Tartaro-Canalbianco-Po di Levante. (https://www.remweb.it)/

Conceptualization of an anti-erosion sensing revetment for levee monitoring: experimental tests and numerical modelling

EGU 2020: Sharing Geoscience Online

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Summary

Project partners:

INNOVATION CENTER MACCAFERRI

CHIARINI ASSOCIATI INGEGNERIA CIVILE E AMBIENTALE

cohaerentia FIBER OPTIC SENSORS FOR SMART DIAGNOSTICS

POLICOM lightwave technology

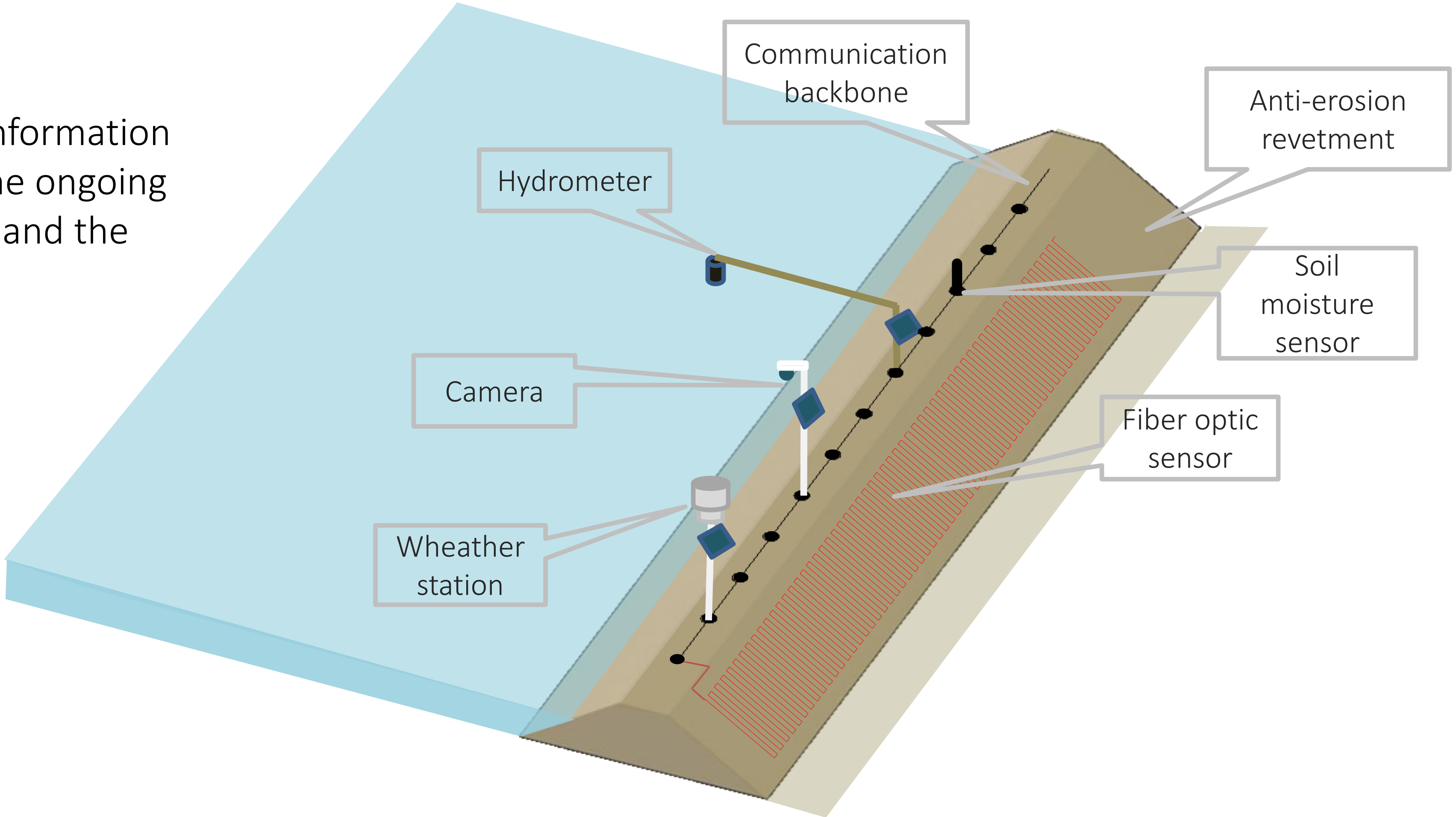
Fondazione Politecnico di Milano

1. Introduction – Problem: Levee breaches

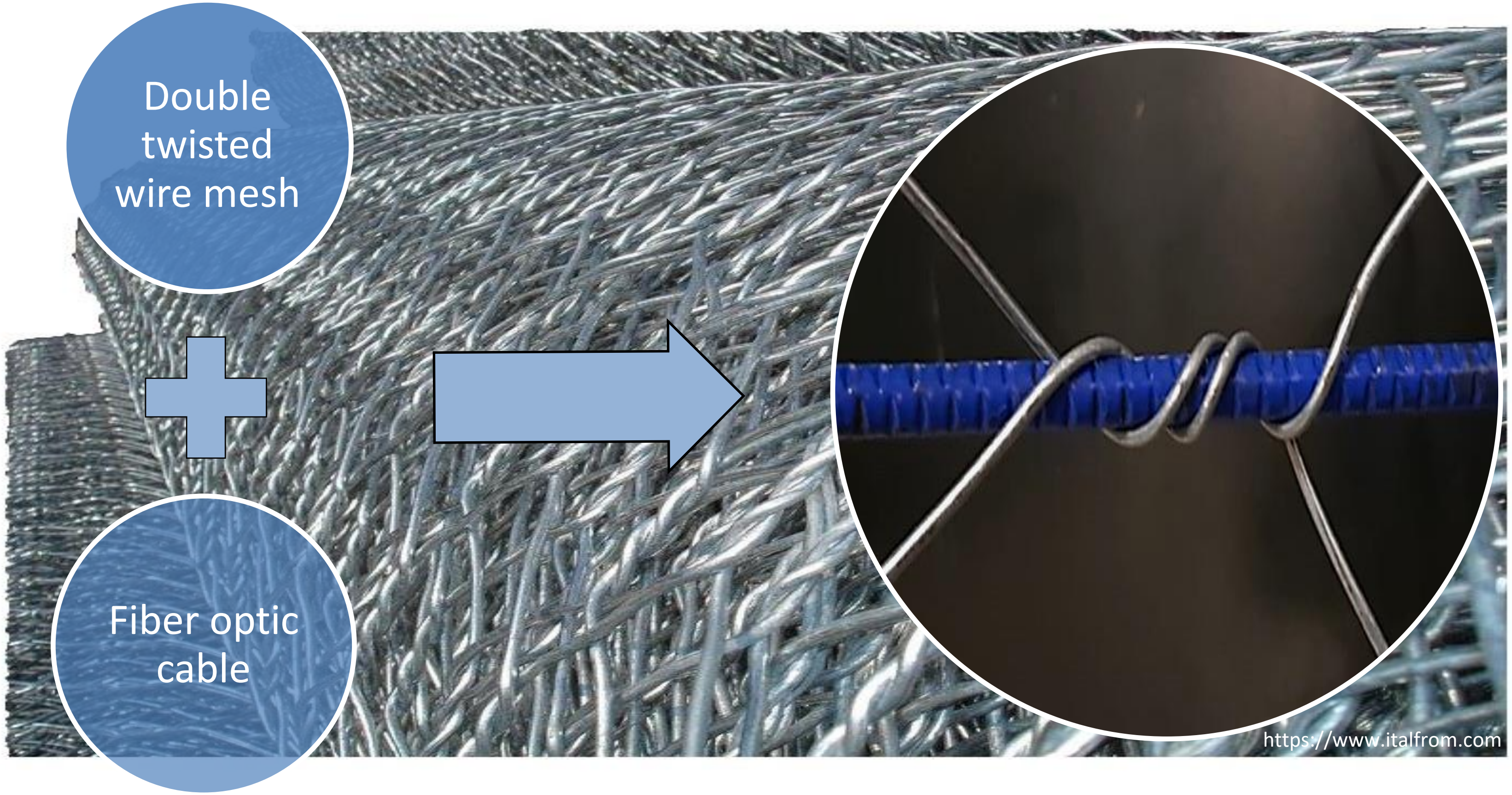
Census on the historical levee breaches of the Po river (Adbpo & CNR-IRPI, 2004)

