ECSA-5
5th International Electronic Conference on Sensors and Applications
15 – 30 November 2018

SAFERUP! Thinking Beyond the Pavement

SMARTBRICK

FULL-SCALE TESTING OF A MASONRY BUILDING MONITORED WITH SMART BRICK SENSORS

A. D'Alessandro[1], A. Meoni[1], E. García-Macías[1], M. Gioffrè[1], N. Cavalagli[1], F. Ubertini[1]

1 University of Perugia (Italy)
2 Universidad de Sevilla (Spain)

DICA DIPARTIMENTO DI INGEGNERIA CIVILE E AMBIENTALE
DIPARTIMENTO DI ECCELLENZA

UNIVERSITÀ DEGLI STUDI DI PERUGIA

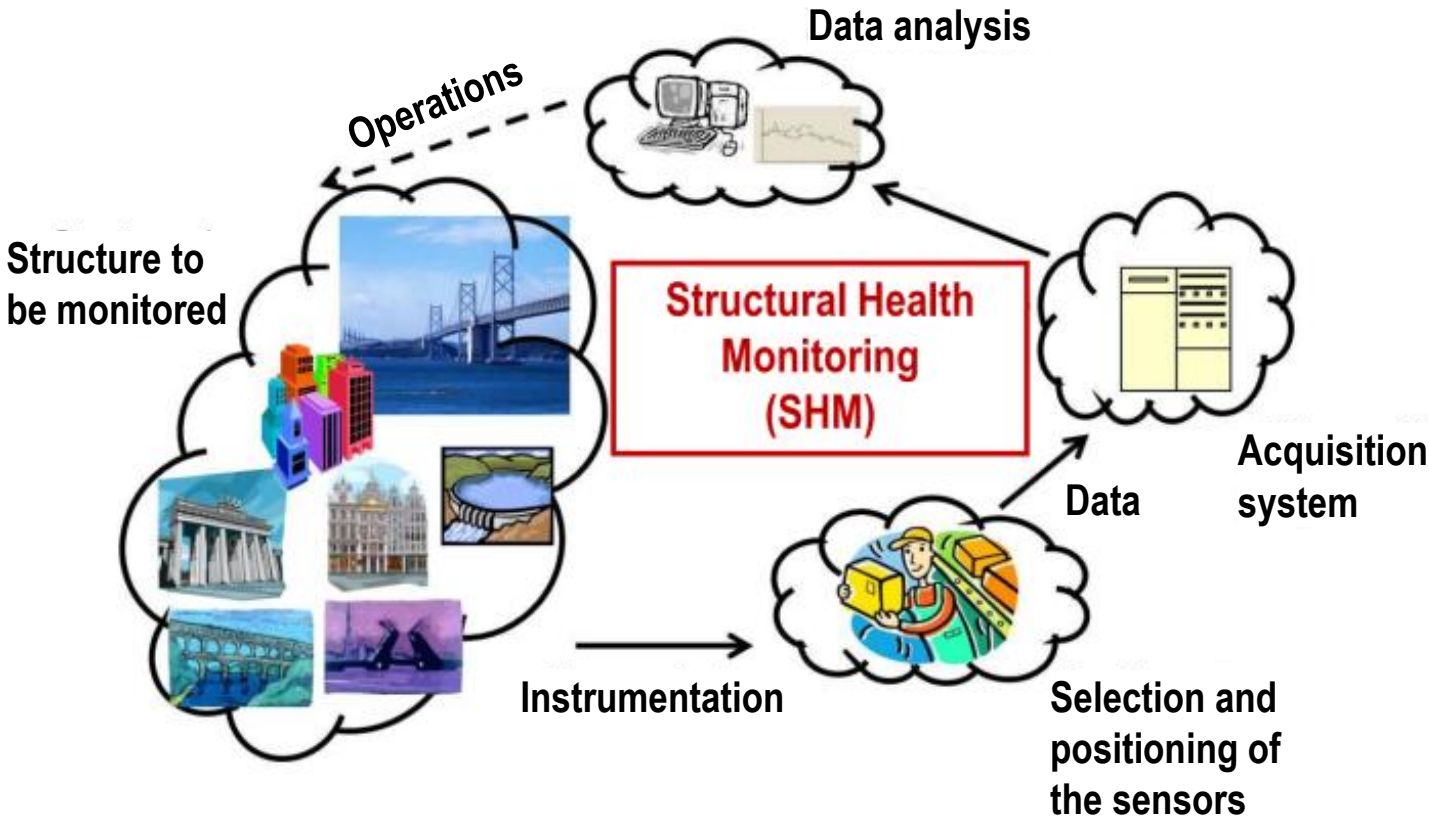
antonella.dalessandro@unipg.it

OVERVIEW

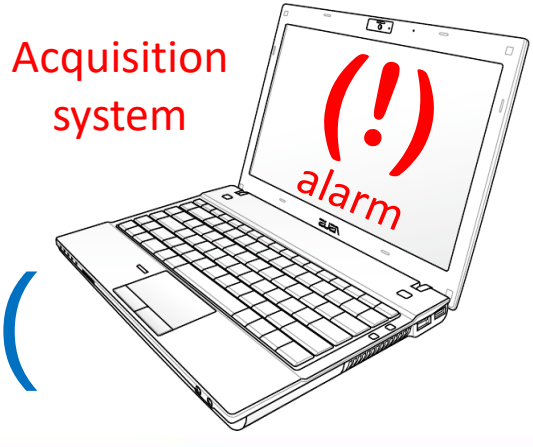
AIM: Structural Health Monitoring of new and existing Masonry Structures

- Motivation
- Smart bricks:
  - Concept
  - Fabrication
  - Sensing characterization
- Smart masonry:
  - Walls
  - Buildings
- Conclusions

