Italian Physical Society

SEZIONE IV

GEOFISICA E FISICA DELL'AMBIENTE

107° CONGRESSO NAZIONALE della SOCIETÀ ITALIANA DI FISICA

An integrated geophysical approach for structural behavior characterization of the Gravina Bridge (Matera, Southern Italy)

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Critical Infrastructures: systems whose destruction or temporal unavailability strongly weaken the normal efficiency of a country

In Italy only the 3% of infrastructures are currently monitored in spite of the seismic context and of the high vulnerability of roads and highways

Morandi Bridge, Genova (Italy), 14th August 2018

43 victims and more than 500 homeless

DEMAND OF AN INFRASTRUCTURE MONITORING SYSTEM FOR PREVENTING ACCIDENTS AND INTERRUPTION OF CONTINUITY

Monitoring: knowledge of infrastructure properties, characterization of their initial state and time evolution.

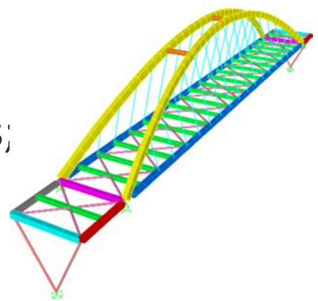
Preliminary fact-finding surveys

In presence of design documentation

Diffuse fact-finding surveys

Without design documentation

- To verify the adherence between the actual state of the structure and the project documents;
- To reduce the modelling uncertainties, thus obtaining more accurate and updated numerical models;
- To have a picture depicting the conditions of the infrastructure in a certain moment of its life.



PROACTIVE MAINTENANCE

VISUAL INSPECTION

OBJECTIVE, MEASUREMENT-BASED APPROACH: NON-DESTRUCTIVE SENSING TECHNOLOGIES

In-situ *vs* Remote Technologies

LOCAL MONITORING

Looking for more localized defects:

- ***Cracks*** *(fiber optics, electrical methods)*
- ***Delaminations*** *(Ultrasonic emissions, Lamb waves, Infrared termography and spectroscopy)*
- ***Hydration conditions*** *(Nuclear magnetic resonance)*
- ***Void spaces*** *(Ultrasonic emissions, Lamb waves, Radar)*
- ***Corrosion*** *(Fiber Optics, Magnetic methods, Electro-optical Imagery)*
- ***Deformations*** *(Laser Scanning, Radar, Speckle interferometry)*
- ***Bridge scour*** *(Electrical reflectometry, Ground Penetrating Radar)*

GLOBAL MONITORING

Structural characterization and time evolution of the infrastructure properties:

- ***Eigenfrequencies*** *(Accelerometers, Velocimeters, Fiber optics, Radar)*
- ***Equivalent viscous damping factors*** *(Accelerometers, Velocimeters, Fiber optics, Radar)*
- ***Mode shapes*** *(Accelerometers, Velocimeters, Fiber optics, Radar)*

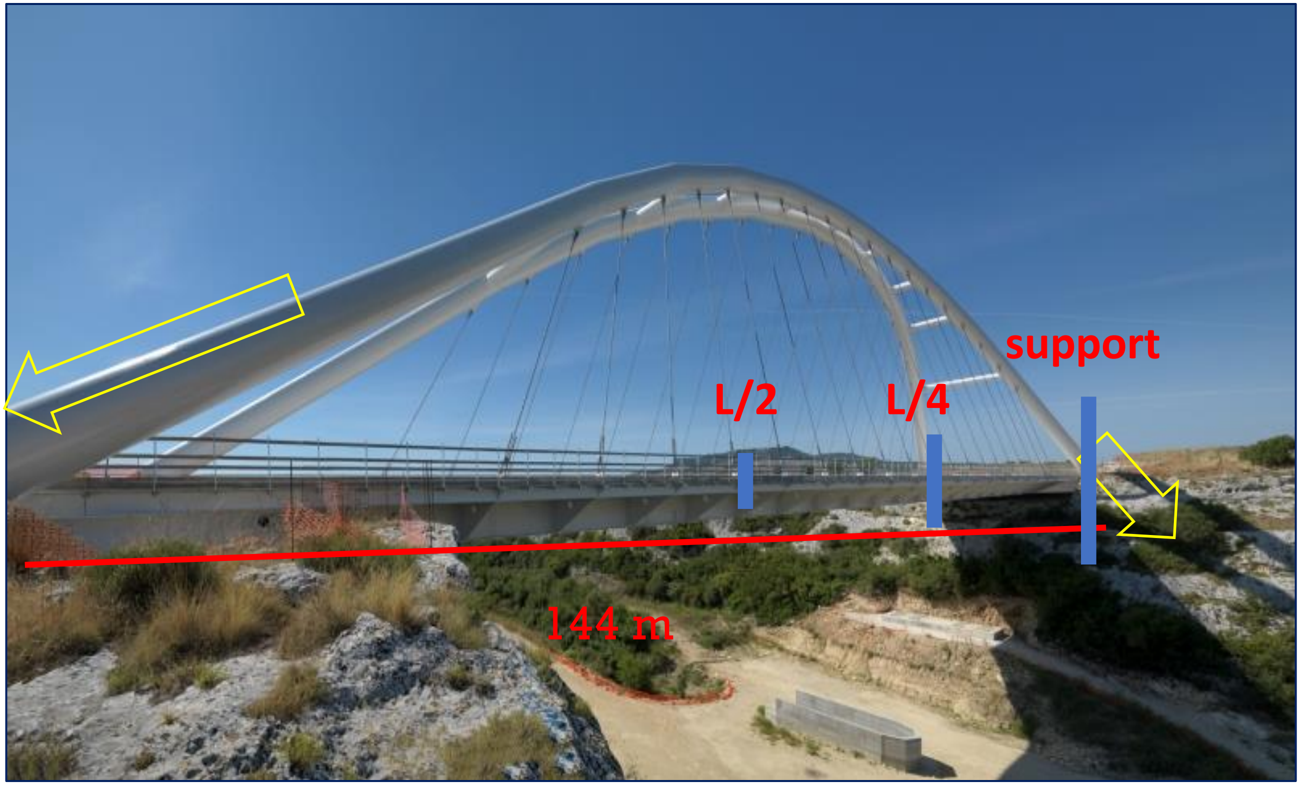
- To develop a tool for the multi-scale and multi-depth level structural health monitoring of critical infrastructures and for the characterization of foundation soil.
  Low-cost, expeditive, non-invasive and non-destructive remote and in-situ technologies on independent geophysical data (seismic and electromagnetic) will be adopted;

- To validate the approach on a real infrastructure (Gravina Bridge, Matera, Southern Italy);

- To set-up the zero-time reference point of structural properties of the bridge (eigenfrequencies, equivalent viscous damping factors and mode shapes) and to investigate its possible interaction with its base isolation system and foundation soils;

- Structural parameter variation as damage proxies.

GRAVINA BRIDGE



Bow – string bridge

Steel-concrete deck
8 elastomeric isolators

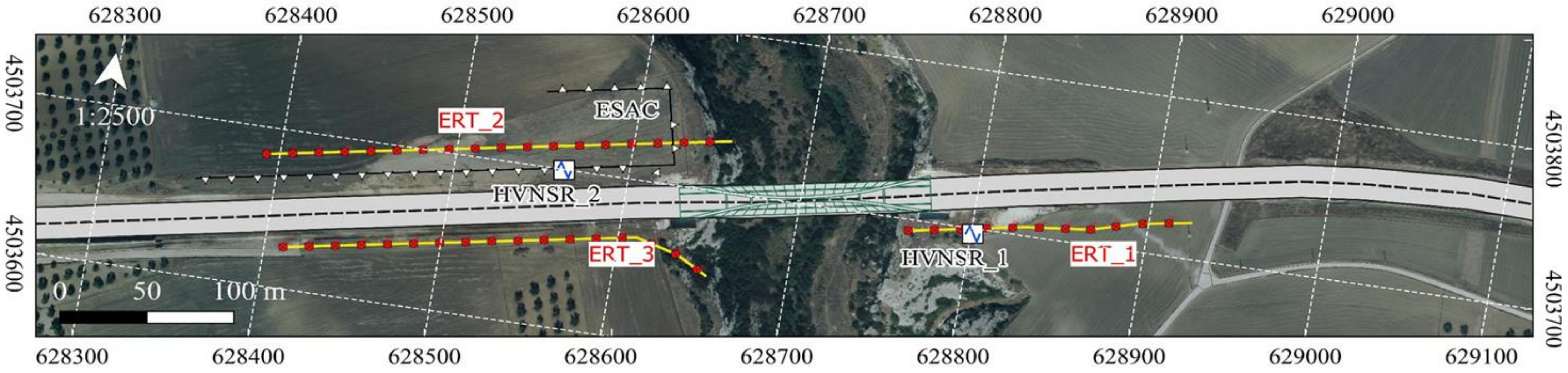
FOUNDATION SOILS

Adopted methodologies

- **One** 2D seismic array **(ESAC)**
- **Two** single station ambient seismic noise measurements **(HVSR)**
- **Three** electrical resistivity tomographies **(ERT)**

