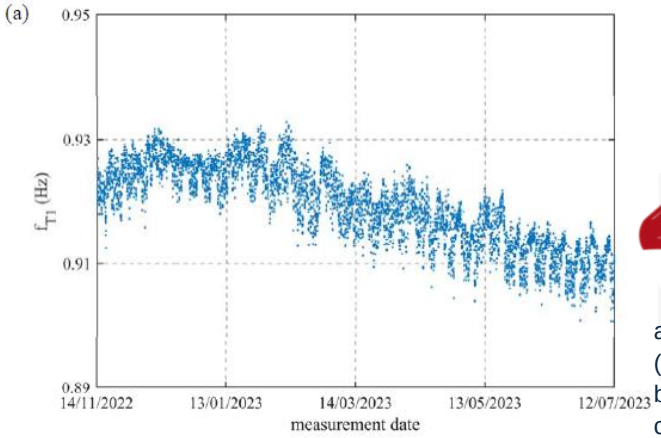
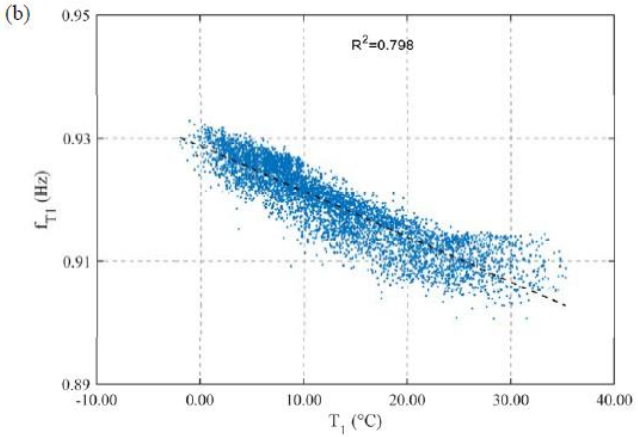
POST PROCESSING

Covariance-driven Stochastic Subspace Identification (SSI-COV)

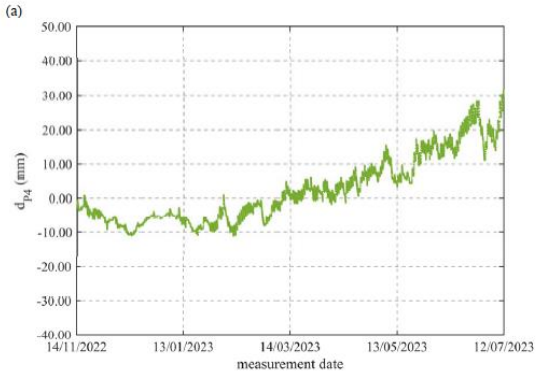






a) Temporal evolution of first (torsional) proper frequency; b) frequency-temperature correlation in the period from 11/14/22 to 07/12/23

a) Temporal evolution of longitudinal displacement over pier n. 4; b) long. disp-temperature correlation in the period from 11/14/22 to 07/12/23



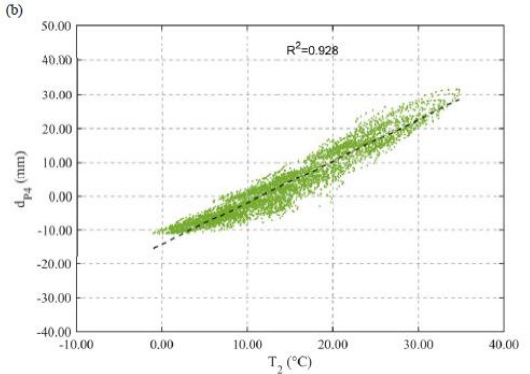
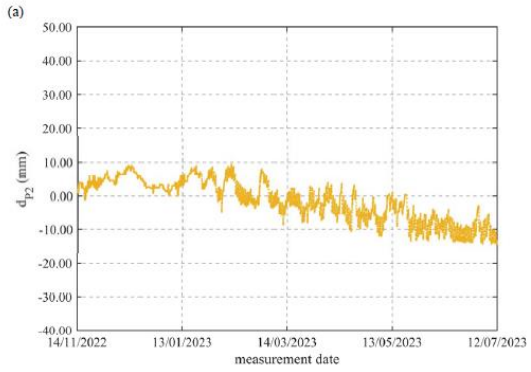