MOTIVATION: Structural Health Monitoring



MOTIVATION: Self-sensing Structures

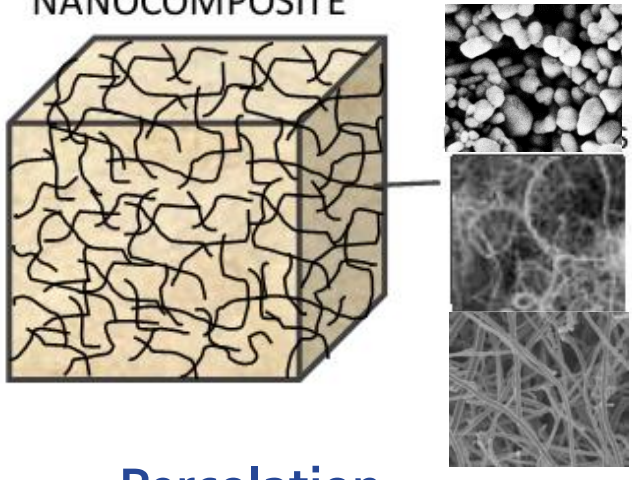


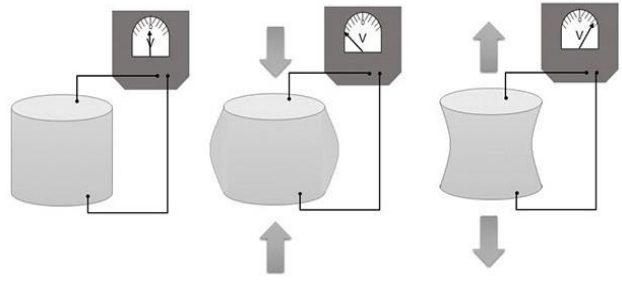
November 15th, 2018

SMART BRICK: Concept

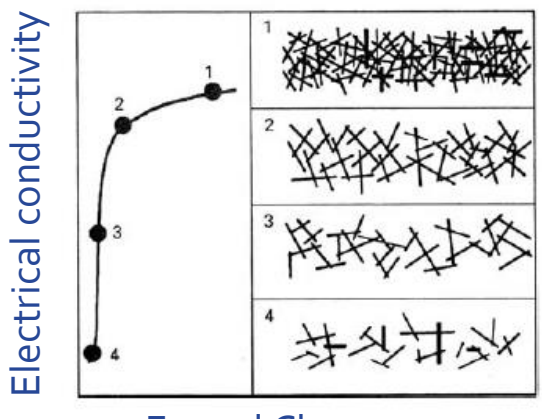
CARBON-BASED NANOCOMPOSITE

NANOFILLERS

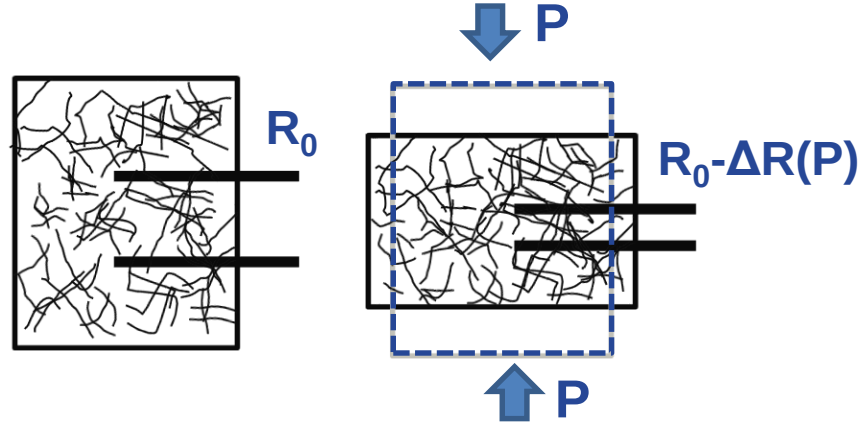




Percolation

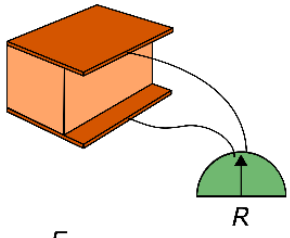


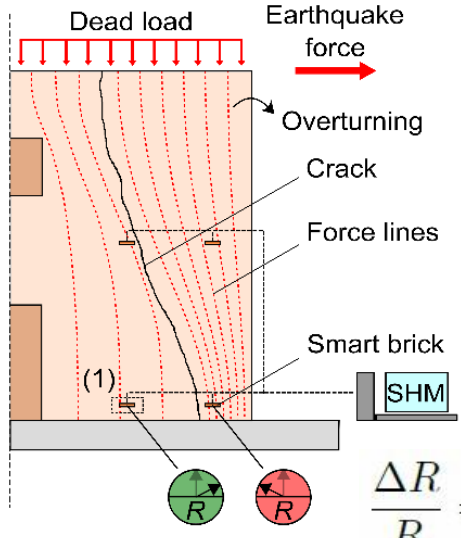
Fu and Chung, 1995

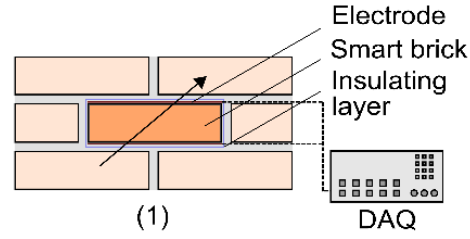


November 15th, 2018

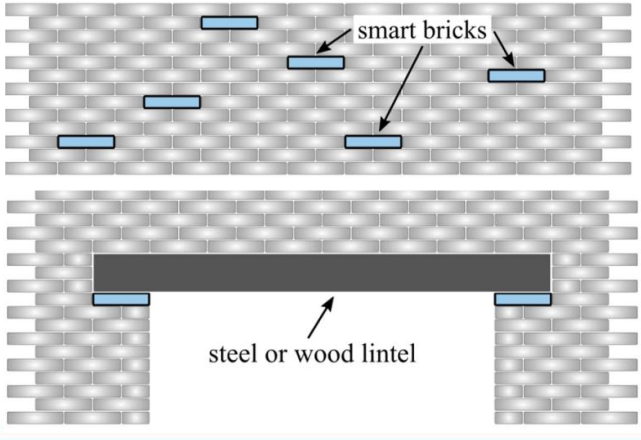
SMART BRICK: Concept

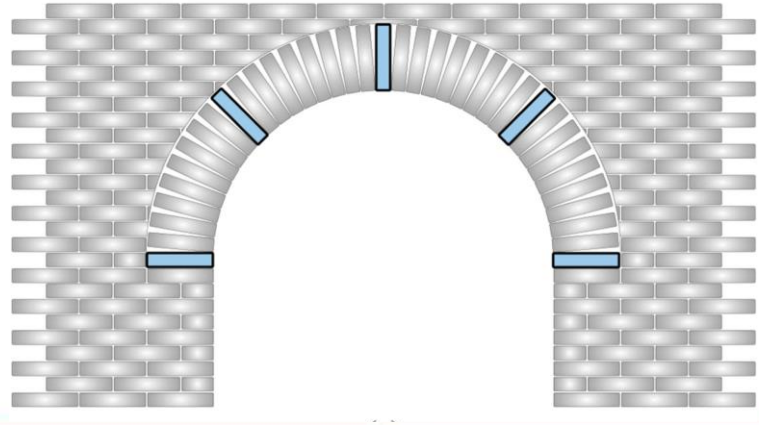






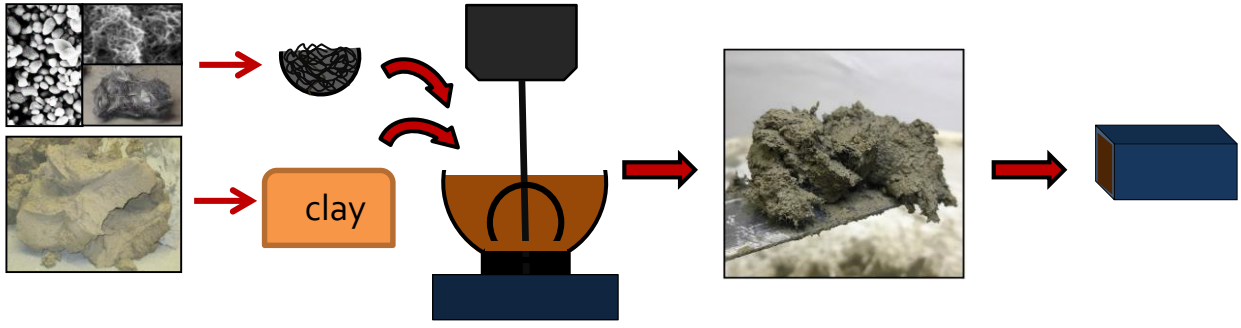
$$\frac{\Delta R}{R} = -\lambda \varepsilon_v = -\lambda(\varepsilon_x + \varepsilon_y + \varepsilon_z)$$