Output

- Litostratigraphic characterization
- Soil fundamental frequencies
- Geomechanical and geoeletrical characterization of the soil



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INFRASTRUCTURE

Monitoring type and adopted methodologies

REAL TIME (27/06/2019 – 31/03/2020)

- **Four accelerometers** (seismic data – 19 earthquakes)

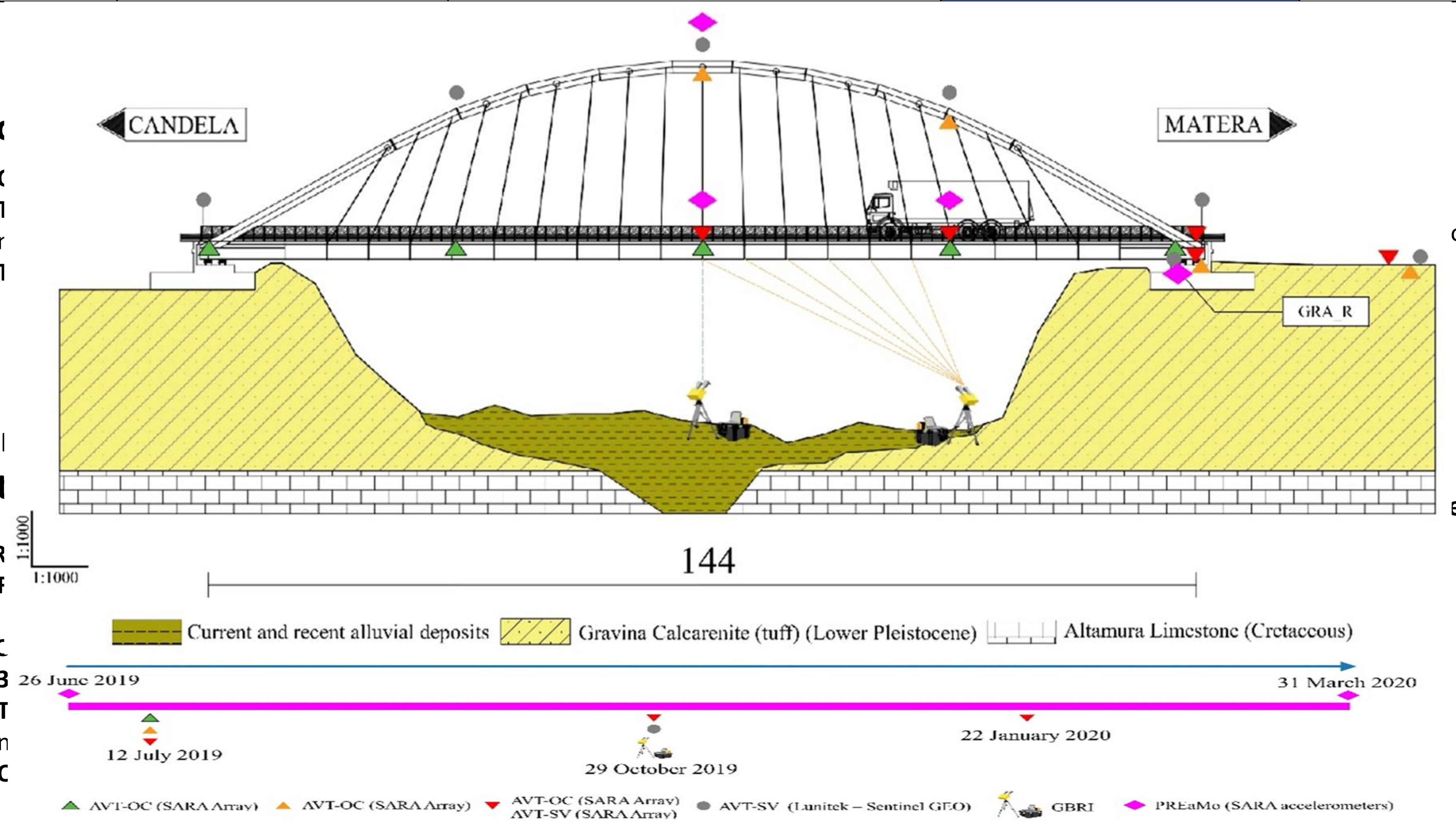
ON-DEMAND
(3 surveys; 12/07/2019; 29/10/2019; 22/01/2020)

- **Twelve** 4.5 Hz **velocimeters** (seismic data – ambient seismic noise in ordinary conditions and during dynamic tests)
- **One Radar Interferometer** (electromagnetic data)