1. Introduction – The smart levee concept

A smart levee collects in real time information on its "health" conditions and on the ongoing interactions between the system and the external environment

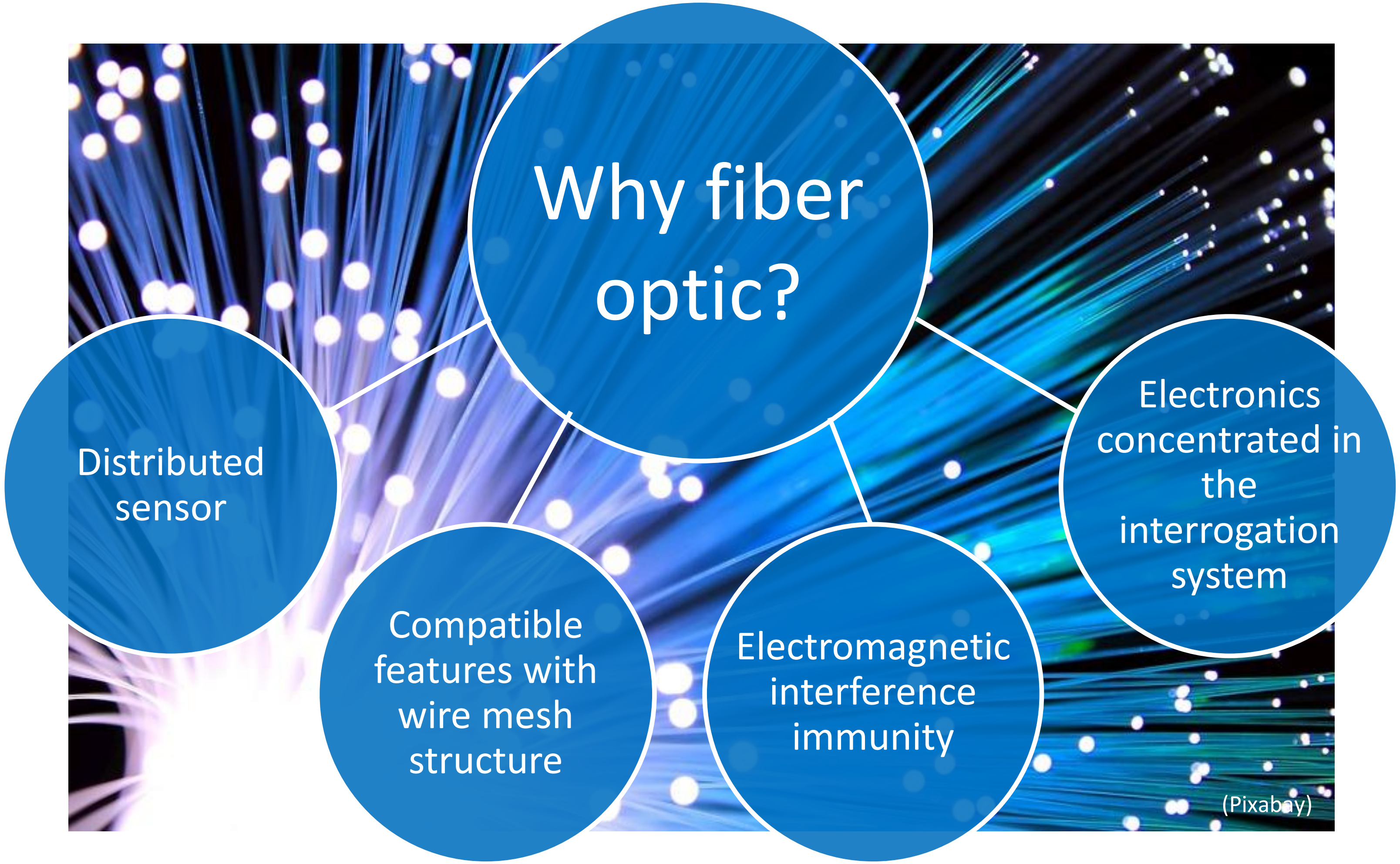


2. Anti-erosion sensing revetment

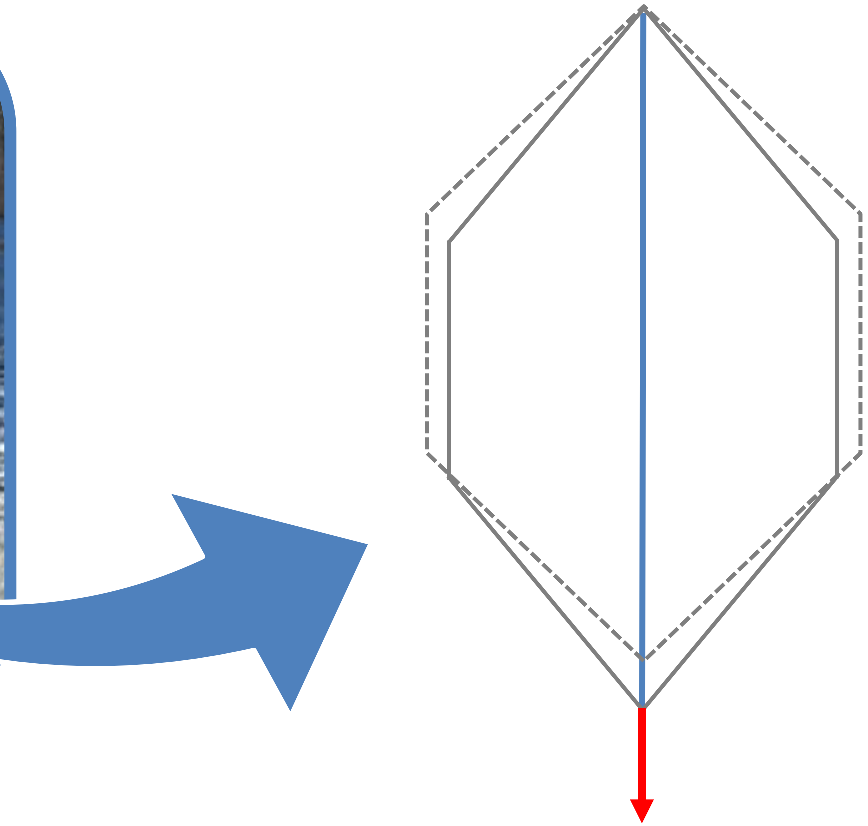


An innovative native sensing revetment: the structural and the sensing component are coupled together during the production process

