Research Projects

Embedded Systems

Consorzio Tre Esse

USE SCENARIO II: UNDERGROUD INFRASTRUCTURE IN ROME (METROPOLITANA LINEA B1 ROMA)

CONSORZIO TREESSE

Information Society

European Commission

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DEPLOYMENT SCENARIO (METROPOLITANA LINEA B1 ROMA)

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Consorzio Treesse is involved in Structural Health Monitoring activities during the exacavation works of the new line of Rome underground (Linea B1).

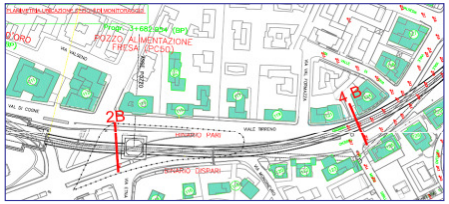
The total length of the B1 line of Rome underground is 5 Km and it consists of four new underground metro stations.

The section connecting the metro station 'Piazza Bologna' with the metro station 'Conca D'Oro'has been completed in last few years.

A new section from the metro station 'Conca D'Oro' to the metro station 'Jonio' has recently been funded and is going to be built in the next few years.

TUNNELS BUILT WITH MECHANIZED EXCAVATION IN URBAN CONTEXTS (TBM EPB – EARTH PRESSURE BALANCE)

INSTRUMENTATION FOR GENESI SYSTEM IN METRO B1



Monitoring-sections plan of Rome underground (Linea B1).
Red lines represent sets of geotechnical instruments, to which Genesi sensor nodes might be applied.

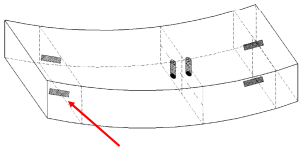
The 2B section consists of:

➢*Strain gauges for concrete, to install in the segments of the definitive tunnel lining; 3 segments (B, E, G) with 6 strain gauges each (altogether 18 pcs).*

The 4B section consists of:

➢*Strain gauge for concrete, to install in the definitive lining segments; 2 segments (B, E) with 6 strain gauges each (altogether 12 pcs).*

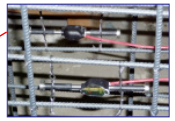
INSTRUMENTED SEGMENT



Strain gauge

INSTALLATION OF THE STRAIN GAUGES AND DATALOGGERS ON THE SEGMENT OF FINAL LINING

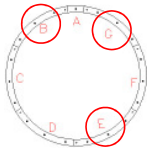
Datalogger in the metallic box welded on the metallic rods (approx. 20cm x 13cm x 2cm)

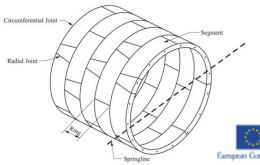


Strain gauges fixed by metallic wires, on the metallic supporting structures of the segment

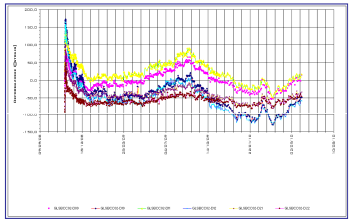
The strain gauges for concrete are used to measure the strain, and to define the stress status inside the final lining of the tunnels.
The strain gauges are installed on the steel supporting structures of the precast segments of the final lining.

Precast segment of final lining

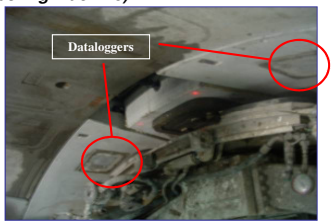




Strain-time chart of a tunnel lining



Ready-installed data-loggers in the tunnel lining (next to tunnel boring machine)

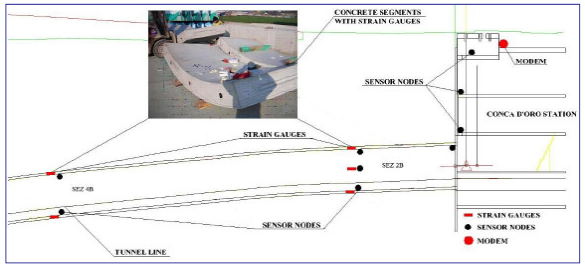


Strain gauges Sisgeo model OVK4200VC00
- Method of installation:embedment.
- Active gauge lenght: 165 mm.
- Range (nominal): 3000με, from -1500με to +1500με.
- Sensitivity: 1.0με
- Accuracy: smaller than 2% full scale, resp. 60με
- Stability: 0.1% FS/yr.
- Typical frequency datum: 800 hertz.
- Coil resistance: 150 Ohm.
- Thermal coeff. of expansion: 11.6 *10^{-6}με/°C
- Temperature range:- -20°C to +80°C
- Reading resolution: 16 bit
- Power requirements: +12V dc (direct current) with variable pulse