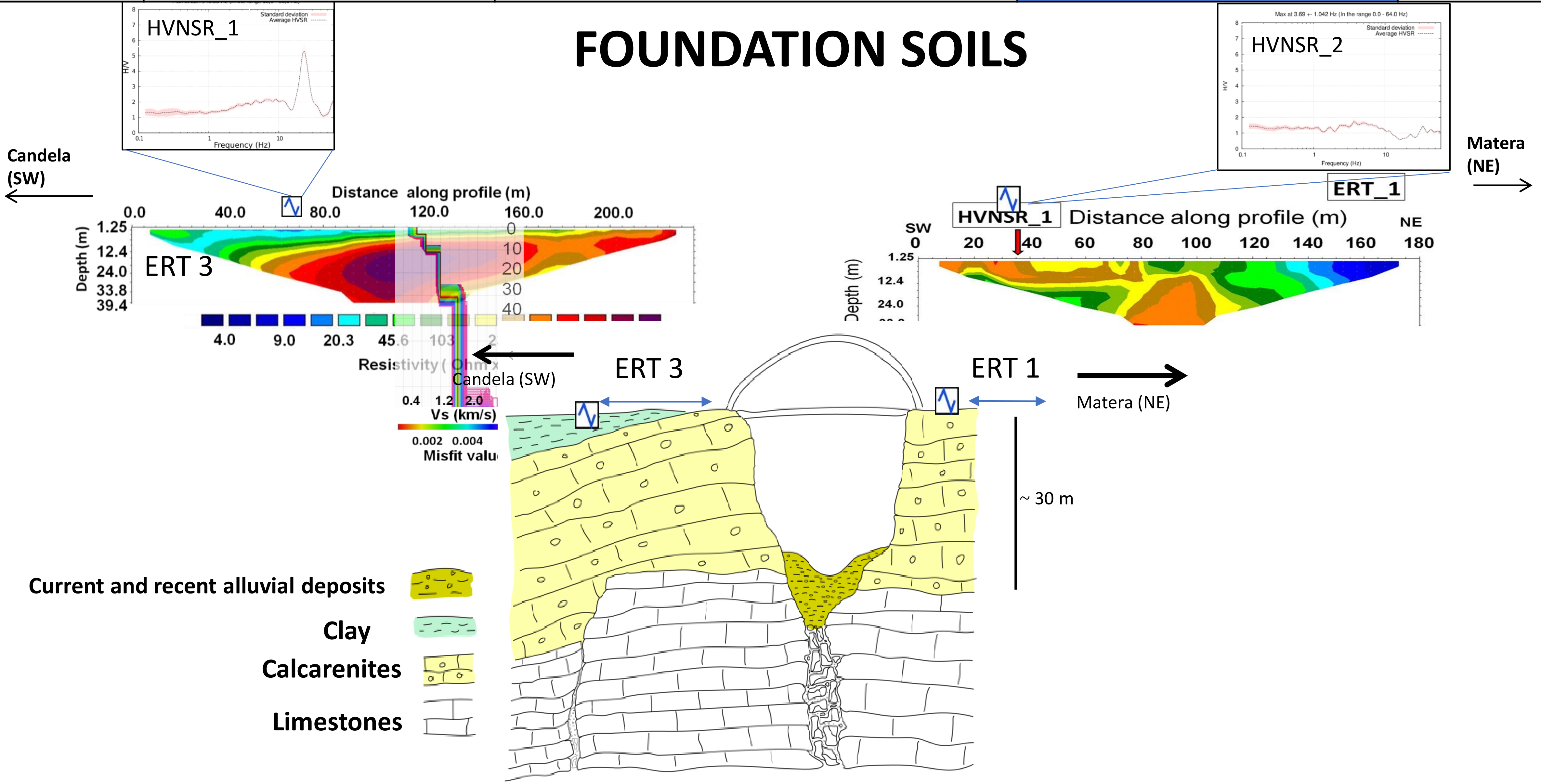
Output

Structural parameters and related time evolution

- Eigenfrequencies
- Equivalent viscous damping factors
- Mode Shapes

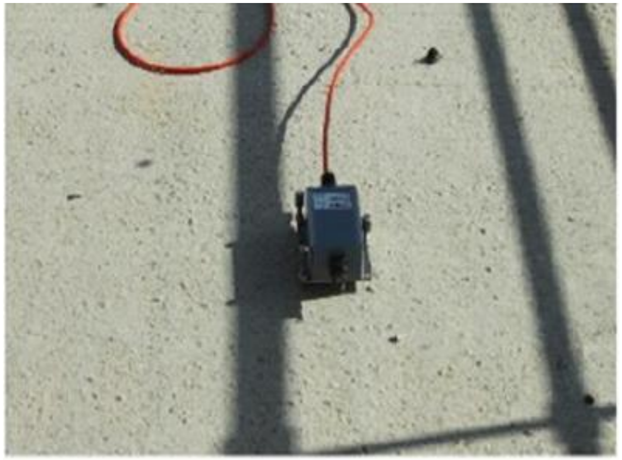

CANDELA
MATERA
GRA_R
1:1000
1:1000
144
Current and recent alluvial deposits
Gravina Calcarenite (tuff) (Lower Pleistocene)
Altamura Limestone (Cretaceous)
26 June 2019
31 March 2020
12 July 2019
29 October 2019
22 January 2020
AVT-OC (SARA Array)
AVT-OC (SARA Array)
AVT-OC (SARA Array)
AVT-SV (SARA Array)
AVT-SV (Lunitek – Sentinel GEO)
GBRI
PREaMo (SARA accelerometers)

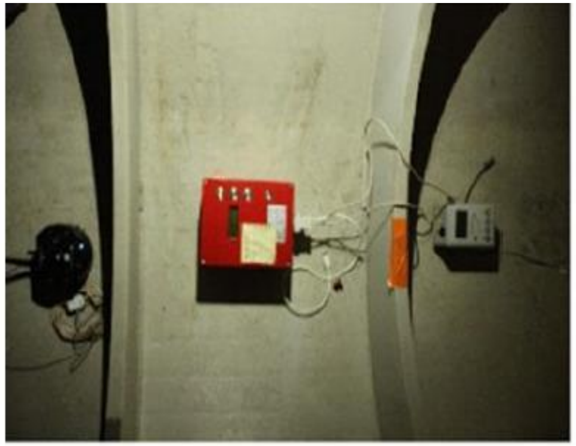
FOUNDATION SOILS



Courtesy of Dr. Cristallo

INFRASTRUCTURE – DATA ACQUISITION





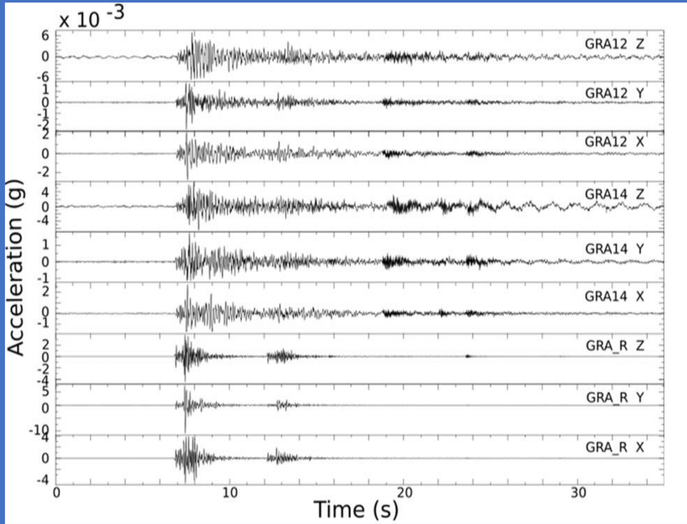
ACQUIRED DATA

- Local and regional earthquakes (19 earthquakes)
- Ambient seismic noise in ordinary conditions
- Ambient seismic noise with tracks used as vibration sources (dynamic tests)
- Electromagnetic data

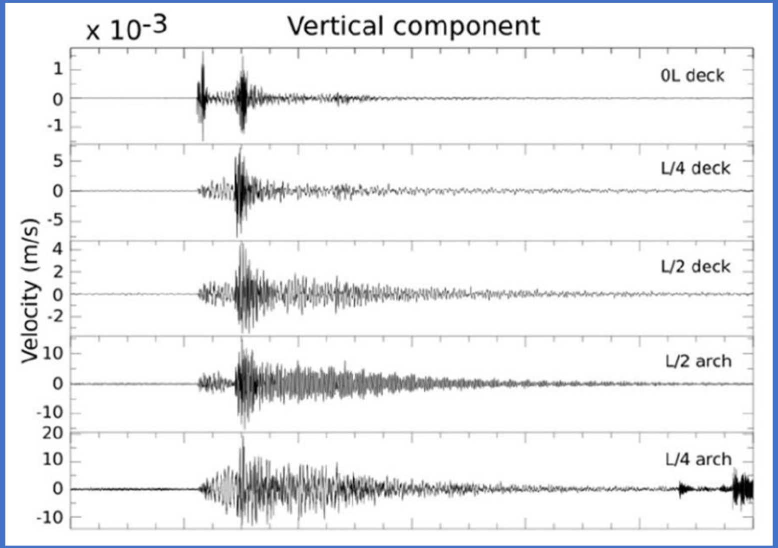
INFRASTRUCTURE CHARACTERIZATION – ACQUIRED DATA

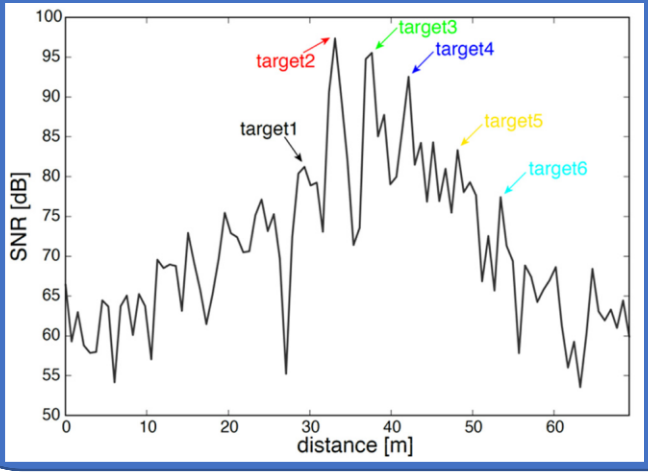
SEISMIC DATA

Earthquake recording



Ambient seismic noise recording during a dynamic test





ELECTROMAGNETIC SIGNAL

Echoes, from six different points of the bridge, of the electromagnetic signal sent by the Radar.