2. Anti-erosion sensing revetment



2. Anti-erosion sensing revetment - working principle



The wire mesh is stressed in its plane by the overtopping water flow

The meshes react to the stress by modifying their geometry: the fiber optic cable, deforming itself, detects this behavior

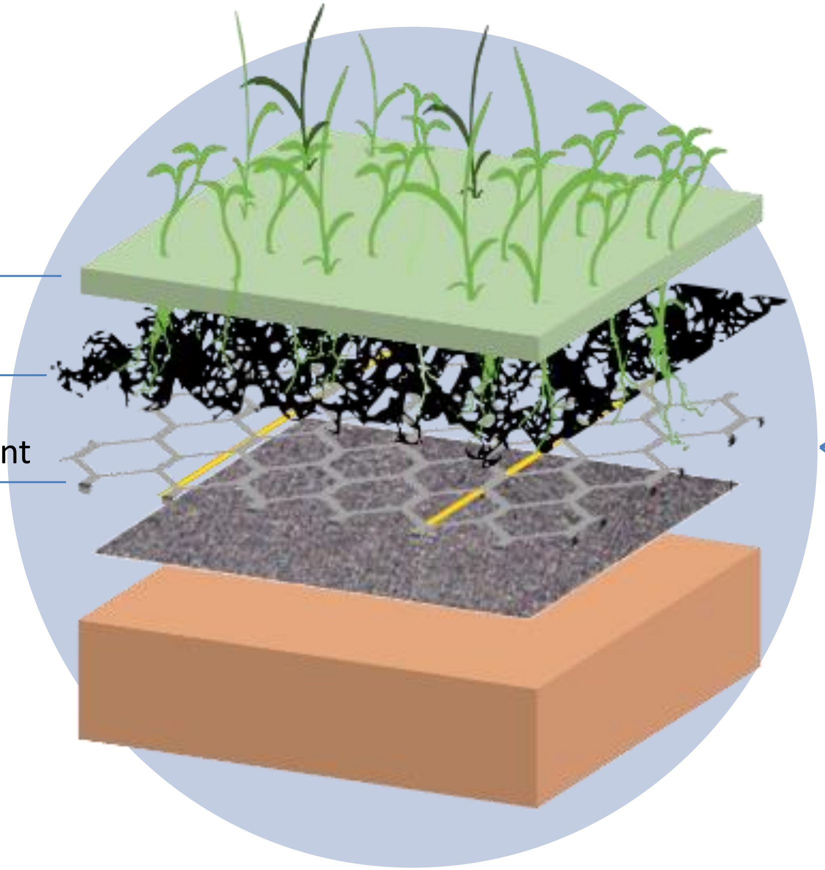
2. Anti-erosion sensing revetment

Layout

Superficial turf

Geosynthetic*

Anti- erosion sensing revetment



Functions

Protection against embankment erosion

Monitoring of the levee conditions

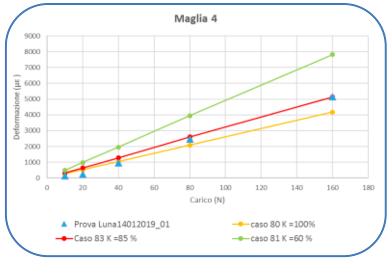
Continuos surveillance during flood events

* Extruded polyolefin layer: it promotes the linkage between the root trellis and the sensing revetment

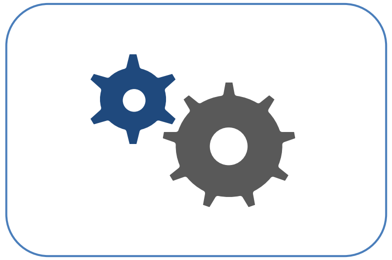
3. Method - Workflow

Experimental tests - 1° cycle

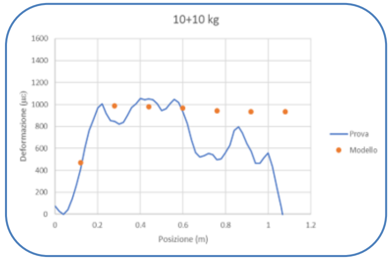
(fiber optic glued to double-twisted sections)



Model calibration



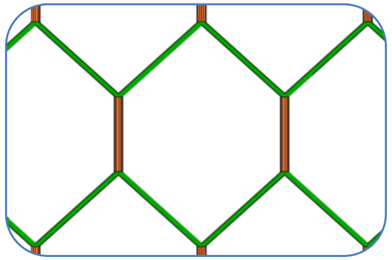
Analysis of the wire-cable interaction



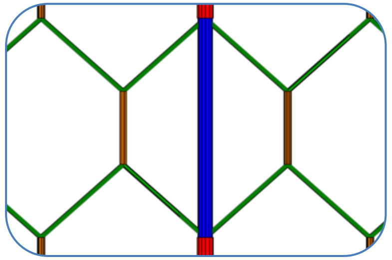
Tests Vs model results:

parameters validation

Wire mesh model (FEM) implementation

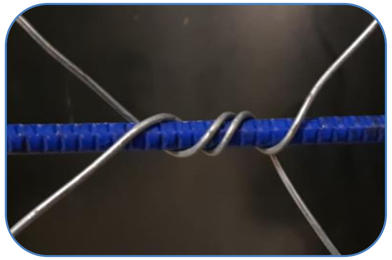


Wire mesh + fiber optic cable model implementation

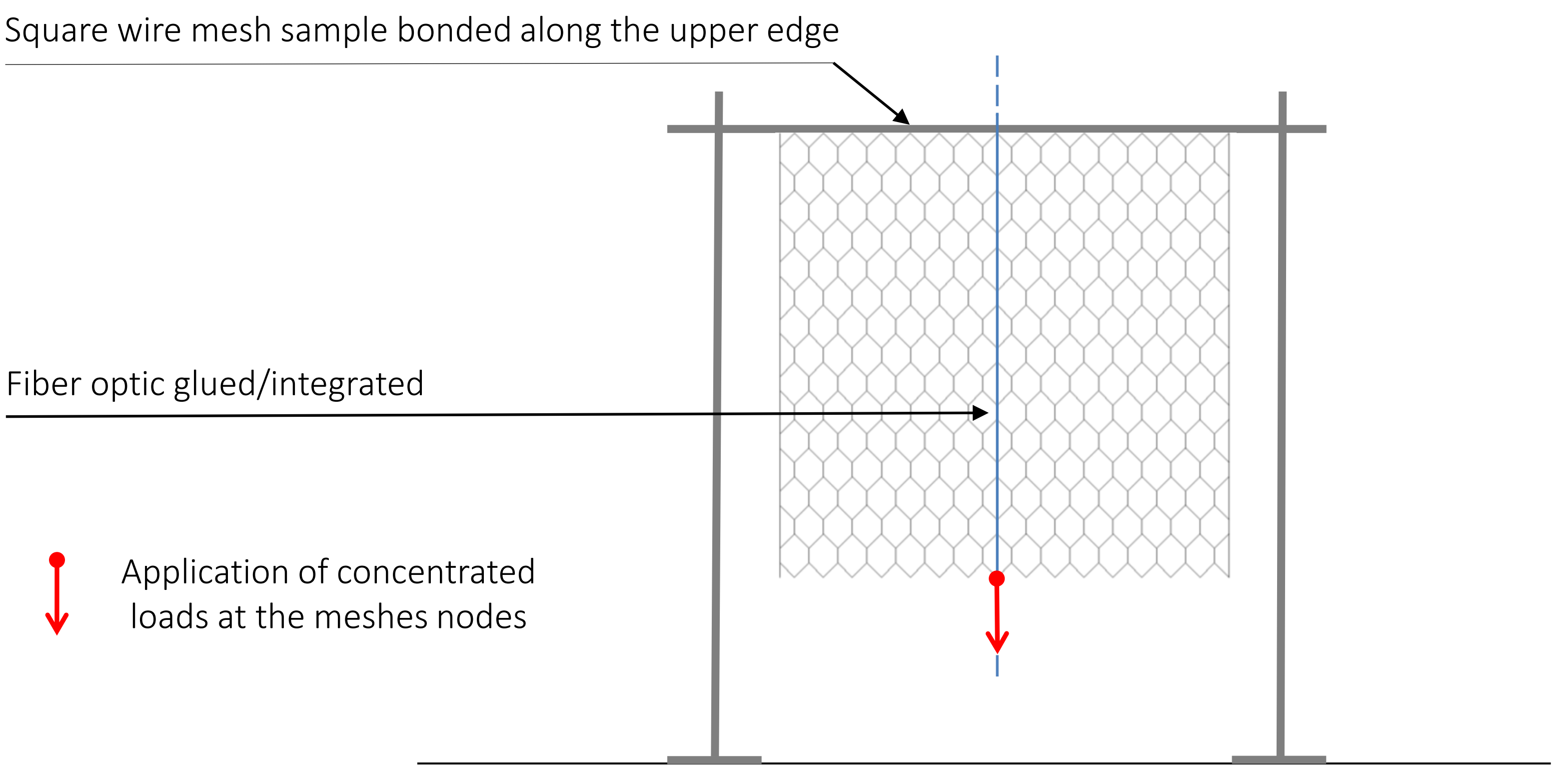


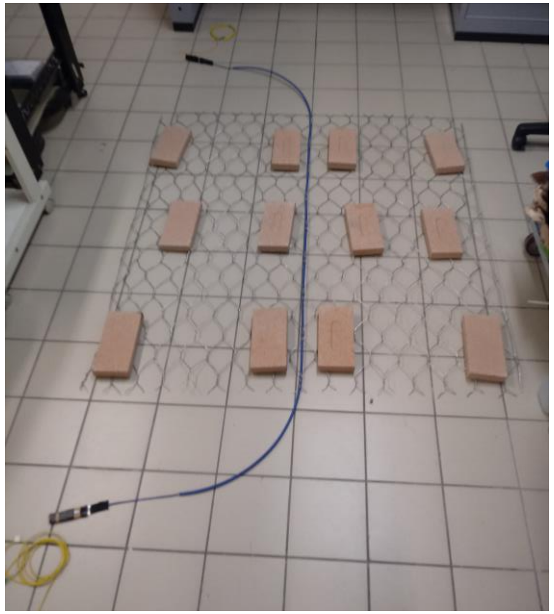
Experimental tests - 2° cycle

(fiber optic cable integrated with wire mesh)



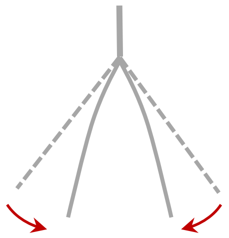
3. Method – Experimental setup





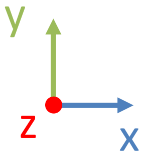
Sample configuration before experimental tests- Policom lab.

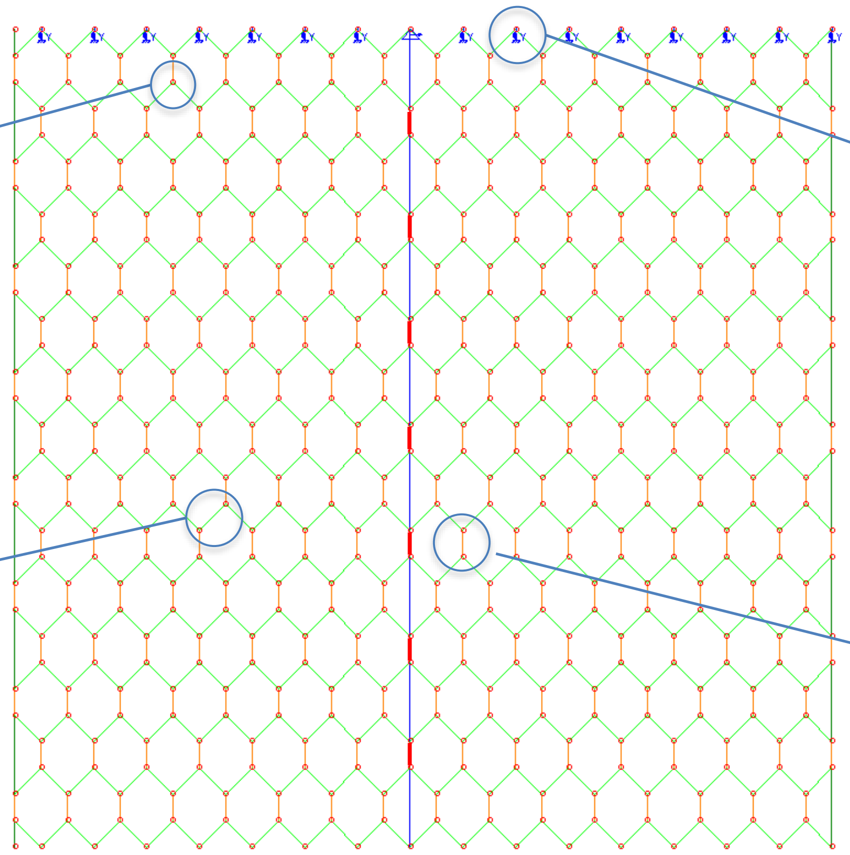
3. Method – Numerical model



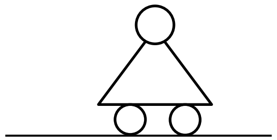
Degree of connection of the elements at nodes on M_Z reduced