TECHNICAL SPECIFICATIONS

Model	nVK4200M/Son	nVK4200M/Com
Description	surface mount type strain-gauge with plank coil and arch weldable end blocks	concrete strain-gauge with flanges for concrete embedment
Method of installation	arch welding	embedment
Active gauge length	165 mm	165 mm
Range (nominal)	3000 με	3000 με
Sensitivity	1.0 με	1.0 με
Accuracy	<2.0% FSR	<2.0% FSR
Stability	0.1% FS/yr	0.1% FS/yr
typical frequency datum	800 Hz	800 Hz
Coil resistance	150 ohm	150 ohm
thermal coeff. of expansion	11.6x10^{-6}/°C	11.6x10^{-6}/°C

Schematic section of the tunnel longitudinal profile with the instrument location



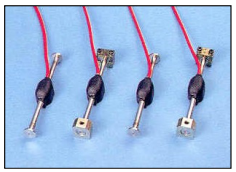
Sensor for Metro Roma

Instrumented Section	Sensor Type	Number of sensors / ports	Shortest sampling interval, scenario critical (SPI)	Sampling interval, scenario normal (SPI)	Latency (LAT) in normal mode
2B	VW strain gauge	18	10 min	6 hours	minutes
	temperature	18	10 min	6 hours	minutes
4B	VW strain gauge	12	10 min	6 hours	minutes
	temperature	12	10 min	6 hours	minutes

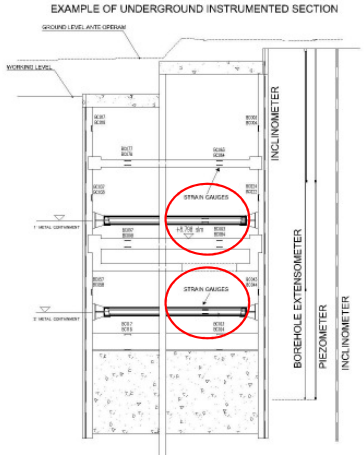
Sensor list for SHM applications

Measured variable	Sensor type	Priorty	Interface / Connection	Supply	Output	Resolution	Time for measurement (warm up)	Comment	Application
Strain / displacement	Vibrating Wire	A	analogue, 2 wires	2.5 - 12V	Resonance-frequency (voltage)	0.1% FS	approx. 1 s	(500 – 2000 Hz) within approx. 100 to 200 ms; Measurement of the frequency	Anchor forces, loads on fundaments, beams, contact points, in concrete lining
Temperature	Resistor YSI 44005	C	analogue, 2 wires		Resistor required range 50kOhm – 1.6kOhm	ca. 0.5°C	< 0.5 s	Standard in VW sensors, may be regarded as linear in the required range (0 to 30 °C)	

Priority levels of sensors:
A – required; very common, in most project and different types of instruments used
C – common but with alternatives



OTHER EXAMPLE OF APPLICATION FOR STRAIN GAUGES



During the excavation phase of a metro station, the vibrating wire strain gauges can be installed on the metal containment and supports structures

INSTRUMENTED CONTEINMENT STRUCTURES BY STEEL STRAIN-GAUGES IN ANNIBALIANO METRO STATION OF ROME LINEA B1

Vibrating wire Strain gauge

Table: Requirement for Metro Roma deployment scenario

Data	
Data format	Collected data of data-loggers may be stored in an ASCII file or Excel compatible worksheet. The basic data acquired by data-loggers about strain are in frequency (hertz) or in digit (artificial electric measure unit). Digit = $(hertz^2)*10^{-3}$. The temperature, instead, is expressed in Ohm or in Celsius degrees.
Types of events/alerts generated	Alarms via sms Thresholds individually set by users / designers
Infrastructure	
Number of Nodes	Approx 5 to 10 nodes (depending e.g. on number of ports per node and max. radio distance, energy management)
Distance between nodes	maximum extension measurement field: in length around 220 m distance in one ring of the concrete lining: around 10 m In addition to the places where the sensors will be placed (where the strain gauges are located) it is possible also to place additional sensor nodes for relaying purposes only. The sensor node will be embedded in the segment
Environment	tunnel conditions, 10 m altitude above sea level Impacts: Dust, humidity, possibly electromagnetic disturbance due to machines and other radio technique Temperature: -10°C to +40°C
Size	approx. 20cm x 13cm x 2cm
Weight	No special limits
System lifetime (in days)	Lifetime of tunnel > 50 years Duration of building site approx. 3 years Lifetime of batteries / full cells should be at least 1 year with 4 acquisitions per day
Sensing parameters	
Actuation parameters	See sensor list interface with the strain gauges is envisioned for this testing site
Measurement accuracy	16 bit A-D conversion preferable