Fig. 6.6 Evoluzione temporale dello spostamento longitudinale medio in corrispondenza del vincolo dell'impalcato su pila P4 nel periodo 14 novembre 2022 – 12 luglio 2023.

a) Temporal evolution of longitudinal displacement over pier n. 2; b) long. disp-temperature correlation in the period from 11/14/22 to 07/12/23



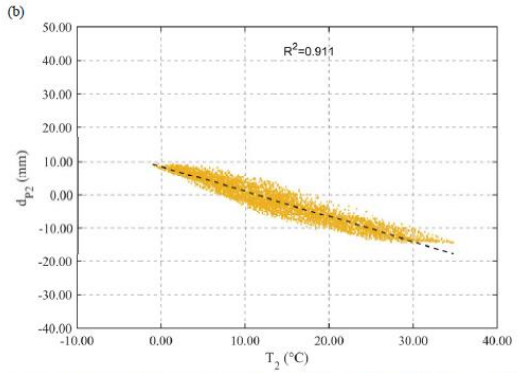
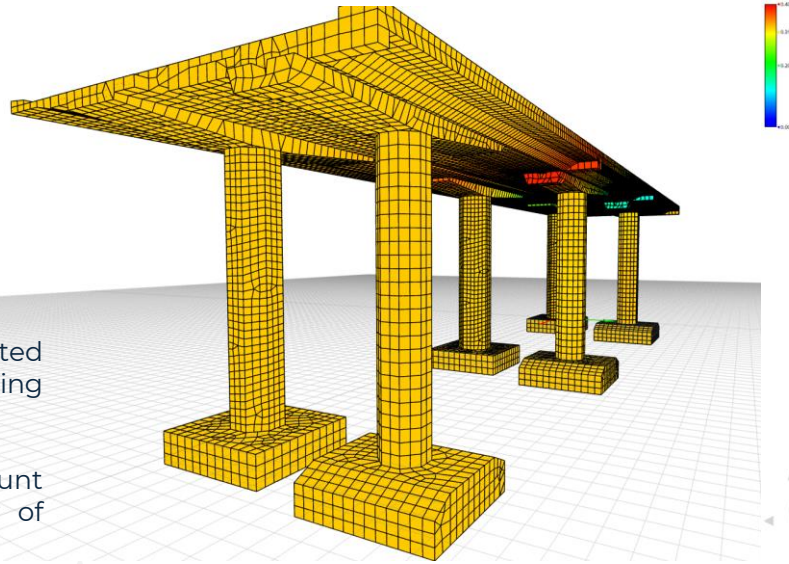
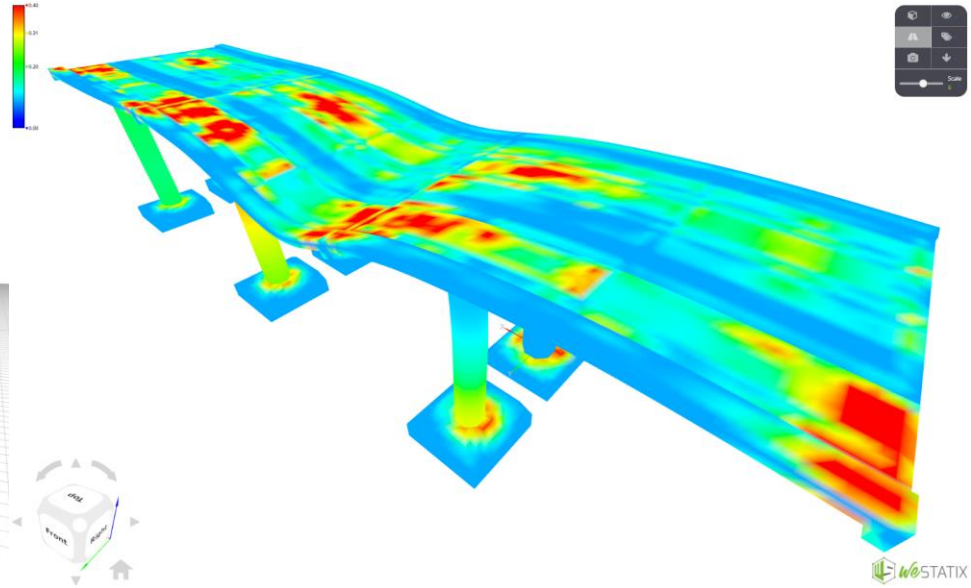