Circular section beam finite elements





Application software: *MasterSap*

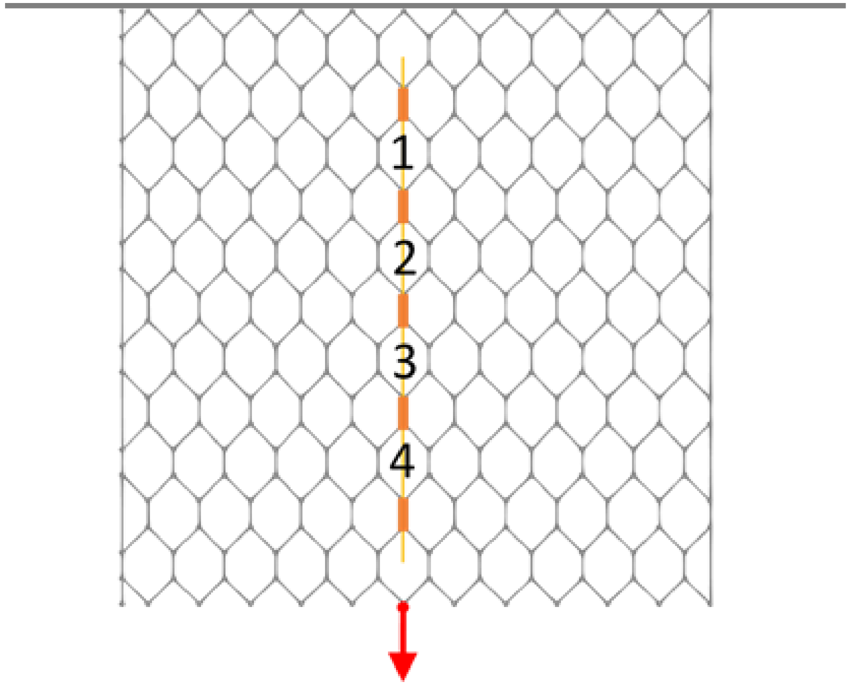


Carriage constraints with stiffness constant along y

Specific modeling for double-twisted (orange) and double-twisted+ fiber optic cable (red) elements

4. Results - Calibration

Experimental tests setup
(fiber optic glued at DT sections)

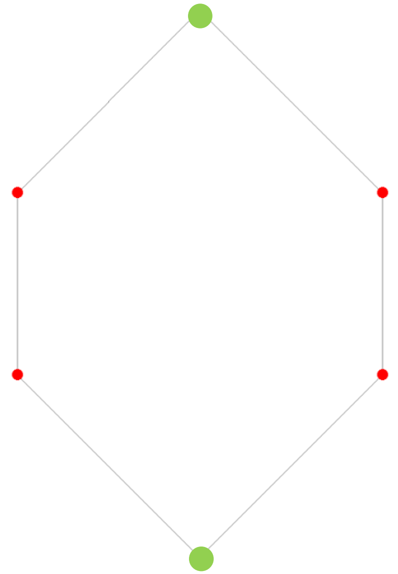


During experimental tests only the 4 central meshes were sensorized with optical fiber

Step	Mass [kg]
Load 01	1
Load 02	2
Load 03	4
Load 04	8
Load 05	16

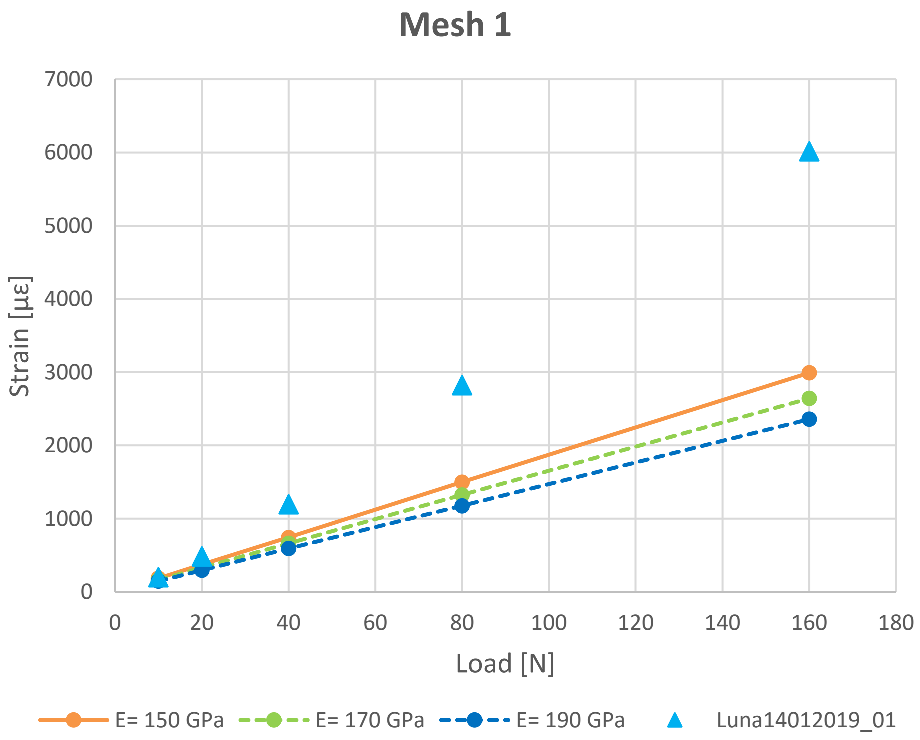
Calibration dataset: mean deformation of each sensorized mesh for each load step

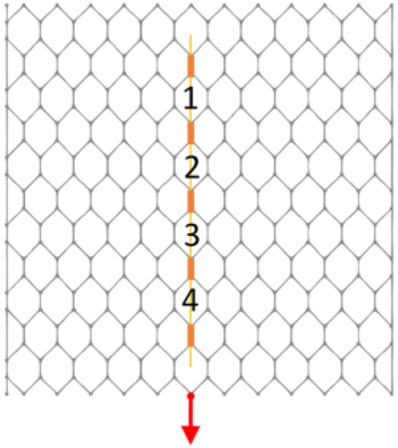
Numerical model
(2D wire mesh 8x10 cm, wire 2.70 mm)

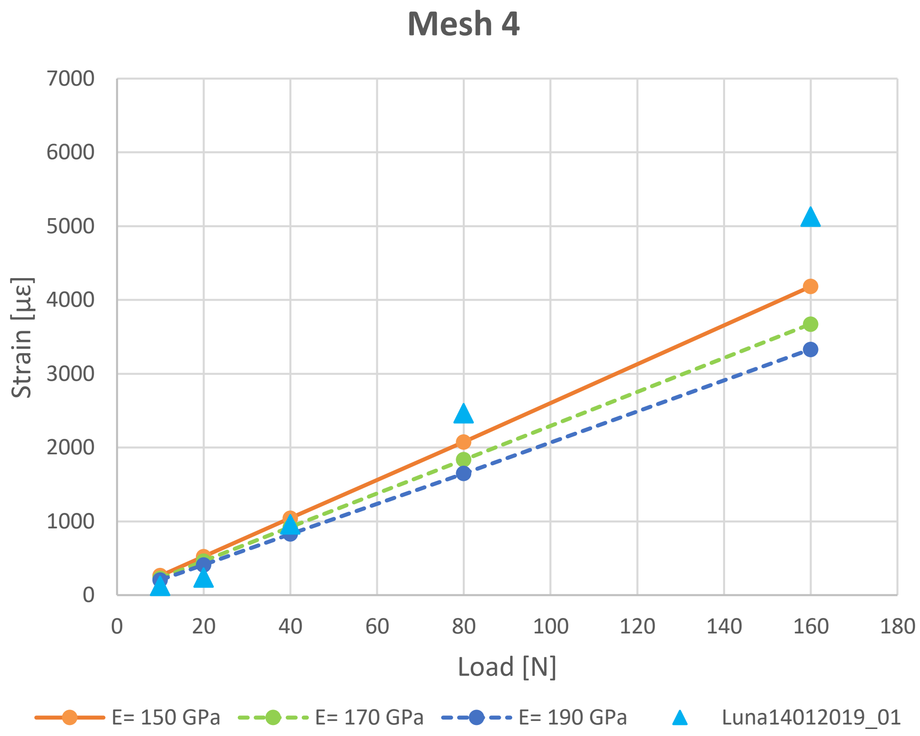


Mesh longitudinal deformation is obtained from the central nodes translation (green)