INFRASTRUCTURE CHARACTERIZATION – ANALYSIS METHODOLOGIES

SEISMIC TECHNIQUES

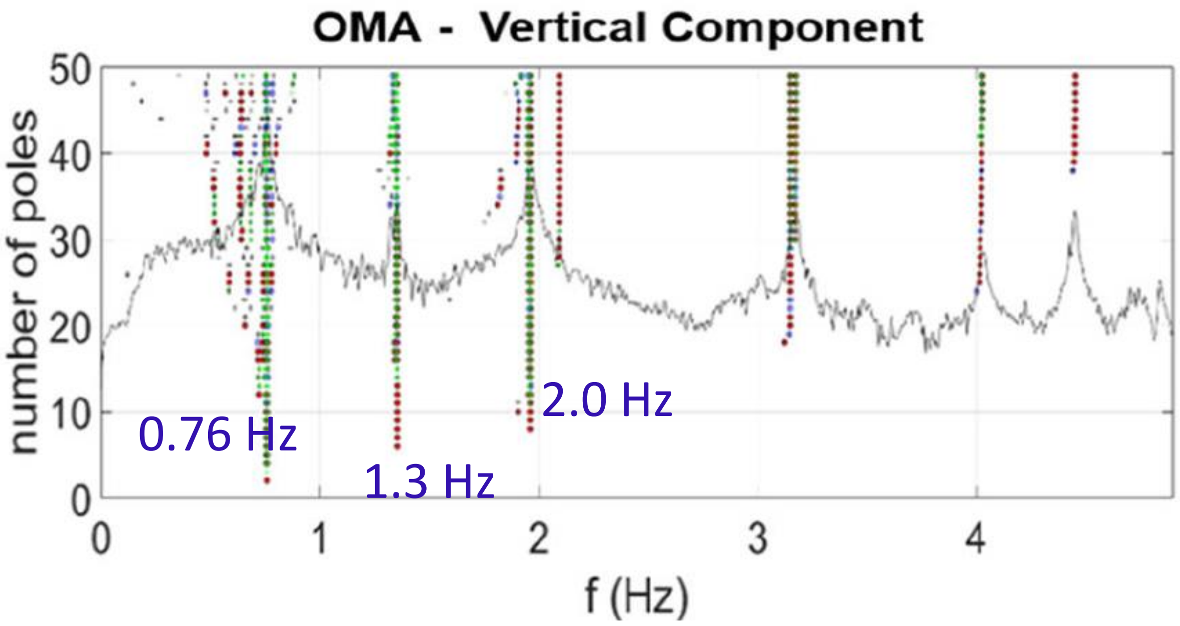
- **Operational Modal Analysis (OMA)**
  (Shipfors and Fabbrocino, 2014)
- **Standard Spectral Ratio (SSR)**
  (Borcherdt, 1970; Parolai et al., 2005; Gallipoli et al., 2009)
- **Damping analysis – Impulse Response function**
  (Clough and Penzien, 1993)
- **S-transform**
  (Stockwell et al., 1996)

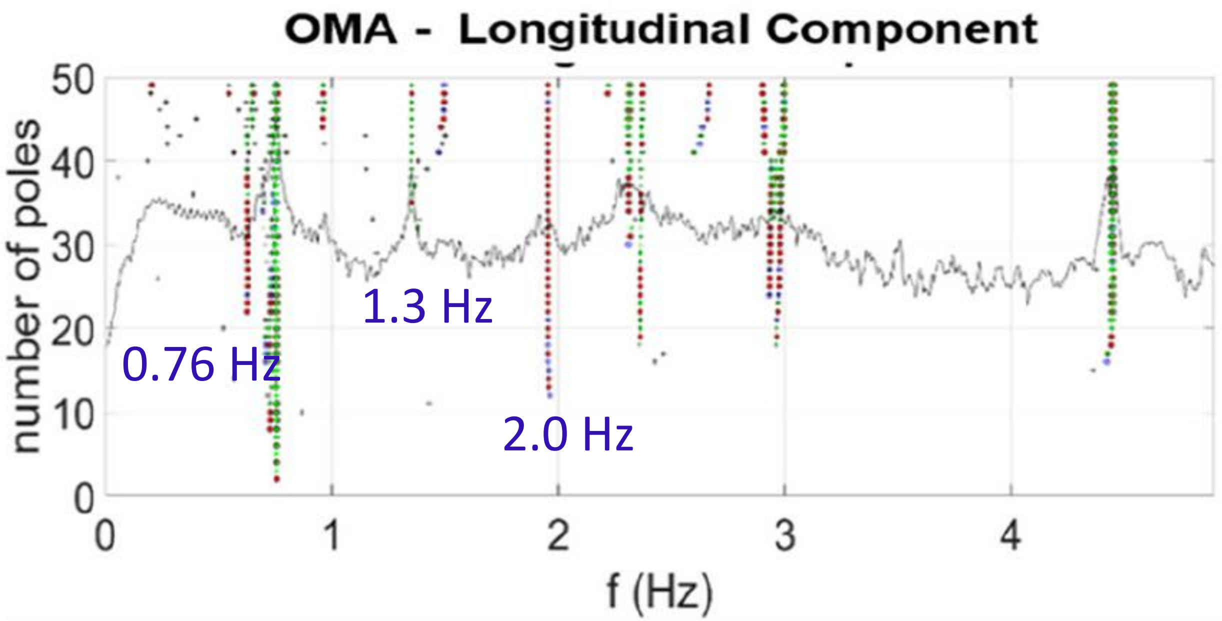
ELECTROMAGNETIC TECHNIQUES

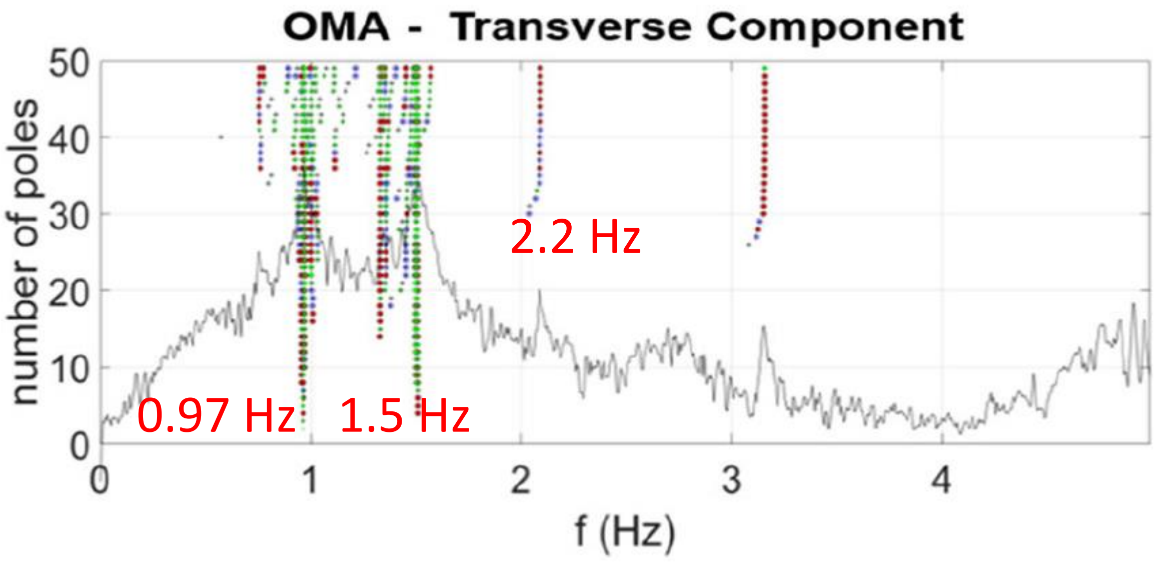
- **Microwave Radar Interferometry**

MULTI-SCALE EVALUATION OF THE DYNAMIC BEHAVIOR OF THE BRIDGE, PROVIDING BOTH A GENERAL OVERVIEW AND A MORE DETAILED STUDY OF PROPERTIES OF THE INFRASTRUCTURE