November 15th, 2018

SMART BRICK: Fabrication



(a) preparation of clay and fillers

(b) mechanical mixing

(c) nanomodified clay

(d) moulding of bricks

(e) embedding of electrodes

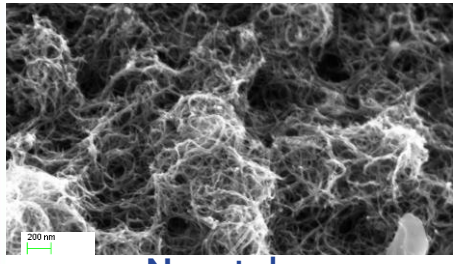
(f) drying in oven

(g) burning at 900°C

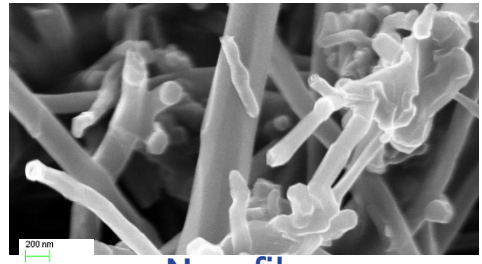
(h) nanomodified bricks

SMART BRICKS: Fillers

Carbon Based



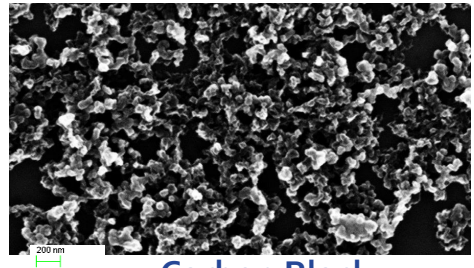
Nanotubes



Nanofibers

Titania

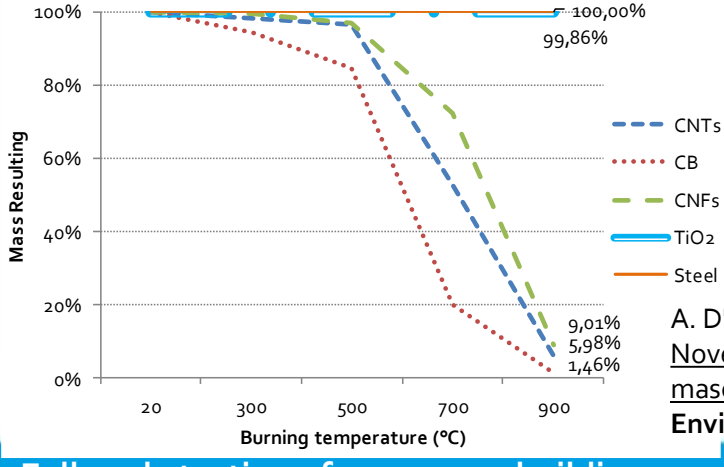
Graphene nanoplatelets



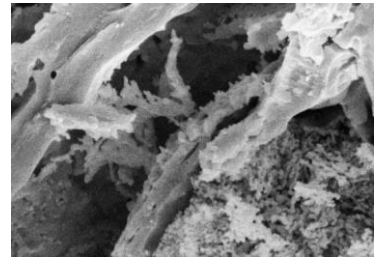
Carbon Black

Stainless steel microfibers

Thermogravimetric analysis



Carbon Nanofibers



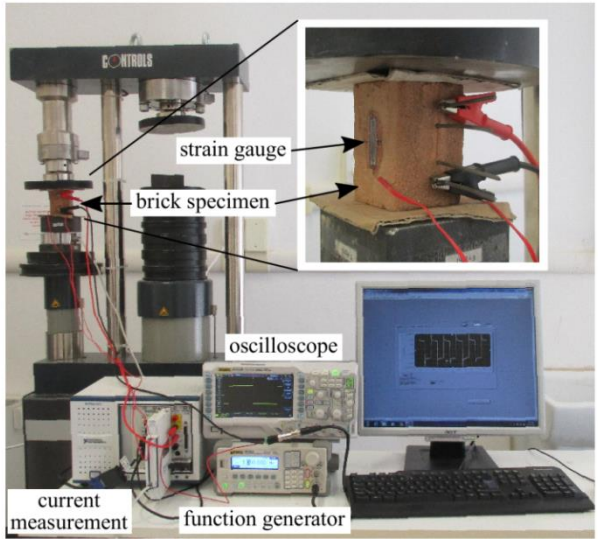
Stainless steel microfibers

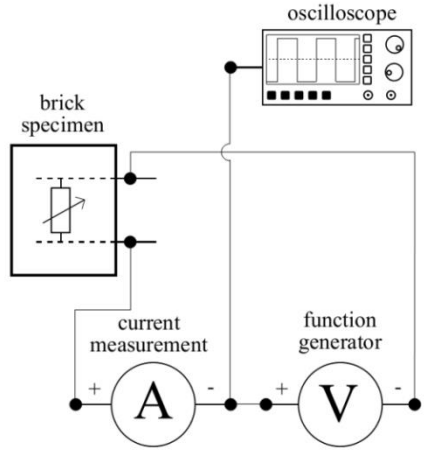
A. D'Alessandro, F. Ubertini, A.L. Materazzi, S. Laflamme, A. Downey, Novel nanocomposite clay brick for strain sensing in structural masonry, EEEIC17, **17th IEEE International Conference on Environment and Electrical Engineering**, Milan june, 7-10, 2017

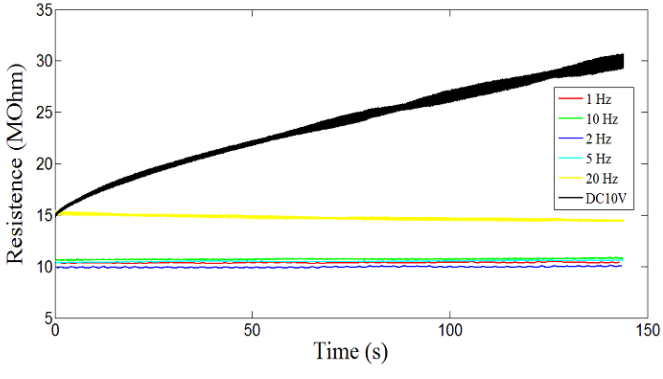
SENSING CHARACTERIZATION

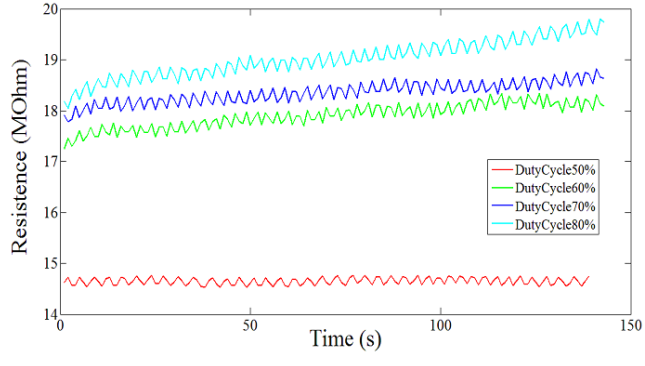
- ✓ Electrical Performance
- ✓ Electromechanical Behaviour
  - Hold loads
  - Cyclical loads
- ✓ Smart Masonry
  - Walls
  - Building

