Fibre-optic sensors

SESSION 2: Digital Inspection and Monitoring Technologies

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Final Event

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InfraROB project – RINA activities on long-term damage detection monitoring system

InfraROB innovative technological solution

- the **long-term damage detection of pavements** relying on the **integration of distributed FOS in asphalt and an automatic laying system** for it.

Road maintenance optimization

- because it permits to **identify the precise point** where **damages** are occurring to the pavement (i.e. cracks) **at very early stage**.

Influence on decision making process

- In **planning timing and sizing interventions** helping in optimizing **balance between the costs and benefits** of maintenance.

InfraROB project – long-term damage detection monitoring system

The main objectives to be achieved:

1. A monitoring system able to withstand the automatic laying process
2. A monitoring system able to withstand the asphalt pavement realization process
3. Validating long distance application of the FO technology
4. To develop a solution for the distributed sensing for pavement damage detection monitoring (DDM)

Fibre Optic sensing technology

Fibre optic (FO) technology can provide integrated sensing with extensive measurements lengths.

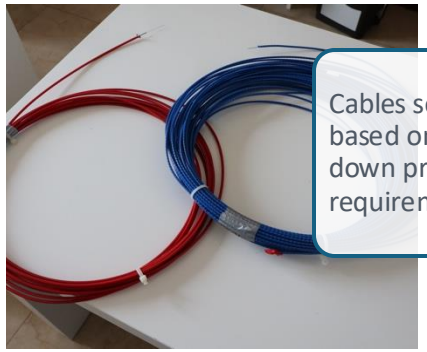
FO sensors match all the requirements needed for the integration in the asphalt lay down process.

Distributed optical fibre sensors (DOFSs) exploiting Rayleigh scattering mechanism can measure both strain and temperature changes with a very high spatial resolution and possibility to monitor up to 2 km of FO cable in a single acquisition.

Asphalt Pavement Monitoring Requirements	
SENSING SYSTEM (CABLE)	
Dimensions	as small as possible
Tensile stiffness	as low as possible (7000-13000 Mpa asphalts stiffness)
Tensile strength:	> 20N
Crushing strength	Minimum 1 MPa
Mechanical resistance against cutting by aggregates	
Maximum operational temperature:	60 °C
Maximum installation temperature:	180 °C for 10-20 minutes
Environmental resistance:	resistant to corrosion
Chemical resistance:	Resistance to bituminous material
Max measurable strain	> 2000 με (0,2%)
SENSING SYSTEM (SCATTERING TYPE)	
Spatial resolution	below 10 cm
Max monitoring length	hundreds of meters

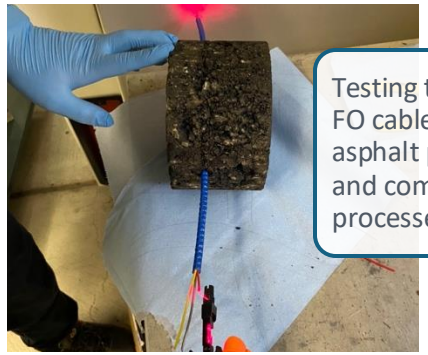
Monitoring system design

FOS selection



Cables selection based on asphalt lay down process requirements

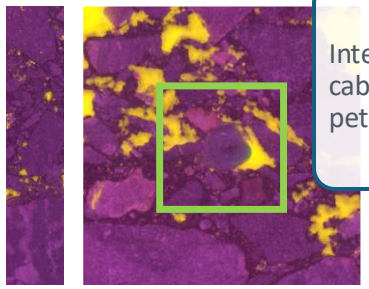
Survival test



Testing the survival of FO cables to the asphalt production and compaction processes

Asphalt

DSS V9

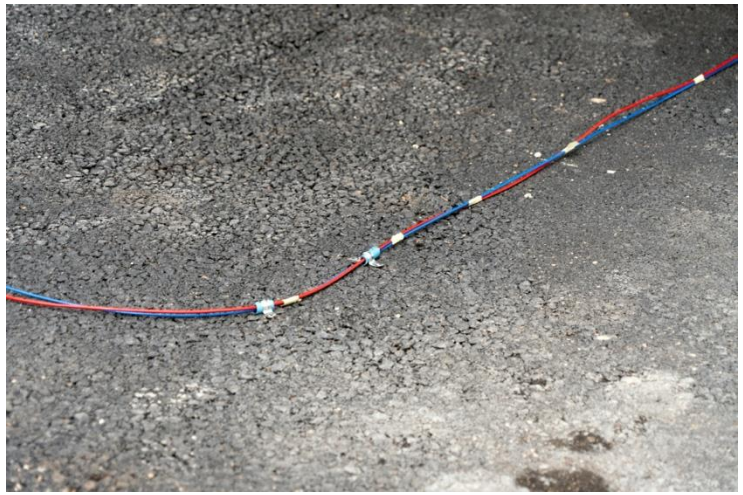


Interaction of FO cables with asphalt petrology

Sensor lab validation

Flexural test in lab to verify sensors response to mechanical stress

Validation in asphalt by manual lay down



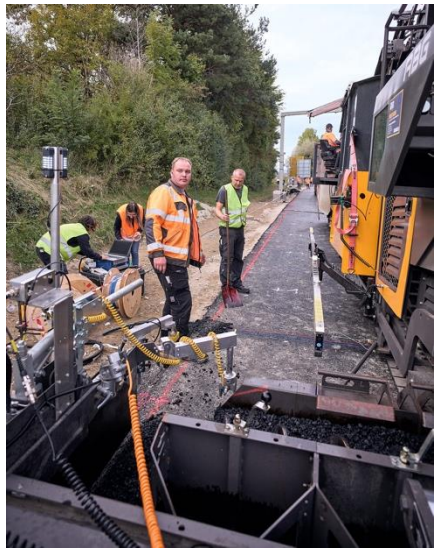
Validation in asphalt by manual lay down