OPERATIONAL MODAL ANALYSIS



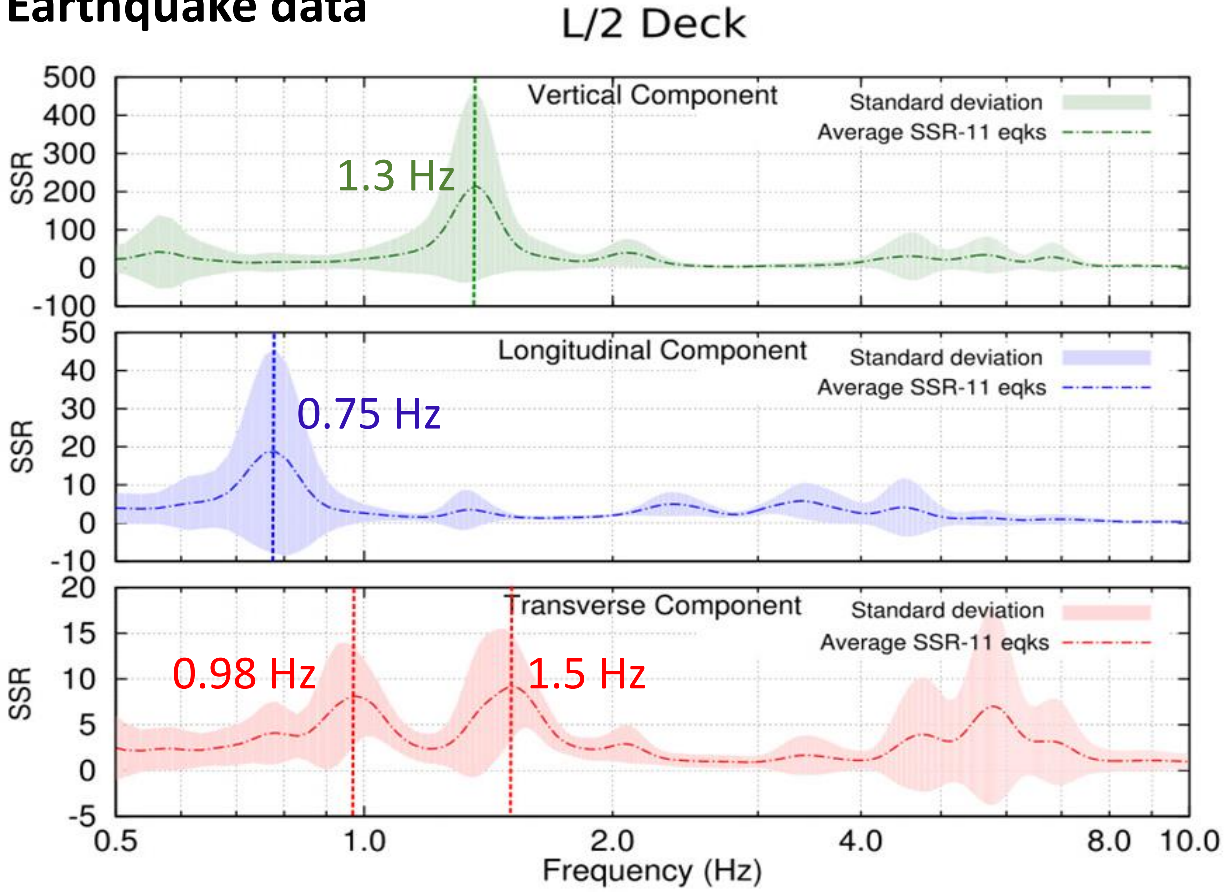




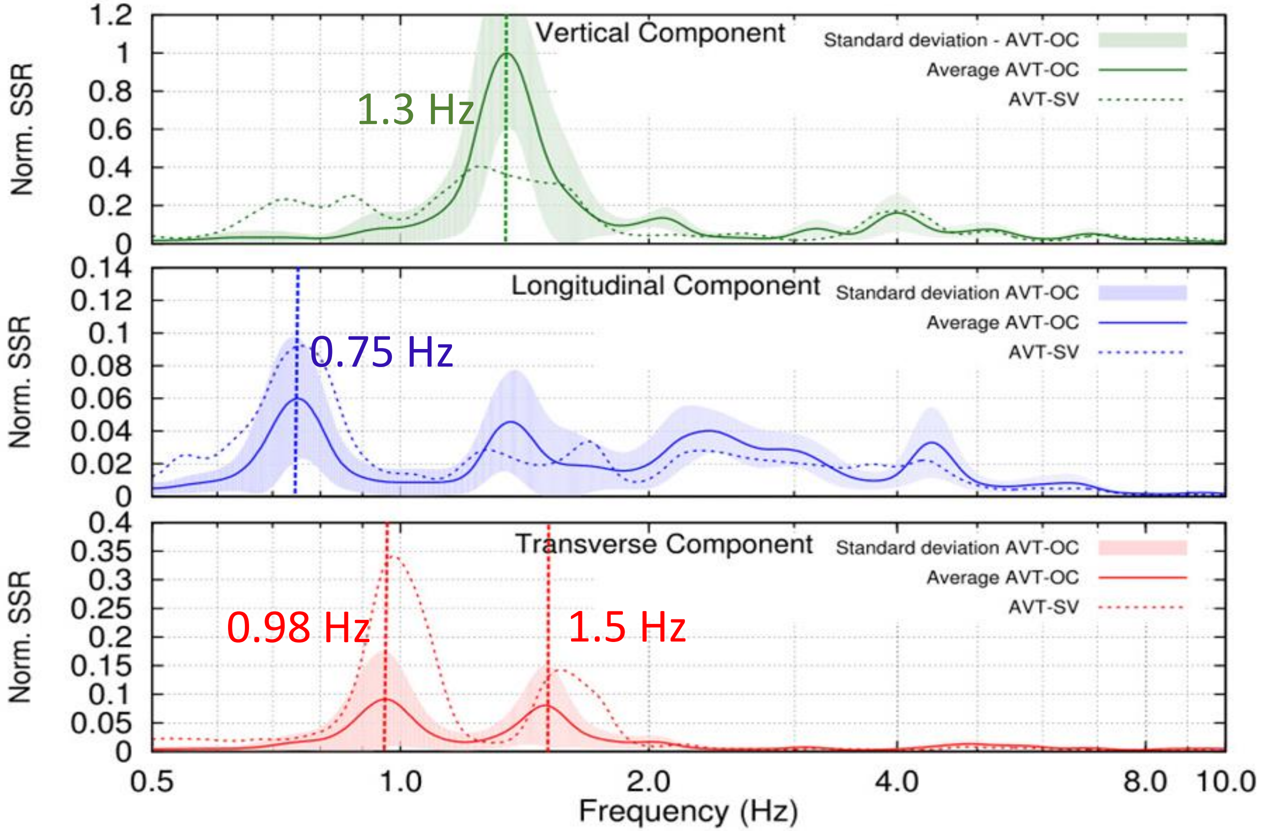
0.75 HZ	VERTICAL
0.95 HZ	TRANSVERSE
1.30 HZ	VERTICAL
1.50 HZ	TRANSVERSE
2.00 HZ	VERTICAL
2.20 HZ	TRANSVERSE