Electrical Performance

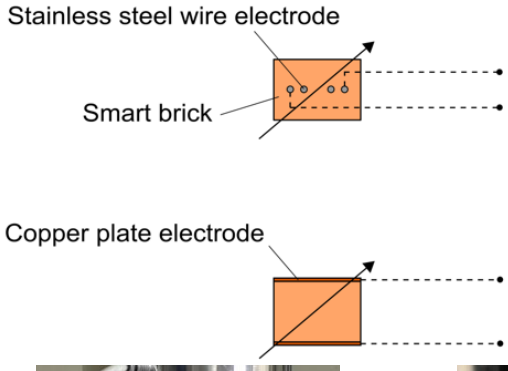


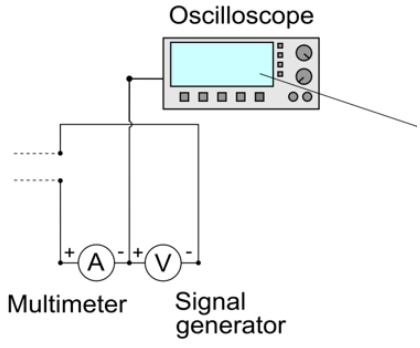


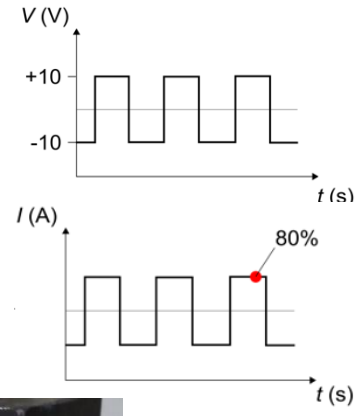


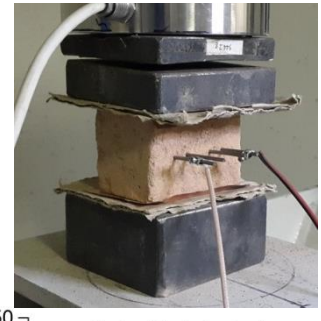


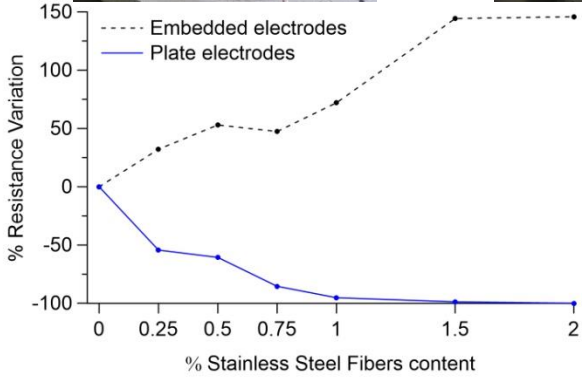
Electrical Performance

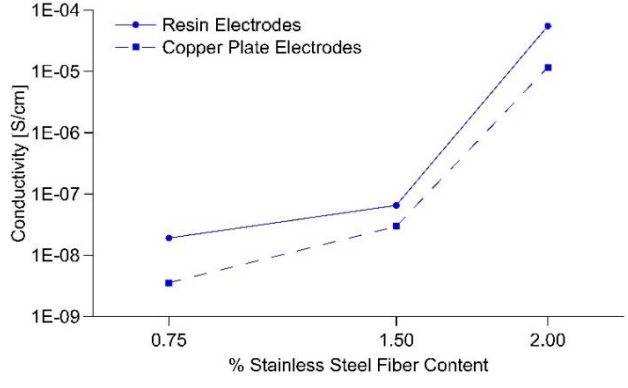






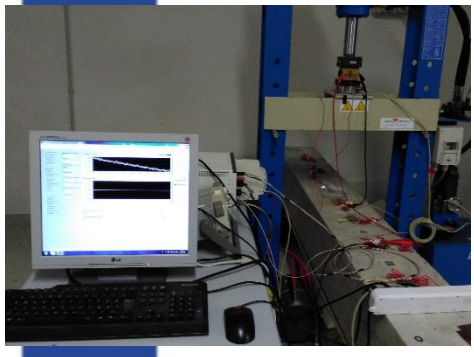


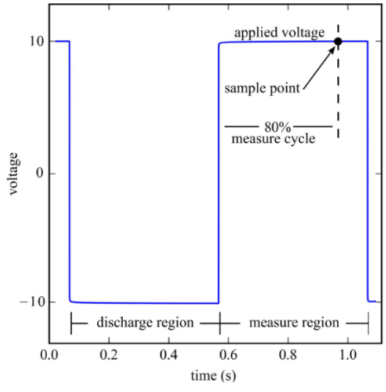


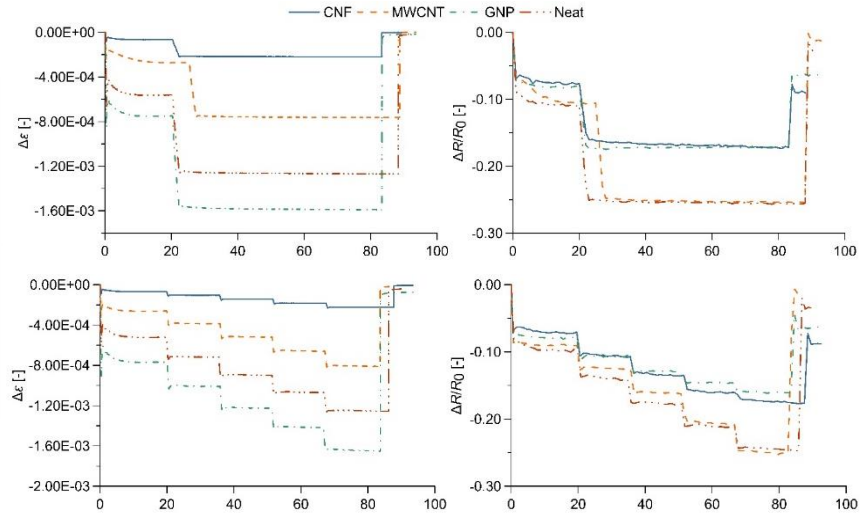


A. D'Alessandro, A. Meoni, and F. Ubertini, "Stainless Steel Microfibers for Strain-Sensing Smart Clay Bricks," **Journal of Sensors**, vol. 2018, Article ID 7431823, 8 pages, 2018. https://doi.org/10.1155/2018/7431823.