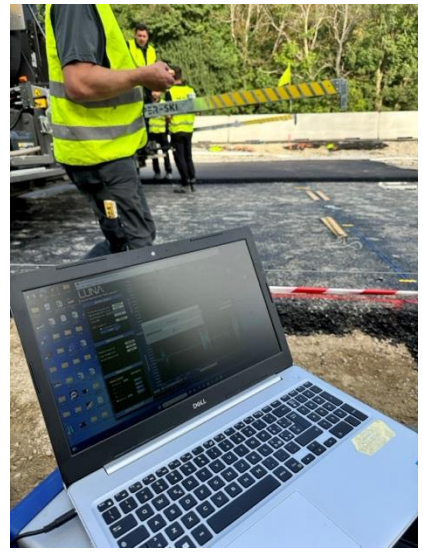
Strain and temperatura were monitored during the asphalt lay down process.

Strain was monitored during the pavement process and the lenght of FO sensor embedded in the asphalt is clearly visible in four different instants (1 →4 in upper graph) of the process.

Temperature change from the initial condition of fixed on the ground (light blue line), the end of asphalt process (red line) and 12 hours later (green line) is also visible.

Validation in automatic laying process





Validation in automatic laying process

FO cables survived to the mechanical stress of the automatic pre-tensioning process for the total length of intervention.

Temperature change during the cool down process was observed.

Integration of data in damage detection monitoring (DDM) system

Data collected have been uploaded in the DDM .

```
Acquired on 10/3/2024 at 10:49:48
Calibrated on 10/3/2024 at 10:43:35
Device Descriptor:  [none]
Scan Range (nm):  1550.337  --  1550.741
Measurement Type:  Reflection
Group Index:  1.500
Gain:  24 dB
Domain:  Time
Spatial Resolution (mm):  1.985709
Frequency domain window was not applied to measurement data.
Gage length:  4.964272 cm
Sensor spacing:  9.928545 cm
Temperature change coefficients
        0.000000
        -1.300000
        0.000000
        0.000000
        0.000000
Number of Data Points (in this file):  1863
NOTE: Data stored in this file is not decimated.

Length (m)      Temperature Change (deg C)
2.24006128E+000 -1.12285061E+001
2.33934665E+000 -1.32250576E+001
2.43863225E+000 -1.43431253E+001
2.53791761E+000 -1.55090809E+001
2.63720322E+000 -1.64674568E+001
2.73648858E+000 -1.56368885E+001
2.83577394E+000 -1.47424097E+001
```

Query | Query History

```
SELECT * FROM pavement.fos_data
ORDER BY id DESC LIMIT 100
```

Scratch Pad

Data Output | Messages | Notifications

	id [PK] integer	fdata jsonb	timestamp timestamp with time zone	type character varying
1	23	{"data": [{"Length": 2.83577394, "Spectral Shift": -14.7424097}, {"Length": 2.93505955, "Spectral Shift": -13.8479919}, {"Length": 3.03434491, "Spectral Shift": -12.6660509}, {"Length": 3....	2024-12-16 19:08:07.570174+01	strain measurement
2	22	{"data": [{"Length": 2.83577394, "Spectral Shift": -14.7424097}, {"Length": 2.93505955, "Spectral Shift": -13.8479919}, {"Length": 3.03434491, "Spectral Shift": -12.6660509}, {"Length": 3....	2024-12-16 19:02:06.410326+01	temperature meas...
3	21	{"data": [{"Length": 4.56067753, "Spectral Shift": -8.96117687}, {"Length": 4.56569624, "Spectral Shift": -8.88095665}, {"Length": 4.57071543, "Spectral Shift": -8.32268143}, {"Length": 4....	2024-10-01 11:11:22.006844+02	[null]
4	20	{"data": [{"Length": 4.56067753, "Spectral Shift": -8.96117687}, {"Length": 4.56569624, "Spectral Shift": -8.88095665}, {"Length": 4.57071543, "Spectral Shift": -8.32268143}, {"Length": 4....	2024-10-01 11:04:38.656705+02	[null]
5	19	{"data": [{"Length": 4.56067753, "Spectral Shift": -8.96117687}, {"Length": 4.56569624, "Spectral Shift": -8.88095665}, {"Length": 4.57071543, "Spectral Shift": -8.32268143}, {"Length": 4....	2024-10-01 10:51:40.347174+02	[null]

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Thank you for your attention

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Infra ROB

Maintaining integrity, performance and safety of the road infrastructure through autonomous robotized solutions and modularization

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