Fig. 6.4 Evoluzione temporale dello spostamento longitudinale medio in corrispondenza del vincolo dell'impalcato su pila P2 nel periodo 14 novembre 2022 – 12 luglio 2023.

ALGORITM





The FEMs have been developed with an elevated geometrical precision, including rebars and prestressing cables.

The present level of stress is evaluated keeping into account the construction phases and the rehological property of concrete (shinkring and creep).

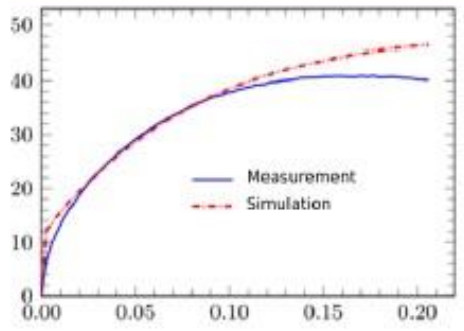
The datas collected by the monitoring system are used by an AI algoritm to adjust, through reverse engineering processes, a group of parameter, such as:

- Elastic Module of materials
- Rehological characteristics
- Level of prestressing
- Behaviour of bearings
- Soil-structure interaction

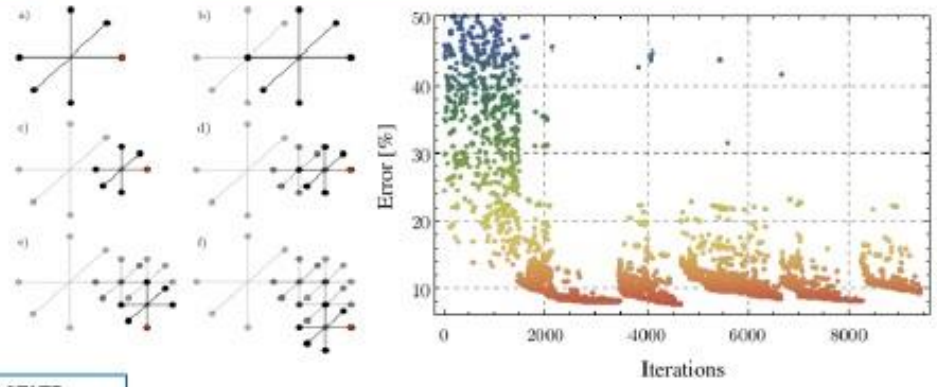
After a great number of iterations the model arrives to be a digital twin of real structure that can be used to predict the structural performances of the structure

The software used to create the FE Model and the Digital Twin is «WeStatiX SHM», developed by CAEMATE.