Electromechanical Behavior: hold loads



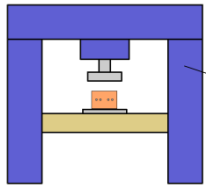




$$\frac{\Delta R}{R_0} = -GF \cdot \varepsilon \qquad S = \frac{\Delta R}{\varepsilon} = -GF \cdot R_0$$

Sample type	R_0 (MΩ)	ΔR (MΩ)	ε ($\cdot 10^{-3}$)	E (MPa)	GF	S (MΩ)
Neat	29.1	2,49	0.447	913	191	5575
MWCNTs	13.3	1,79	0.557	735	241	3206
CNFs	34.2	2,67	0.150	2997	520	17760
GNPs	24.4	2,30	0.765	571	123	5575

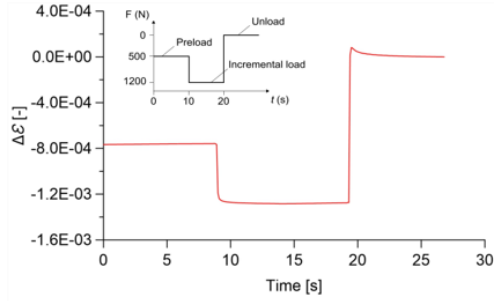
Electromechanical Behavior: hold loads

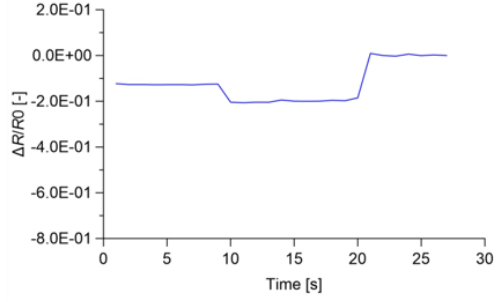


COPPER PLATES

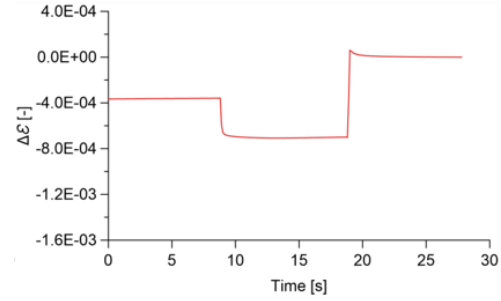
GRAPHITE-BASED RESIN

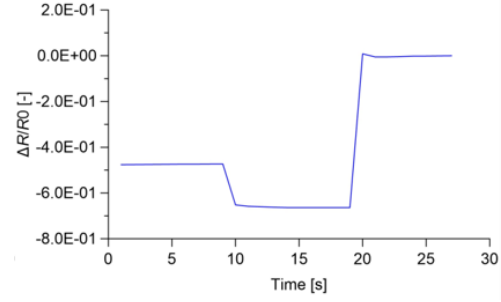
NORMAL BRICK