STANDARD SPECTRAL RATIO

Earthquake data

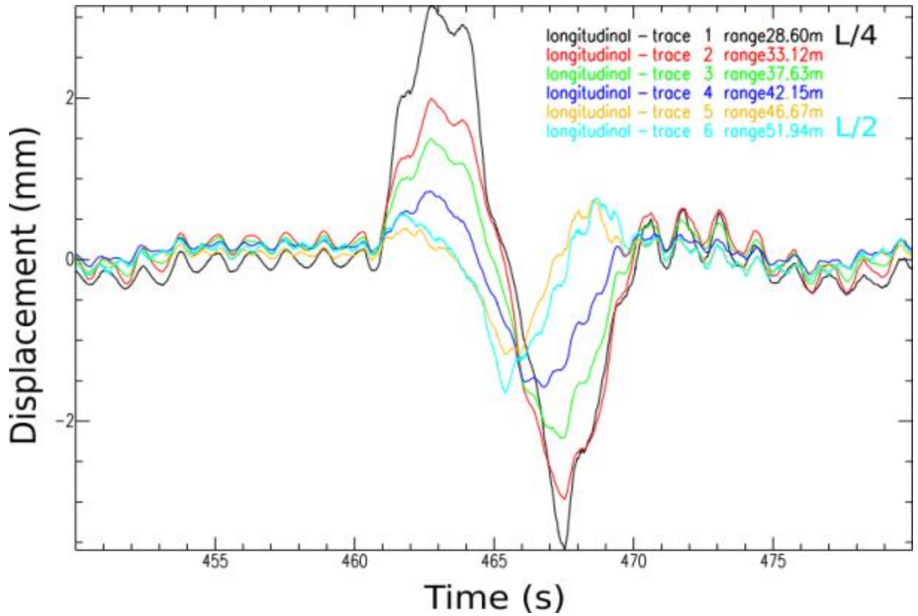


Seismic noise data

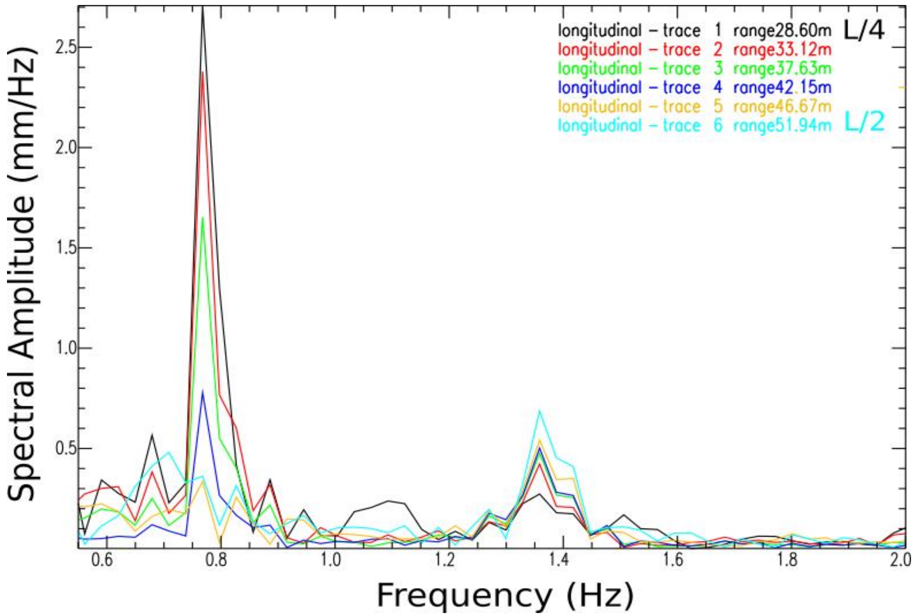


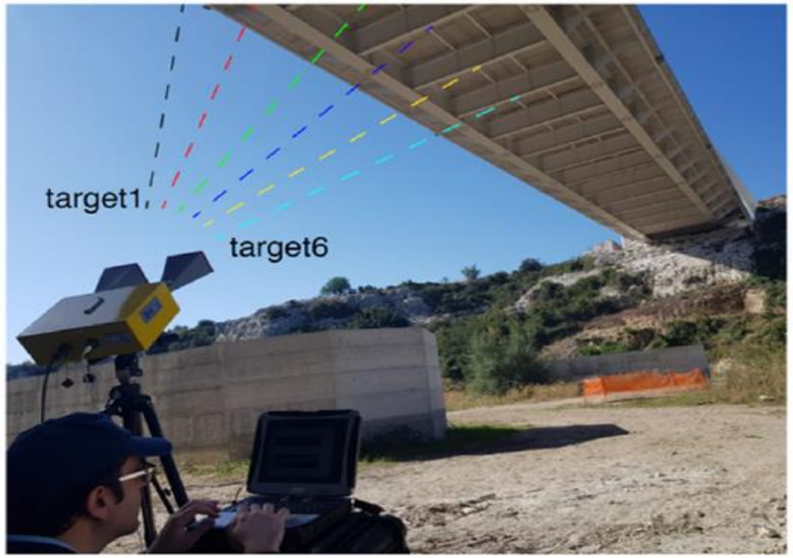
STRONG AGREEMENT BETWEEN THE ESTIMATIONS RETRIEVED FROM THE ANALYSIS OF SEVERAL KINDS OF DATA RECORDED BY SENSORS PLACED AT THE MIDDLE OF THE DECK

MICROWAVE RADAR INTERFEROMETRY

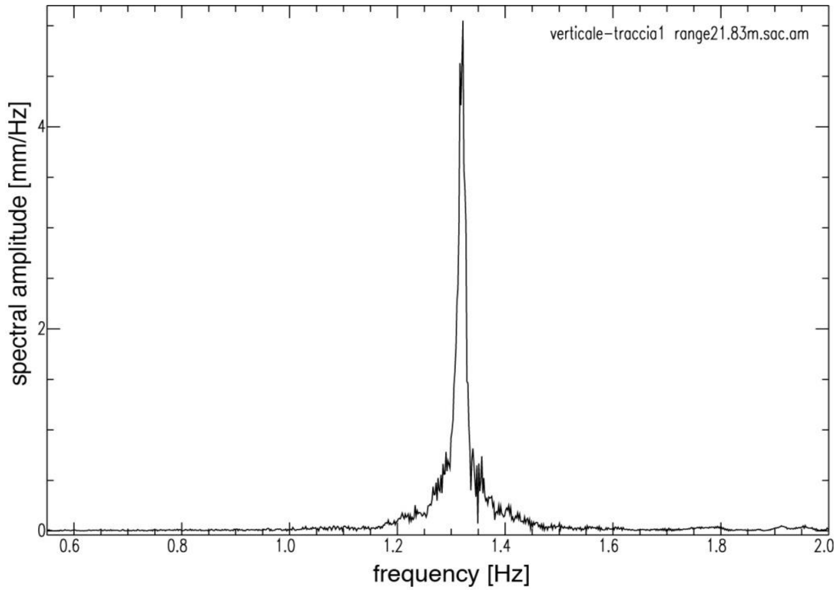


Longitudinal configuration





Vertical configuration

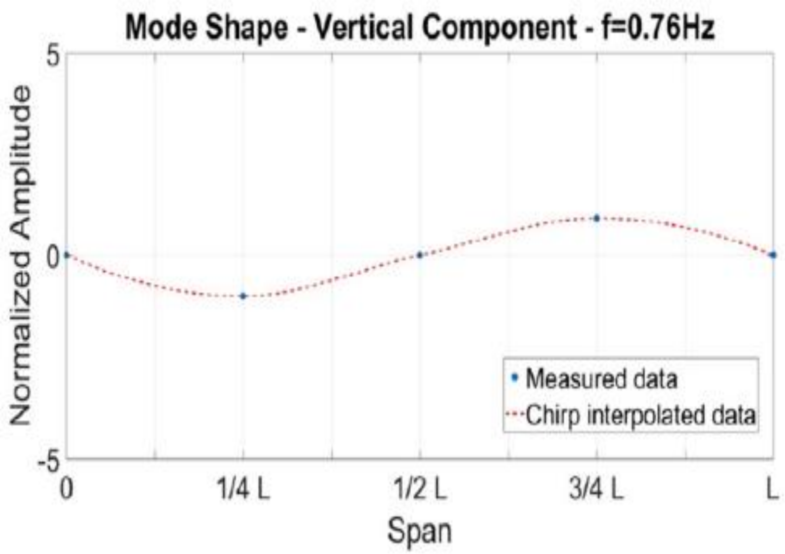


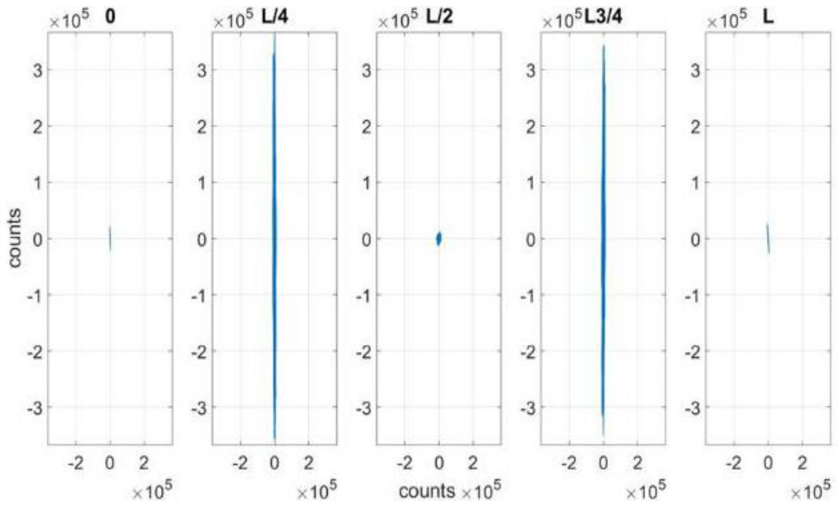
MODE SHAPES

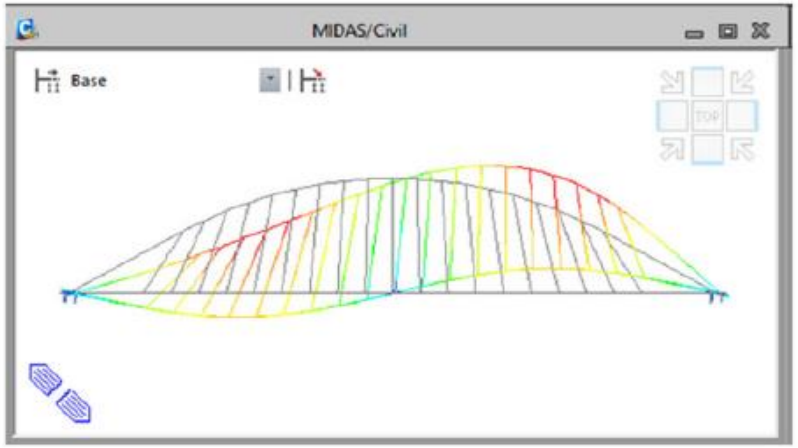
Experimental mode shapes Fourier Analysis