4. Results - Steel wire Young modulus calibration (E)

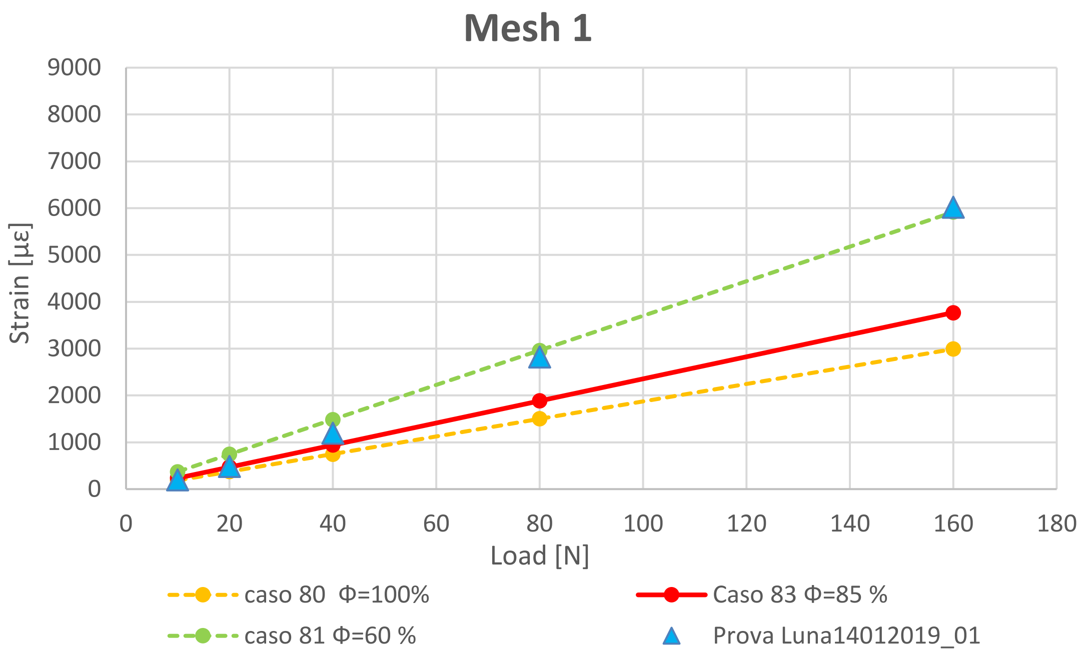


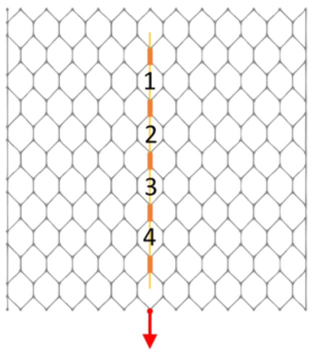


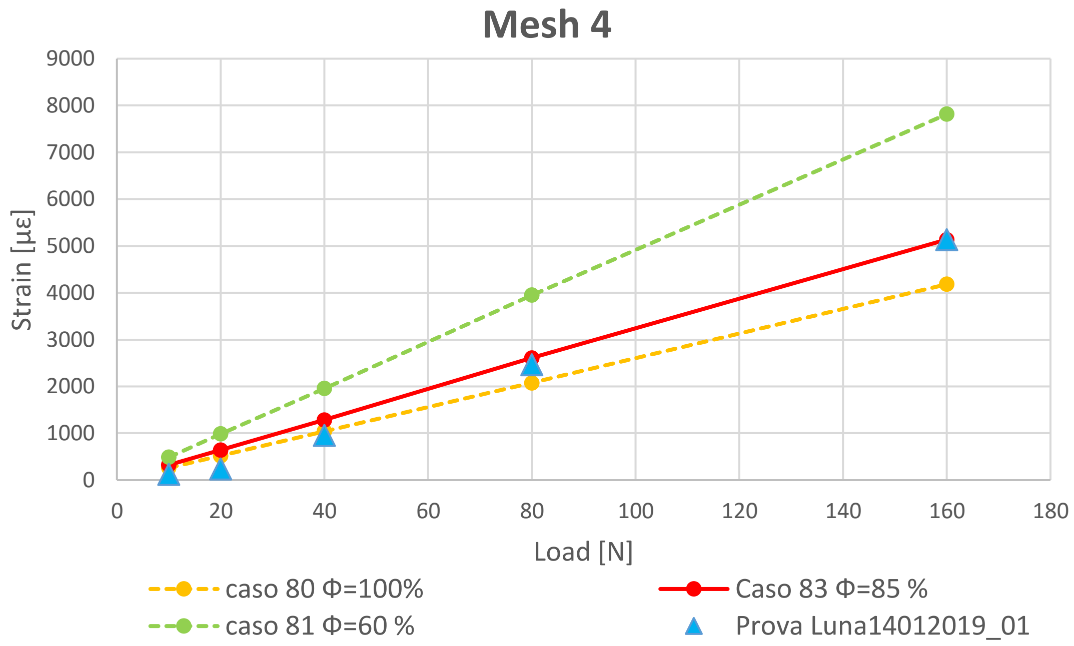


- 2D wire mesh model, linear analysis
- Parameter range: [150-190] GPa
- Calibrated value: **E= 150 GPa** (lower bound of the E varibility range of the material)

4. Risultati – Connection degree elements-nodes calibration (Φ)





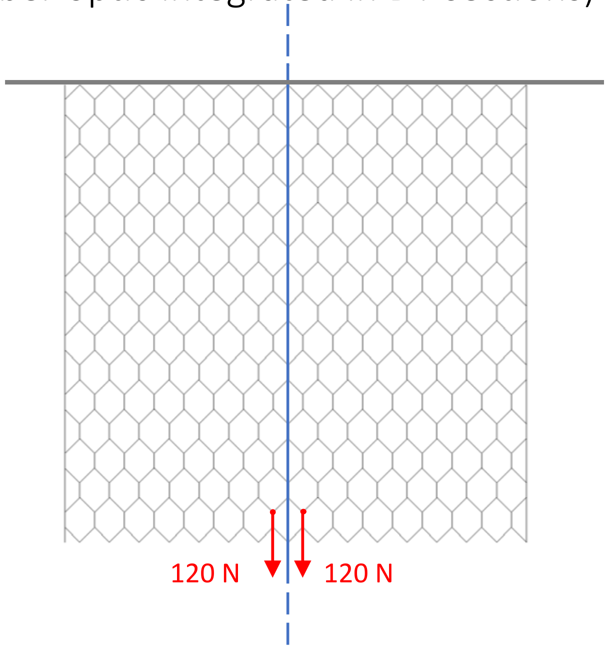


Mean absolute error [με]			
Mesh	Φ=100%	Φ=85 %	Φ=60 %
1	985	700	190
2	399	290	798
3	491	364	913
4	368	215	1256