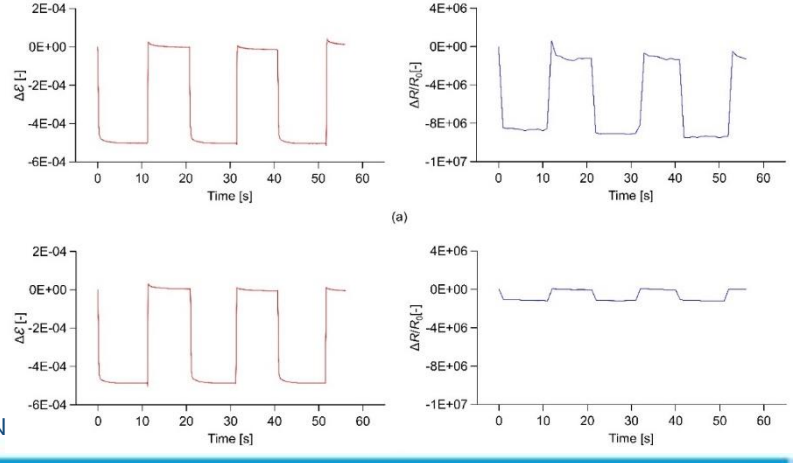




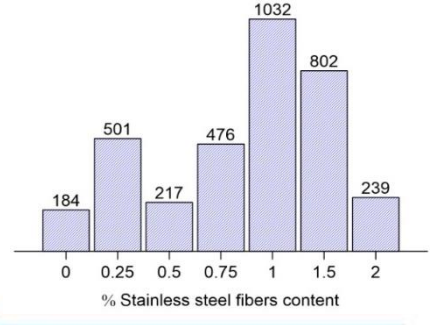
STEEL FIBER BRICK



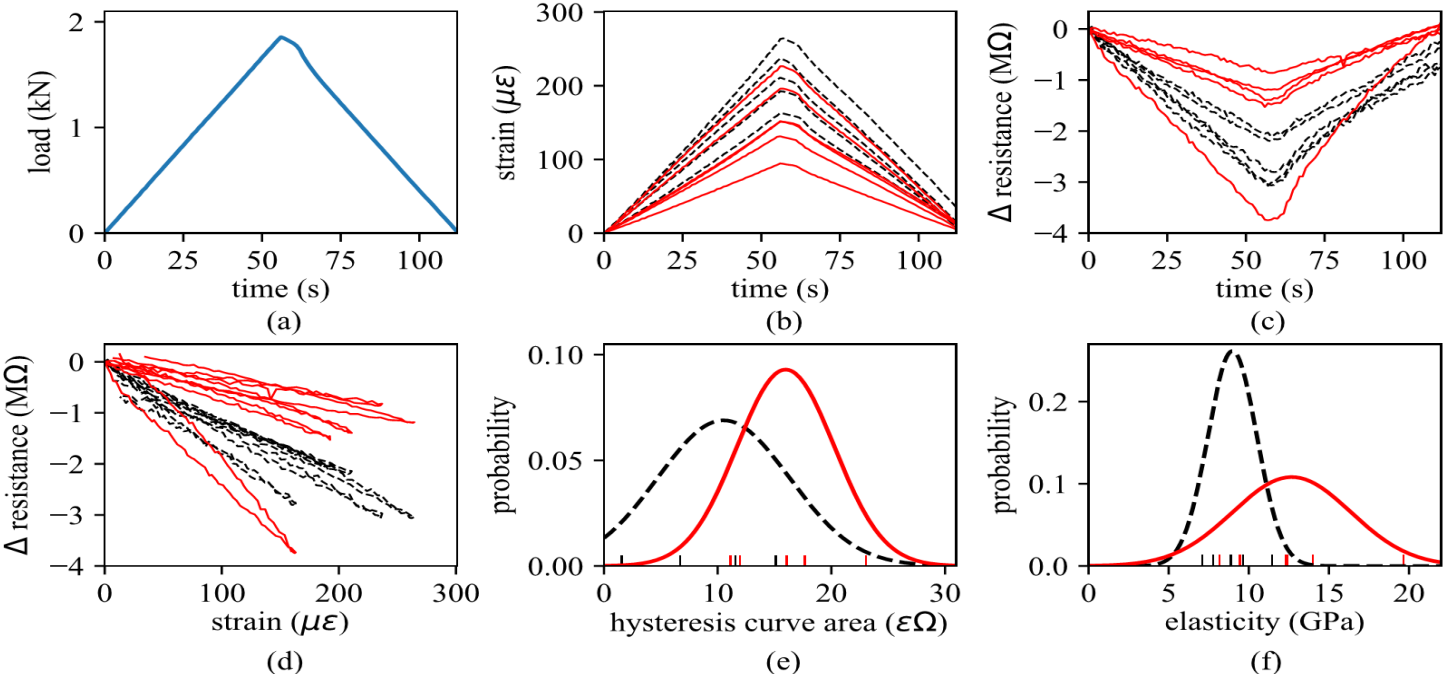


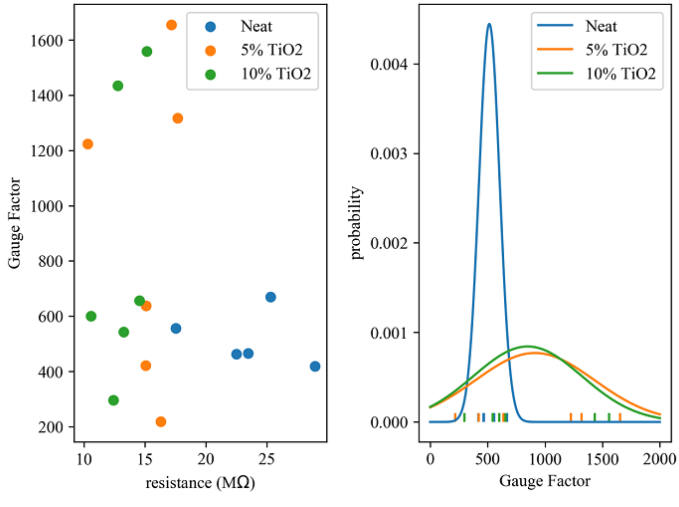


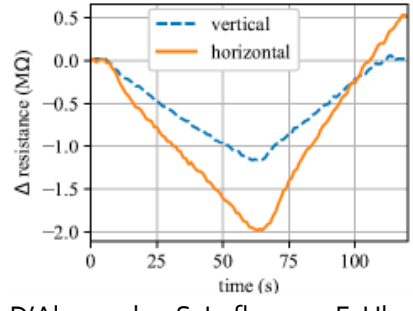
GAUGE FACTORS



Electromechanical Behavior: cyclical loads

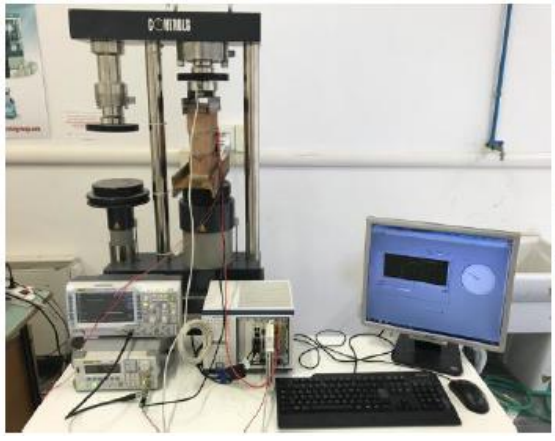


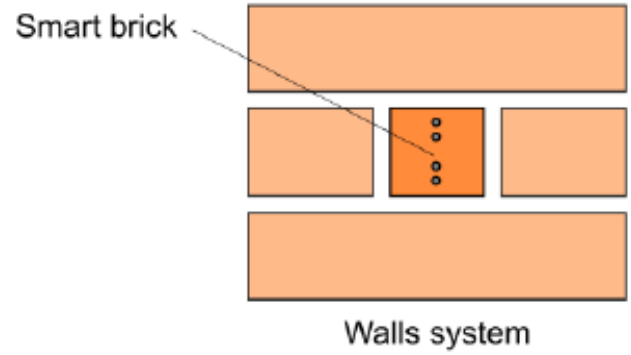


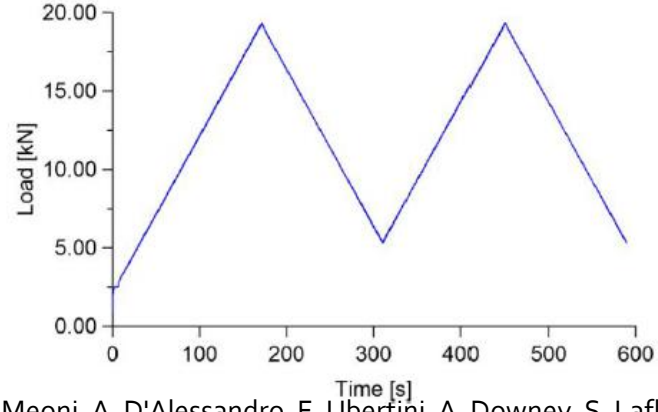


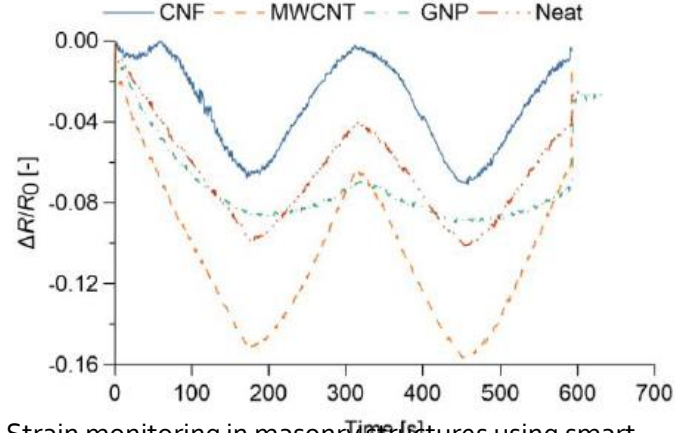
A. Downey, A. D'Alessandro, S. Laflamme, F. Ubertini Smart bricks for strain sensing and crack detection in masonry structures, **Smart Materials and Structures** 27(1) (2018) 015009 (15pp)