Advantages of Genesi System over existing traditional systems:

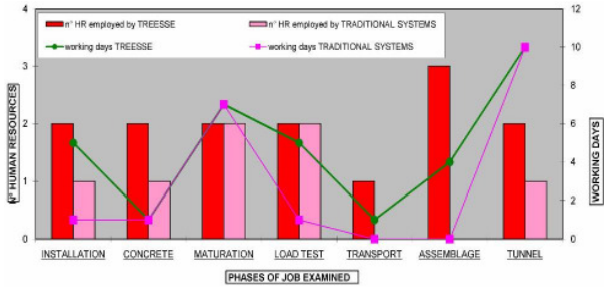
➢*Low impact on construction works and real-time information provided also in phase of the construction works where they are not currently available. Today in the most critical phase of construction it is extremely difficult and sometimes not possible to get information in real-time (e.g. when the instrumented segments are installed by TBM, the presence of the shield and its parts prevents direct access to the strain gauges data-loggers). Therefore the initial data, acquired by data-loggers immediately after the installation of the instrumented ring of the final lining, will be available only after the TBM is advanced about 30-40 meters.*

➢*Acquisition and transmission of data in difficult environments, both during the tunnel construction and during the entry into service of the underground section.*

➢*A significant time saving and consequently economic gain, using an innovative, less invasive, monitoring system, which does not require cables installation and installation of data-loggers.*

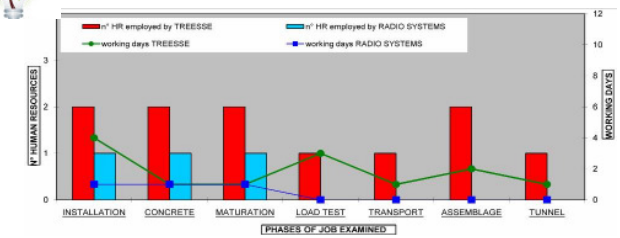
ADVANTAGES OF GENESI SYSTEM

The following charts quantify the advantages of deploying a wireless monitoring system based on wireless dataloggers instead of a traditional cable-based one (source: Consorzio Treesse). The data and charts refer to a tunnel scenario and more specifically to a vibrating wire strain gauges installed in the final tunnel lining, made of precast segments.



Number of human resources devoted to maintenance and repair of a traditional system (pink) out of the total number of people involved in deploying and supervise a structural health monitoring system (red). The data are typical of real-life ordinary operations of existing systems.

ADVANTAGES OF GENESI SYSTEM

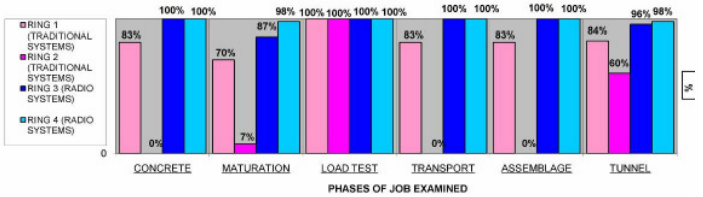


Human resources devoted to maintenance and repair of a monitoring radio-based system. We can see that the number of human resources devoted and the number of working days decrease substantially compared to a traditional cable-based monitoring system.

THE SAVING TIME WILL BECOME A SIGNIFICANT ECONOMIC GAIN DUE TO THE HIGH COSTS OF THE CIVIL WORKS CONSTRUCTION

Construction works often use very expensive machines and infrastructure (tunnel boring machine 7 to 8 million Euro, special excavators, water pumps etc.), so that the daily costs (together with the special trained personnel) add up to several tens of thousands of Euros. This makes a clear case for the economical gain which can be achieved simply by reducing downtime and impact of structural health monitoring on the activities at the construction site.

IN ADDITION THE PERCENTAGE OF THE ACQUIRED DATA FROM THE SENSORS INCREASES IN THE DIFFERENT PHASES OF THE TUNNEL CONSTRUCTION



Percentage of data received from sensors during different phases of system operations. Difference between radio monitoring systems and traditional cable-based monitoring systems.