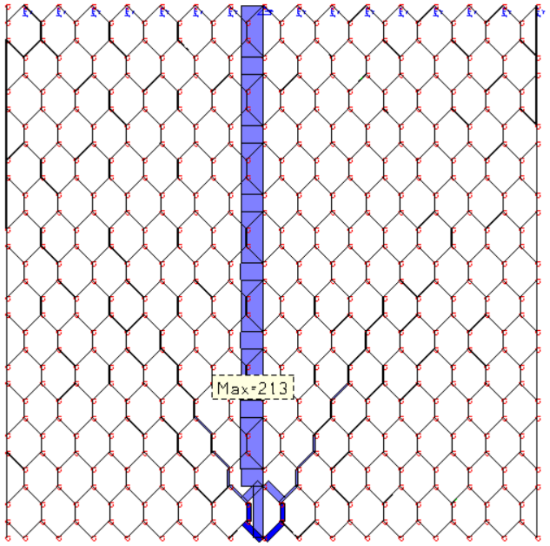
- 2D wire mesh model, linear analysis (E=150 GPa)
- *Parameter range* : [100-60]%
- Calibrated value: Φ= **85 %** (It minimizes the mean absolute error in 3/4 meshes)

4. Results – Wire-cable interaction

Experimental tests setup
(fiber optic integrated in DT sections)



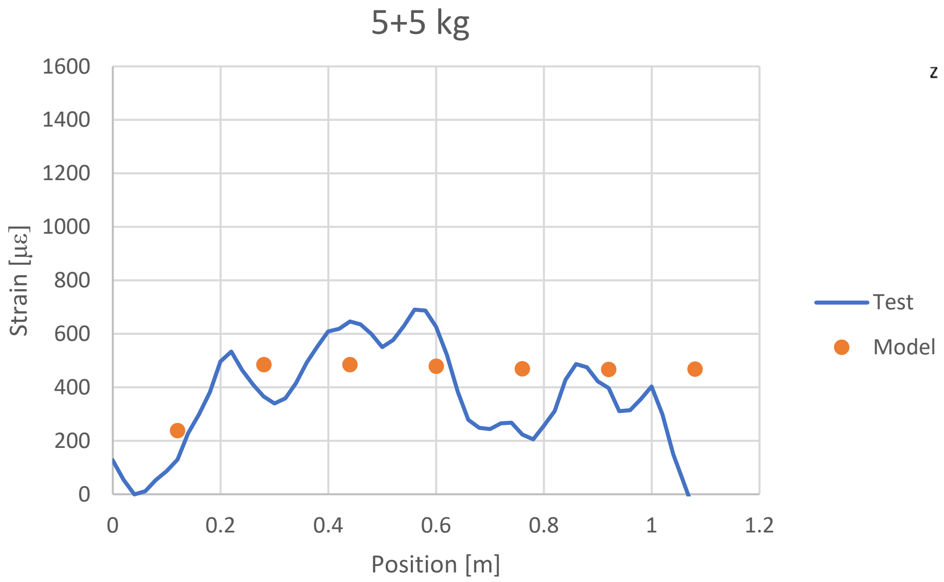
Wire mesh + optic fiber cable numerical model
(Axial actions in elements)

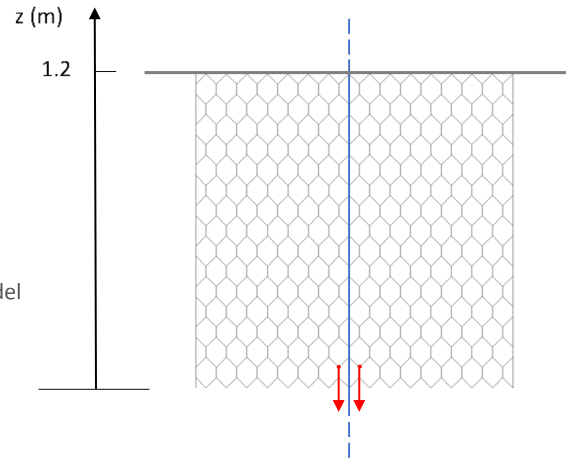


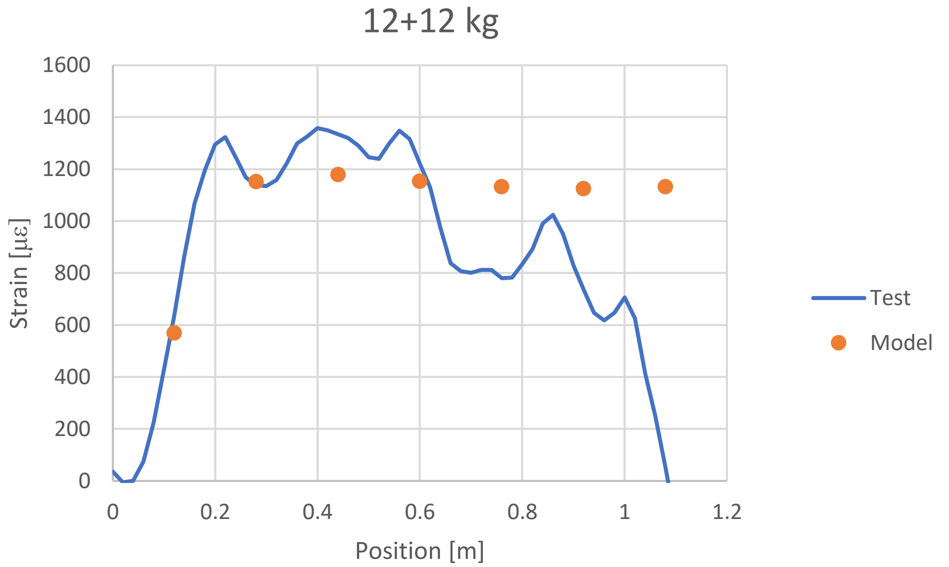
Values in [N]. Maximum load applied: 240 N

The cable takes on almost all of the applied load, becoming a «load-bearing» element of the system