SMART MASONRY: Small Walls



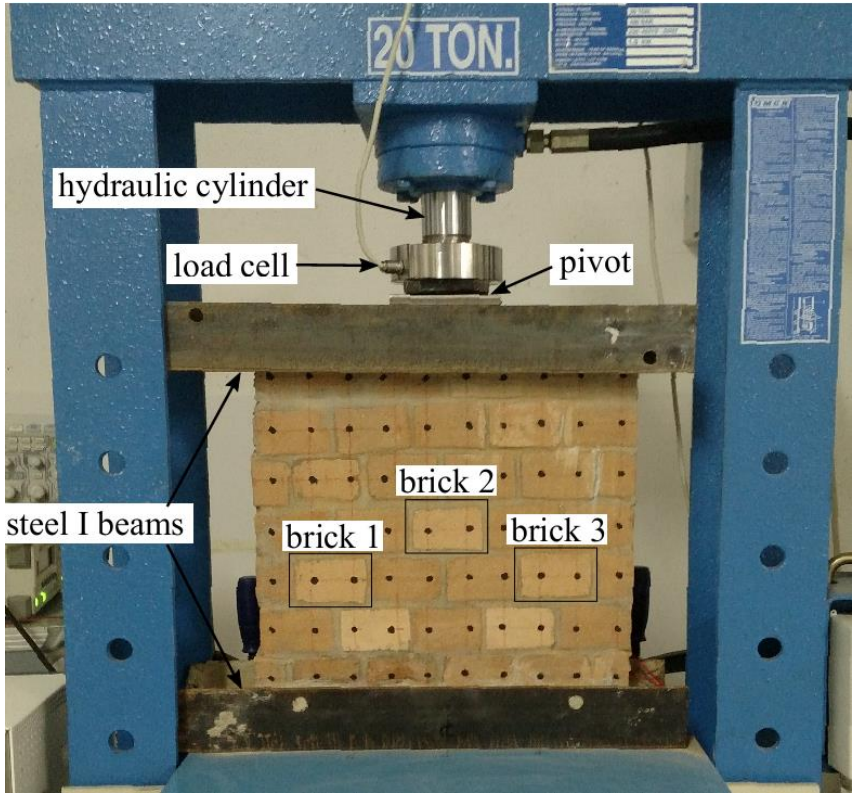


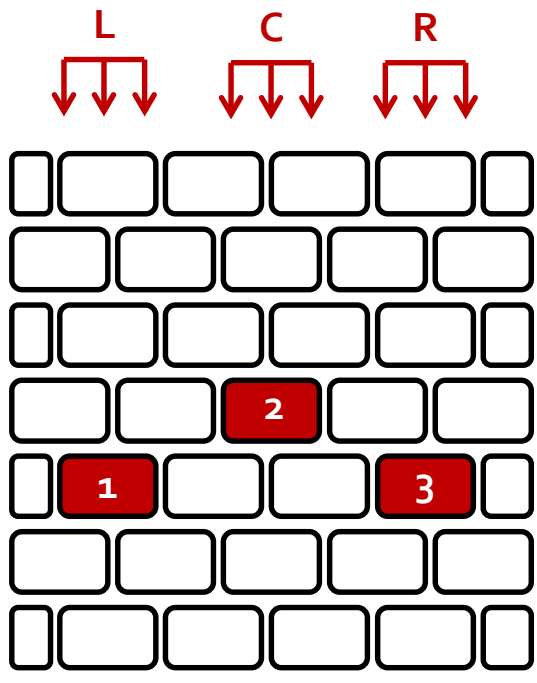




A. Meoni, A. D'Alessandro, F. Ubertini, A. Downey, S. Laflamme Strain monitoring in masonry structures using smart bricks, (2018) Proceedings of **SPIE 2018 - The International Society for Optical Engineering** doi: 10.1117/12.2297526

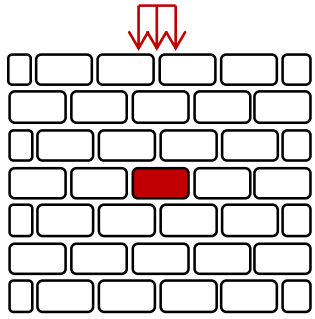
SMART MASONRY: Walls

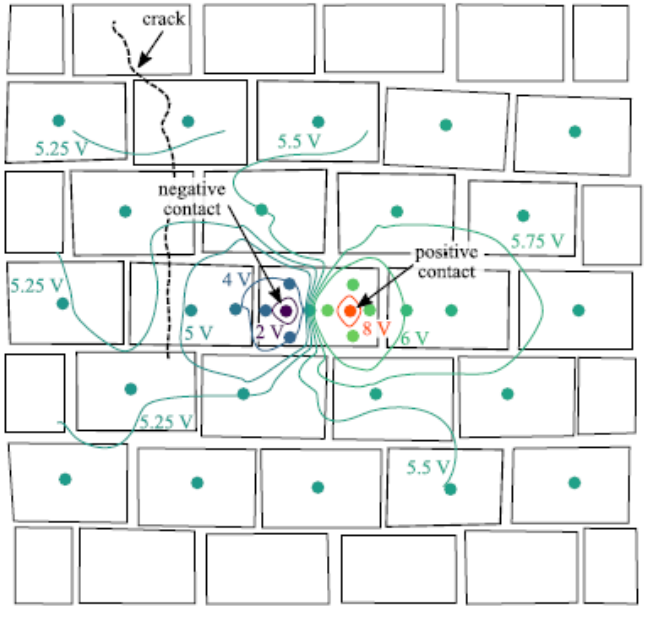


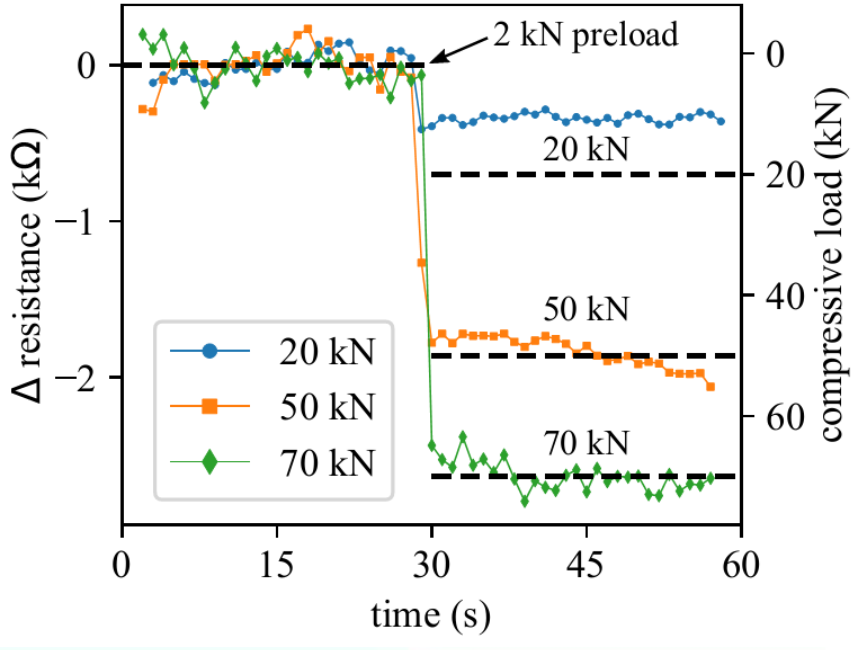


A. Downey, A. D'Alessandro, S. Laflamme, F. Ubertini Smart bricks for strain sensing and crack detection in masonry structures, **Smart Materials and Structures** 27(1) (2018) 015009 (15pp)