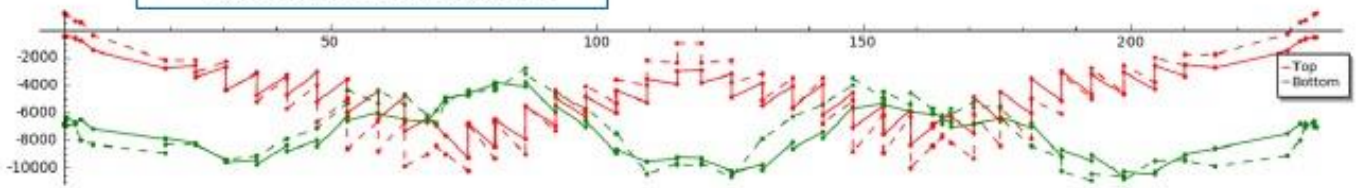
COMPARISON MEASUREMENT/CALCULATION



CALIBRATION THROUGH INVERSE ANALYSIS



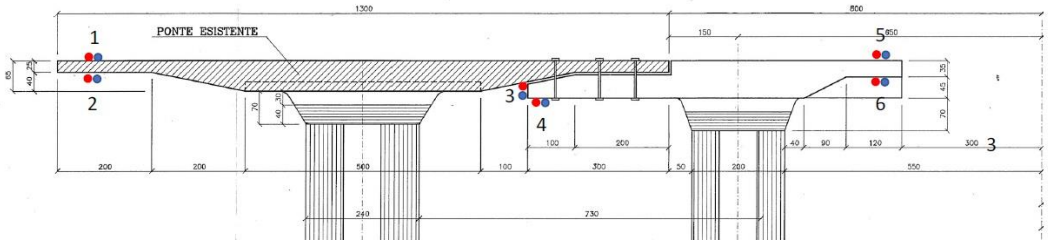
PREDICTION OF STRUCTURE STATE



«PARCHI» VIADUCT MONITORING

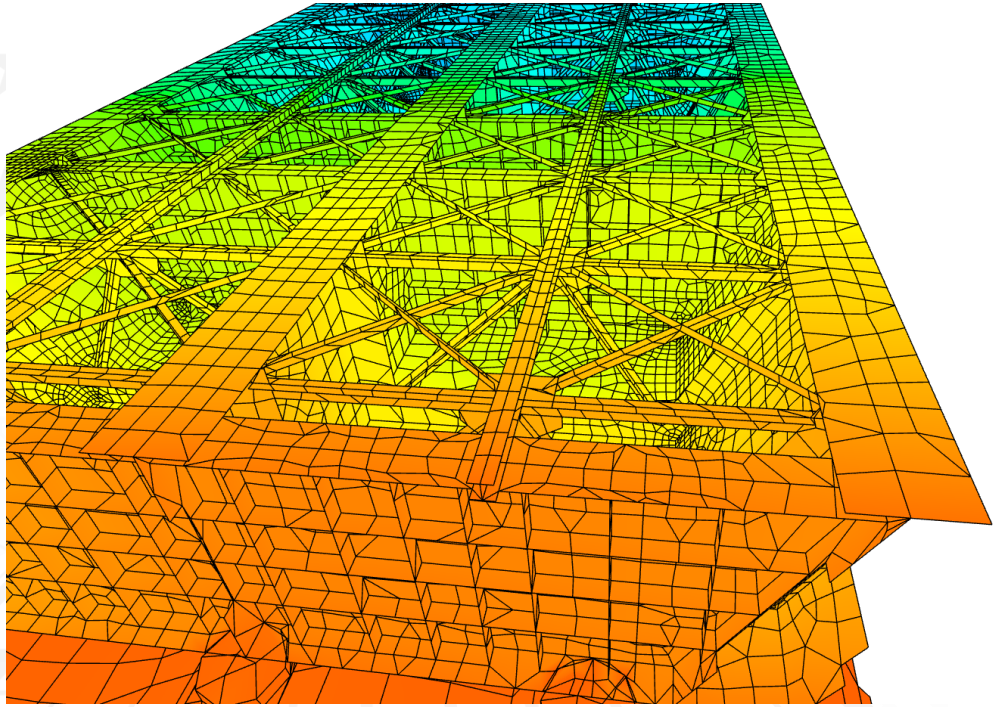
The «viadotto dei Parchi» was realized in 1960 along the A51 highway with presteressed concrete structure. The number of spans is 121 for the carriageway in direction Venice and 124 in the opposite direction.
The high number of spans led to the choice to use, instead of discrete sensors such as accelerometers and inclinometers, a system of distributed optical fiber sensors (DOFs).