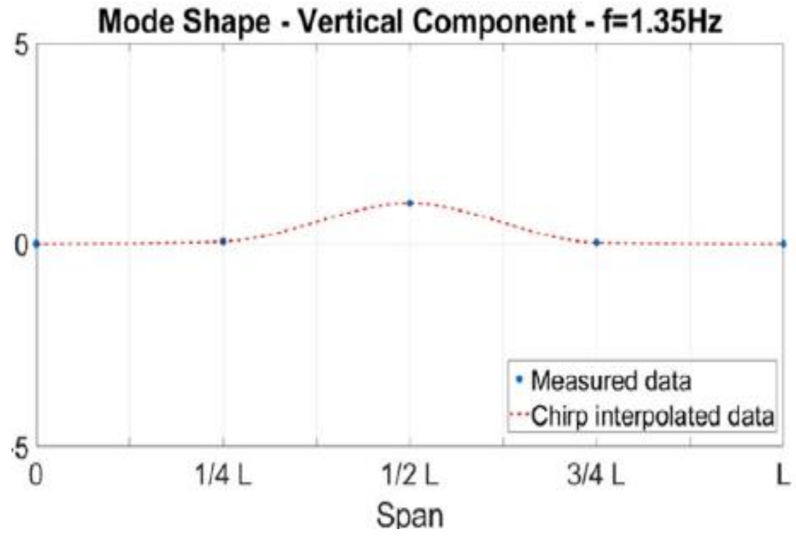
Experimental mode shapes-Particle Motion Analysis