4. Results – Numerical model vs tests





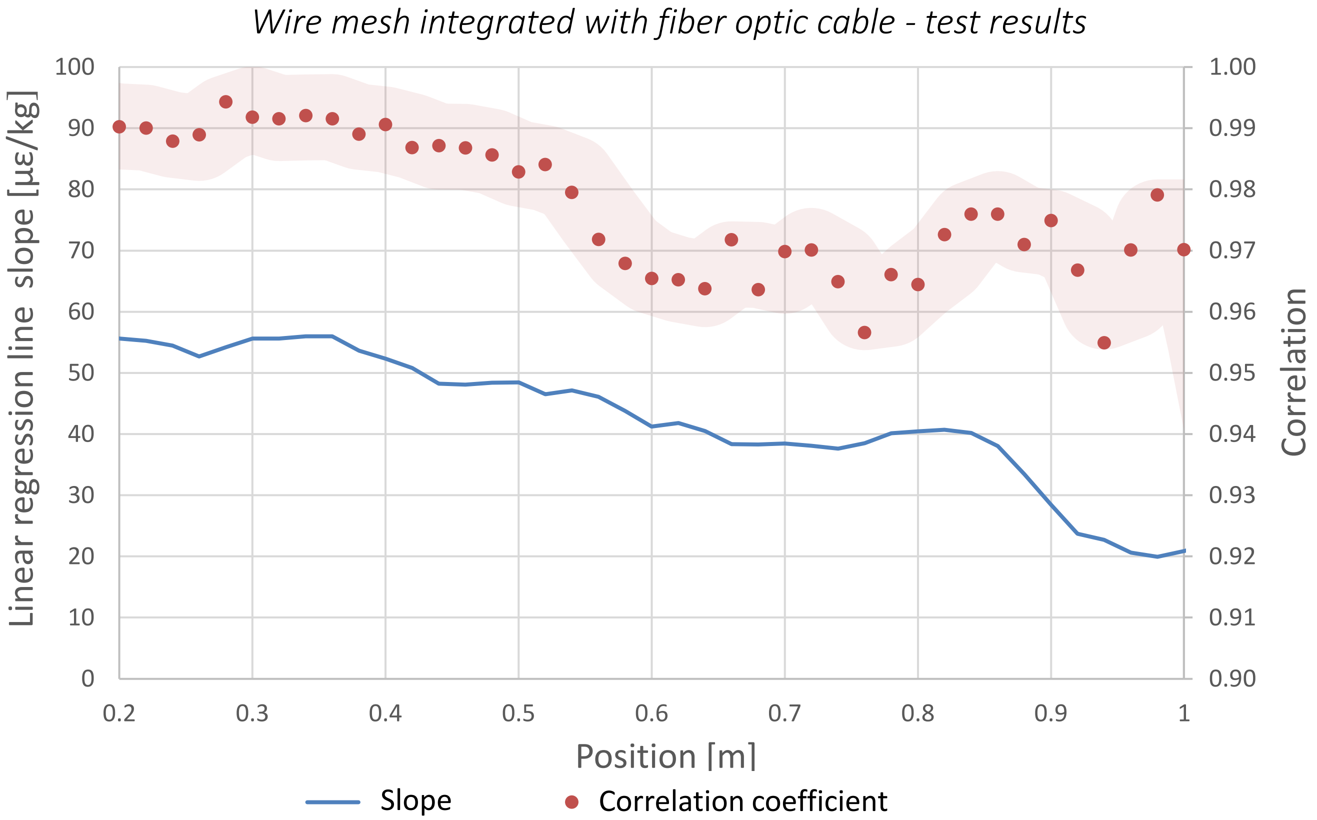


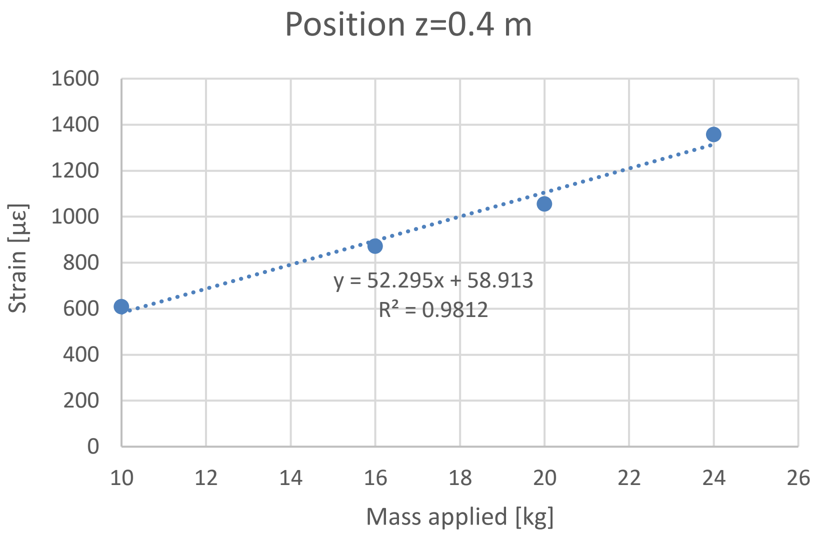
- 2D model, linear analysis
- Experimental tests on wire mesh sample integrated with optical fiber cable
- Numerical results (orange points) are positioned on the upper vertex of each mesh sensorized

Mean strain for [0.2-1] m position	5+5 kg	8+8 kg	10+10 kg	12+12 kg
Model strain [με]	477	769	961	1149
Test strain [με]	442	625	785	1055
Model strain/Test strain	1.08	1.23	1.22	1.09

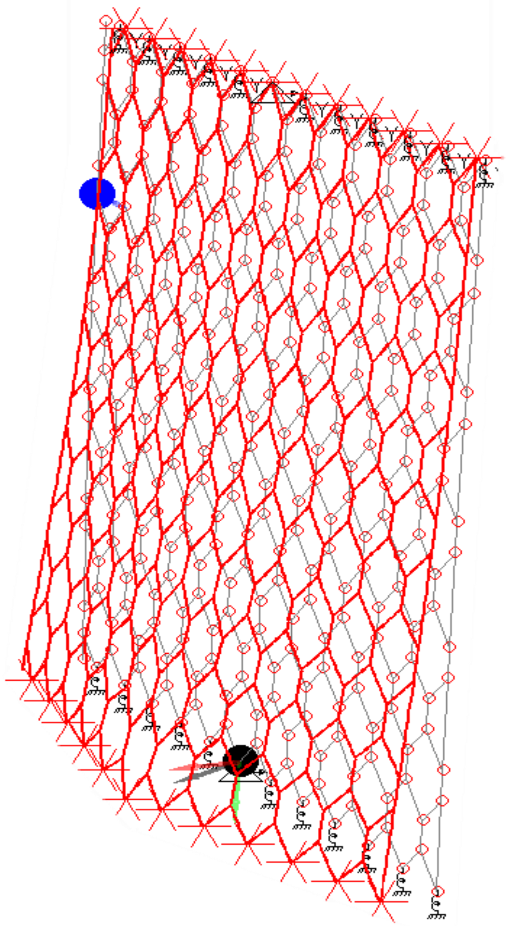
5. Conclusion

1. The double-twisted wire mesh, stressed in its plane with concentrated loads in the range 10-160 N, shows a good linearity in the deformation behavior





5. Conclusion



2. The fiber optic is suitable for the integration with the wire mesh. Its insertion does not change the linearity of the mechanical behavior of the wire mesh.

3. The micromechanical numerical model has been calibrated and validated by experimental tests, reaching the definition of a «digital twin» of the prototype of the sensing revetment.

4. The digital twin can be used for the product designing and it allows to study the possible solutions for its installation on the embankment.

6. Perspectives

Definition of the product layout, with a particular focus on the sensoristic component management

Conceptualization of a custom fiber optic cable

New experimental tests able to simulate an overflowing current on the sensing revetment

Product testing on a real scenario


Thanks for your attention
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