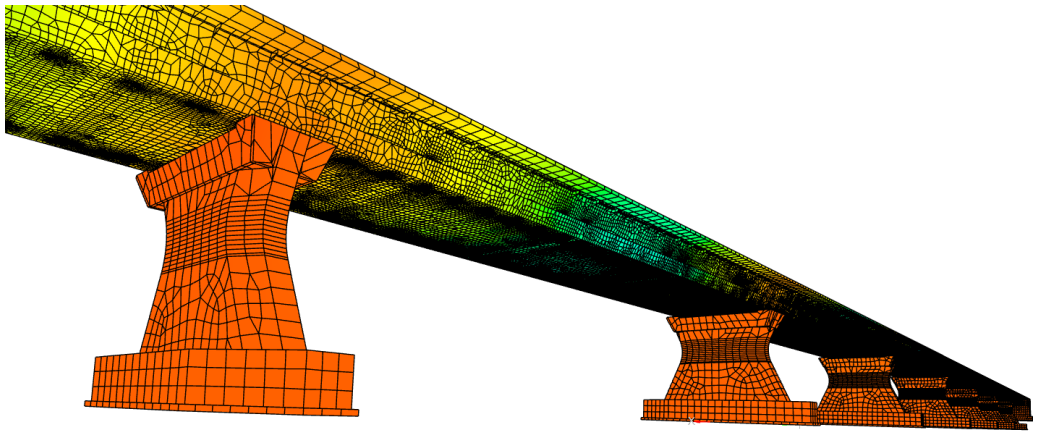
The measurement principle is based on a coherent detection of the non-linear Brillouin phenomenon which returns an absolute measurement of the fiber deformation with resolution of a few micro-epsilons in deformation, and spatial resolution which can be varied from a few meters up to a few centimeters (in function of the query time). The measurement is automatically temperature compensated, a parameter that can also be read using the interrogator itself.



The DOFs are therefore able to measure the variations in length of the individual spans and their rate with great precision. By arranging the fibers both on the intrados and extrados and extrados of the deck it is possible to determine the curvatures and, by integration, the rotations and lowerings of the structure. From the measure of strain rate it's possibile to apply the OMA to obtain the modal parameters

Model of the Bridge over the river Po (highway A7)





The structure is a steel box girder with a reinforced concrete slab, prestressed over the piers. The total lenght is 831 m and the viaduct presents 12 spans.

The simulation model is built with solid, shell, and bar finite elements defining the prestressing tendons. The nonlinear calculation is temperature- and time-dependent, taking into account the entire load history of the structure.

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Model of the Forlanini viaduct