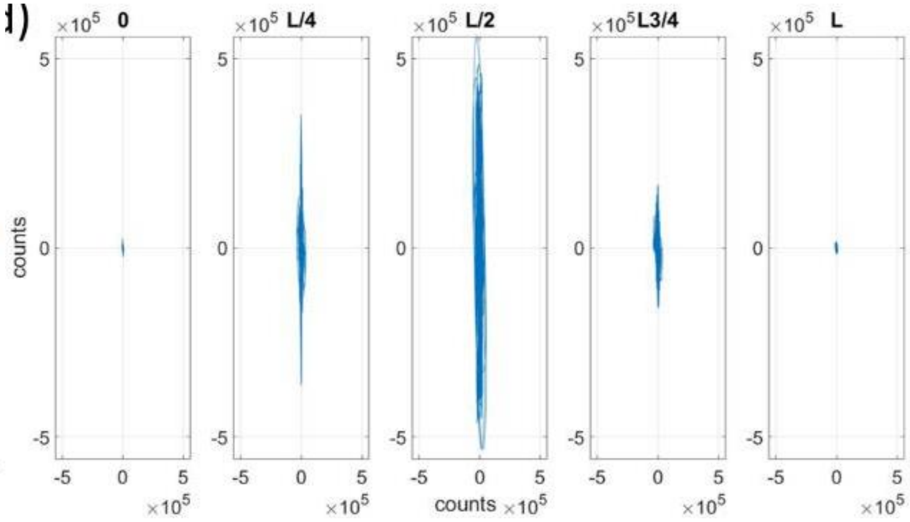
Numerical mode shapes

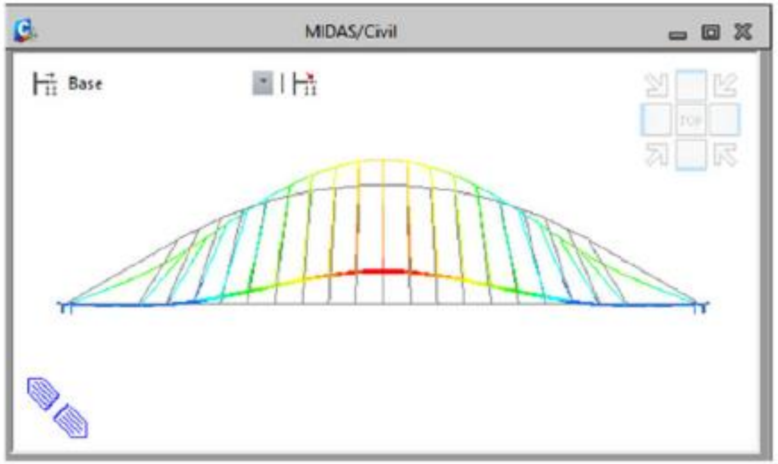




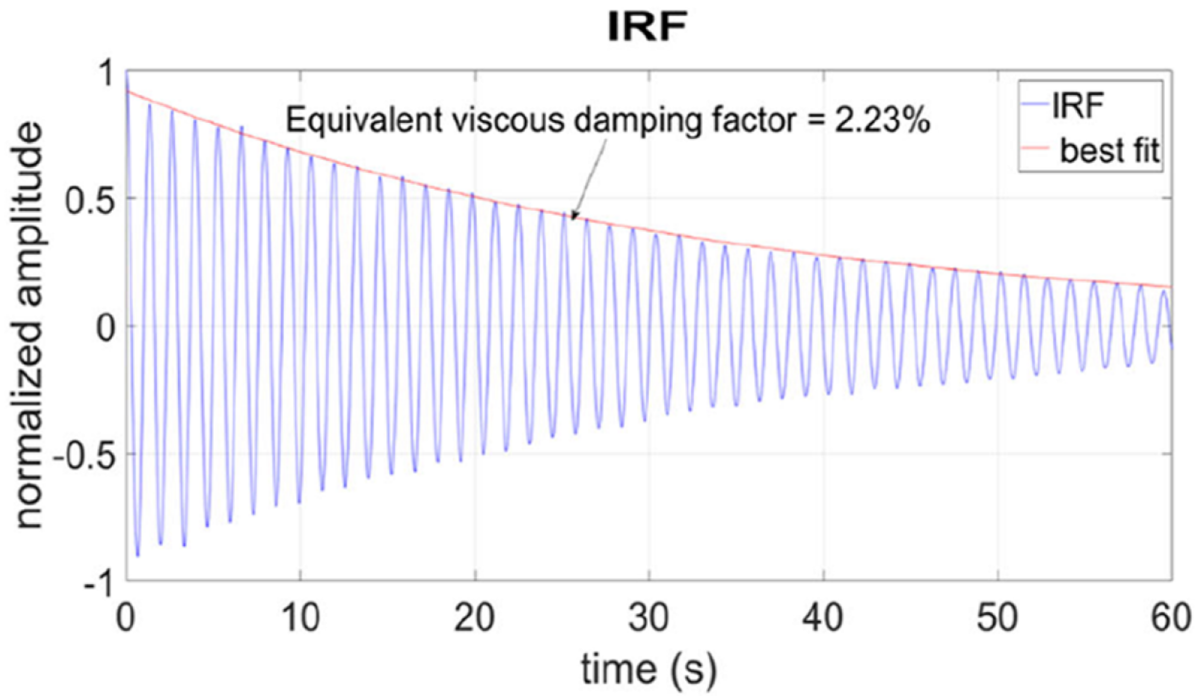


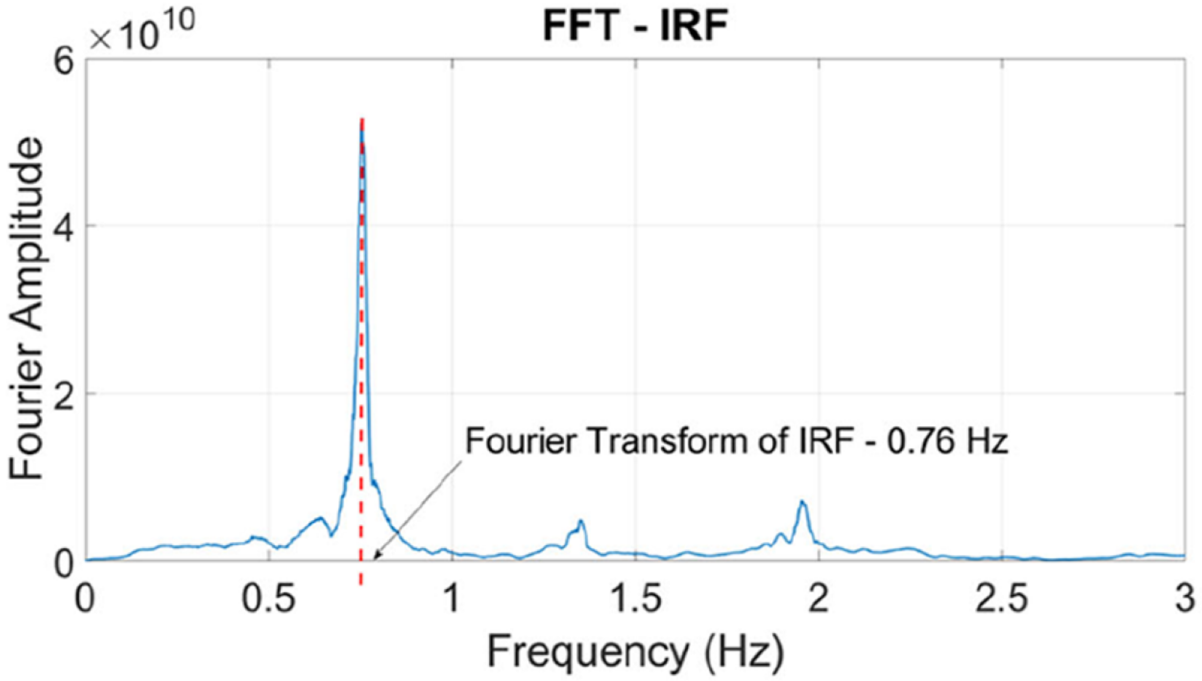






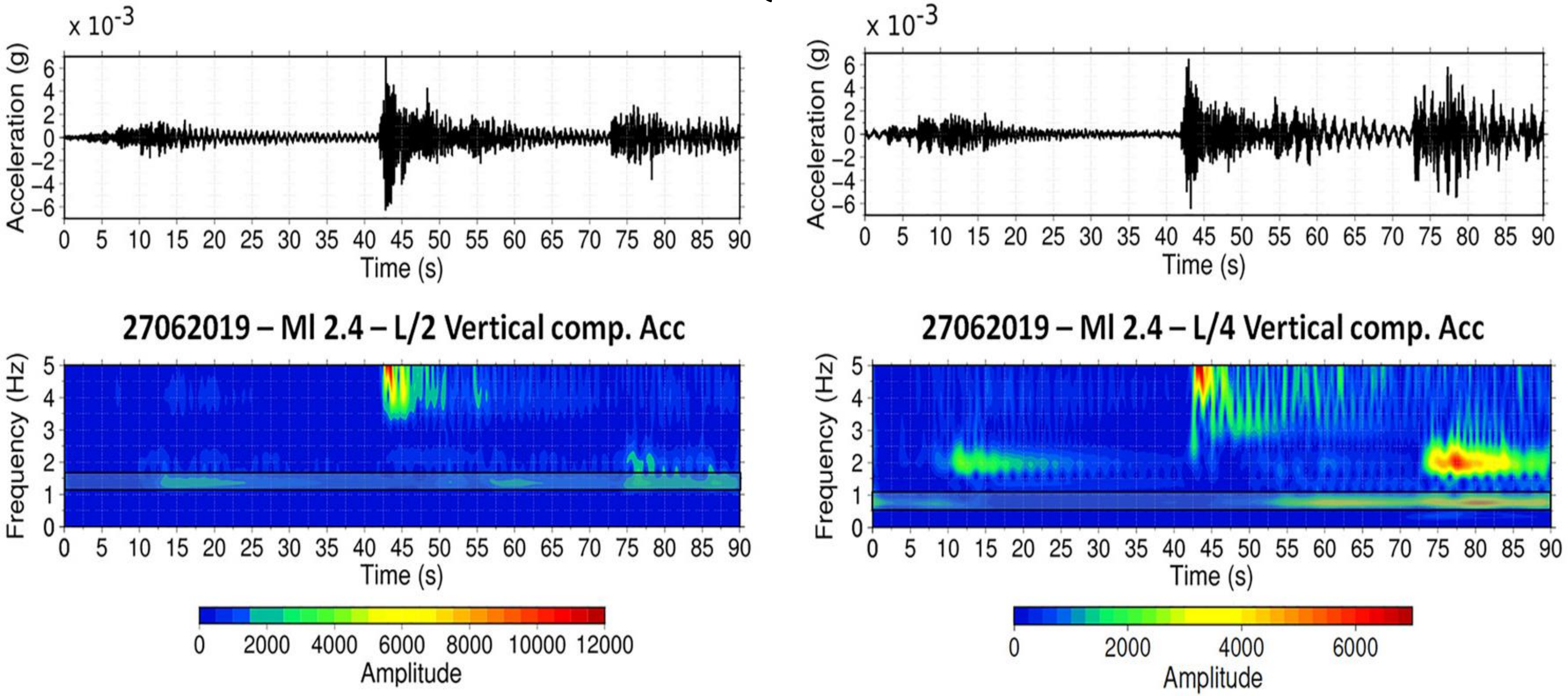
DAMPING ANALYSIS – LOGARITHMIC DECREMENT METHOD





FREQUENCY VARIATIONS AS DAMAGE DETECTIONS

EARTHQUAKE DATA



	Eigenfrequency OMA (Hz)	Eigenfrequency SSR (Hz)	Eigenfrequency MRI (Hz)	Damping LDM-IRF (%)	Direction of motion
First mode	0.76	0.76	0.75	2–3	Vertical
Second mode	0.97	0.97		2–3	Transverse
Third mode	1.3	1.35	1.35	2–3	Vertical
Fourth mode	1.5	1.5		2–3	Transverse
Fifth mode	2.0			2–3	Vertical
Sixth mode	2.2	2.1		2–3	Transverse

STRONG AGREEMENT BETWEEN EIGENFREQUENCIES ESTIMATIONS FROM DIFFERENT METHODOLOGIES APPLIED ON INDEPENDENT GEOPHYSICAL DATA

WE VALIDATED THE ROBUSTNESS OF THE PROPOSED APPROACH AS A USEFUL TOOL FOR MULTI-SCALE AND MULTI-DEPTH LEVEL CHARACTERIZATION OF INFRASTRUCTURES

KNOWLEDGE OF INITIAL PROPERTIES OF THE GRAVINA BRIDGE:

- **ZERO-TIME REFERENCE POINT OF THE STATIC AND DYNAMIC CHARACTERISTICS OF THE INVESTIGATED BRIDGE;**
- **STARTING POINT FOR IMPLEMENTING NUMERICAL MODELS, NECESSARY FOR DETERMINING THE MOST PROPER MAINTENANCE STRATEGIES.**

PUBLICATIONS

An integrated approach for structural behavior characterization of the Gravina Bridge (Matera, Southern Italy)

Vincenzo Serlenga[1], Maria Rosaria Gallipoli[1], Rocco Ditommaso[2,3], Carlo Felice Ponzo[2], Nicola Tragni[1,2], Angela Perrone[1], Tony Alfredo Stabile[1], Giuseppe Calamita[1], Luigi Vignola[4], Raffaele Franco Carso[5], Domenico Pietrapertosa[5] and Vincenzo Lapenna[1]

Structural Health Monitoring
1–22

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Structural Health Monitoring

Structural Behavior Characterization of the Gravina Bridge (Matera, Southern Italy)

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European Workshop on Structural Health Monitoring

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