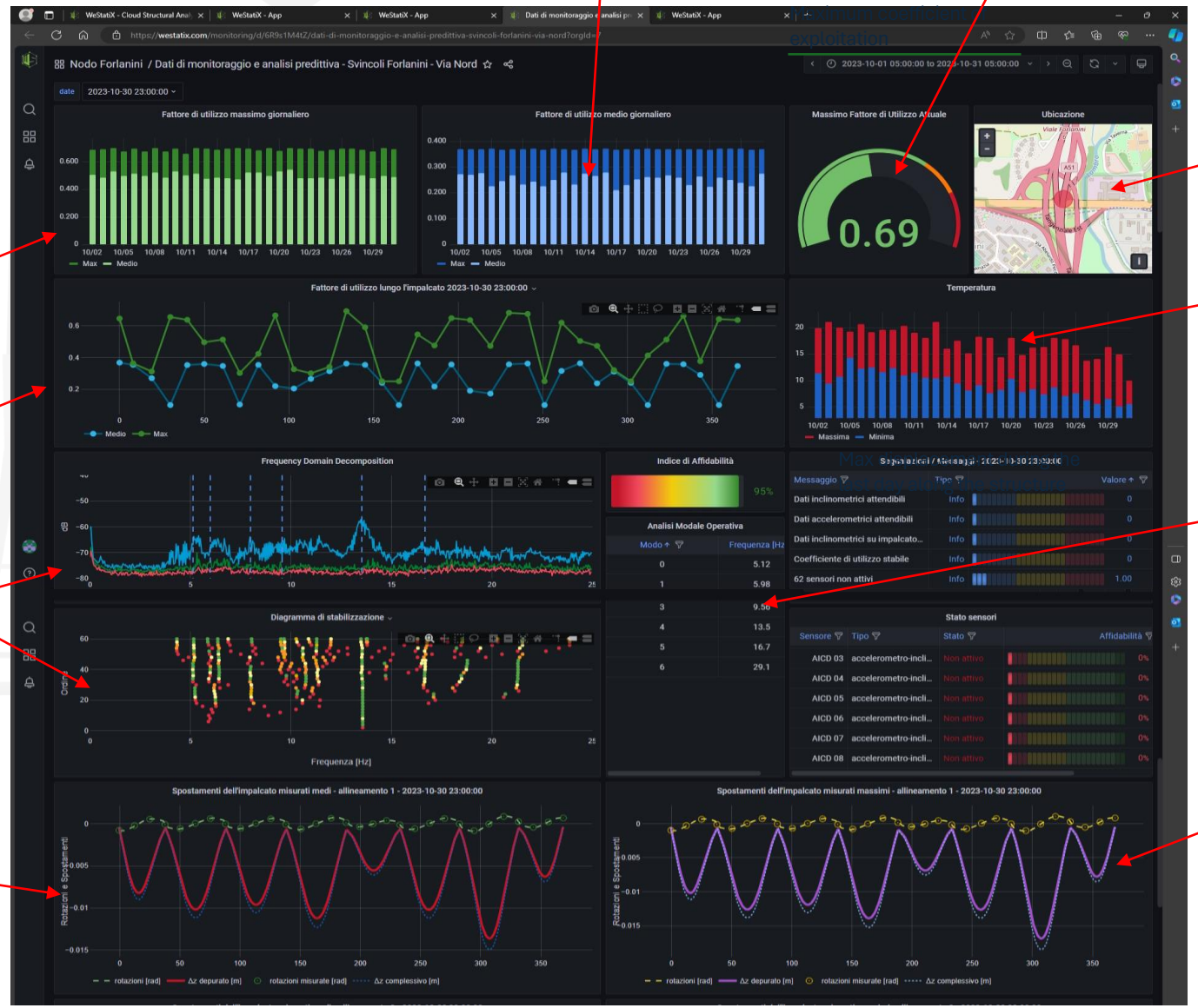
The Forlanini Viaduct is a structure located at the Forlanini interchange on the Milan East Ring Road (A51), built in 2008. The static scheme is a continuous beam with 8 spans with around 50 meters length, made of a mixed steel-concrete structure with two main beams and solid crossbeams.

The thermomechanical finite element model includes shell and three-dimensional solid elements able to simulate reliably long-term and transitory effects. The interaction between the steel substructure and the concrete slab is modeled in detail through appropriate one-dimensional connection elements.

The Dashboard

Maximum coefficient of exploitation at present

Daily average coefficient of exploitation



Localization of structure

Daily max coefficient of exploitation

Daily max and min temperature

Coefficient of exploitation along the structure

Values of proper frequencies (from OMA)

Frequency domain decomposition

Maximum displacement during the last day along the structure

Average displacement during the last day along the structure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THANK YOU

GRAZIE

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