SMART MASONRY: Walls

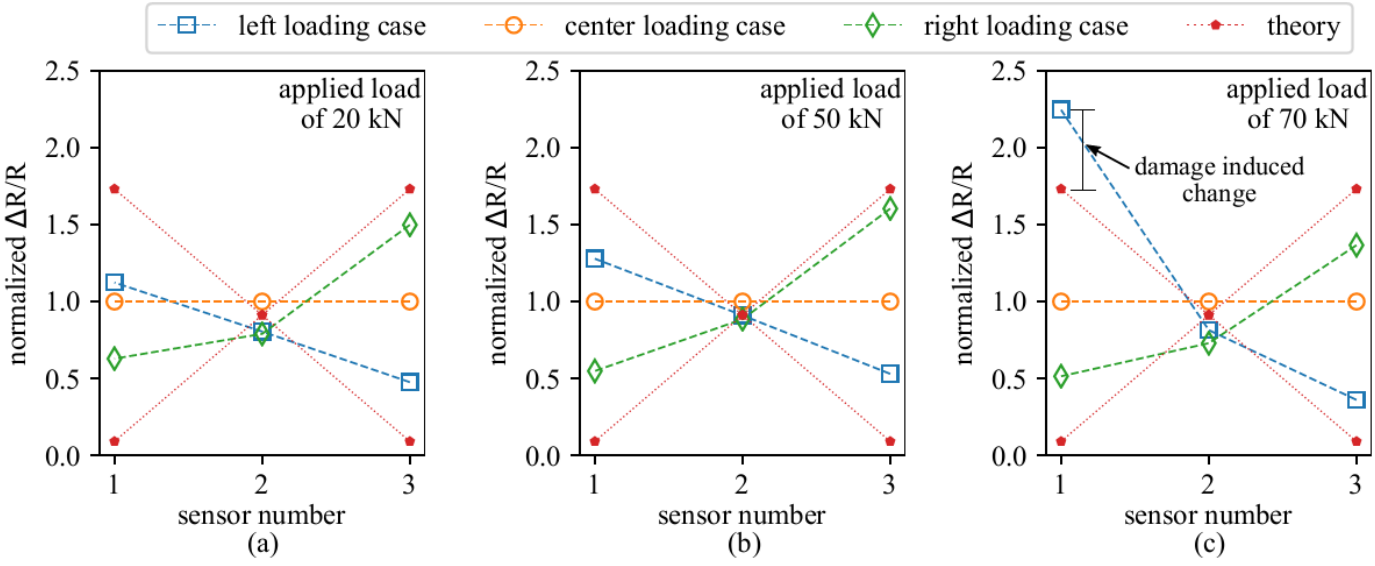


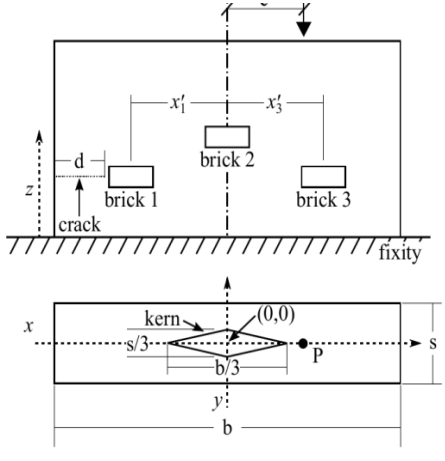




November 15th, 2018

SMART MASONRY: Walls

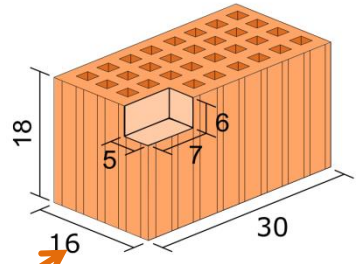


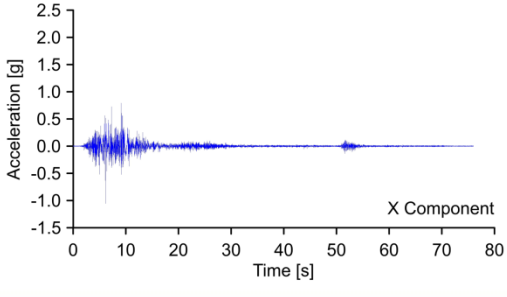


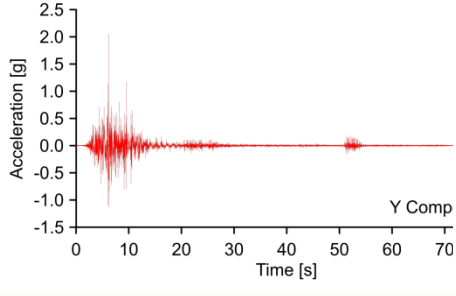
$$\overline{\Delta R}(x) = \frac{\Delta R(x)}{\Delta R(x)|_{e=0}} = 1 + \frac{eA}{J}x = 1 + \frac{12e}{b^2}x$$

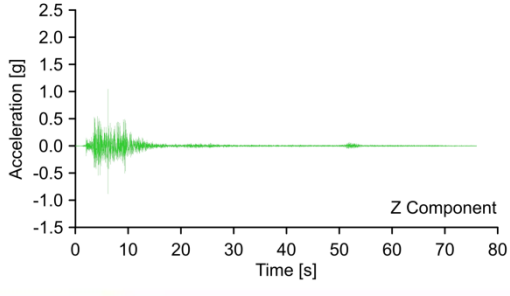
November 15th, 2018

SMART MASONRY: Buildings



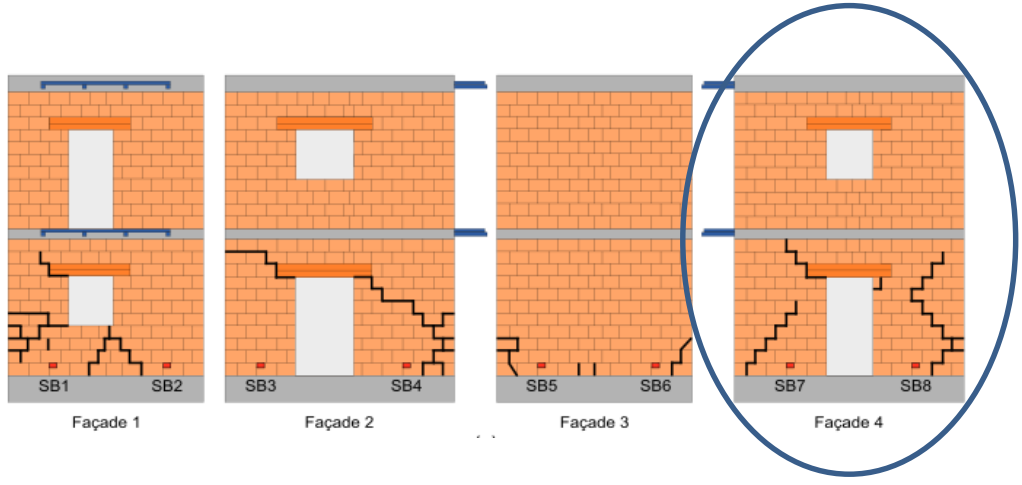




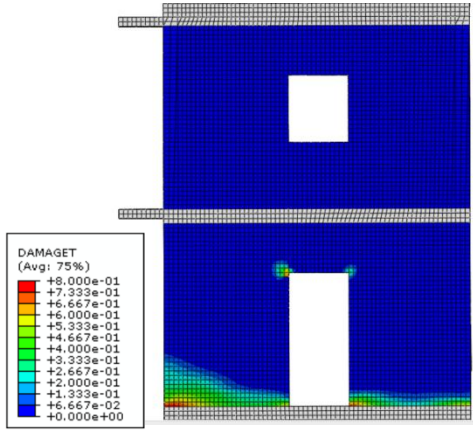


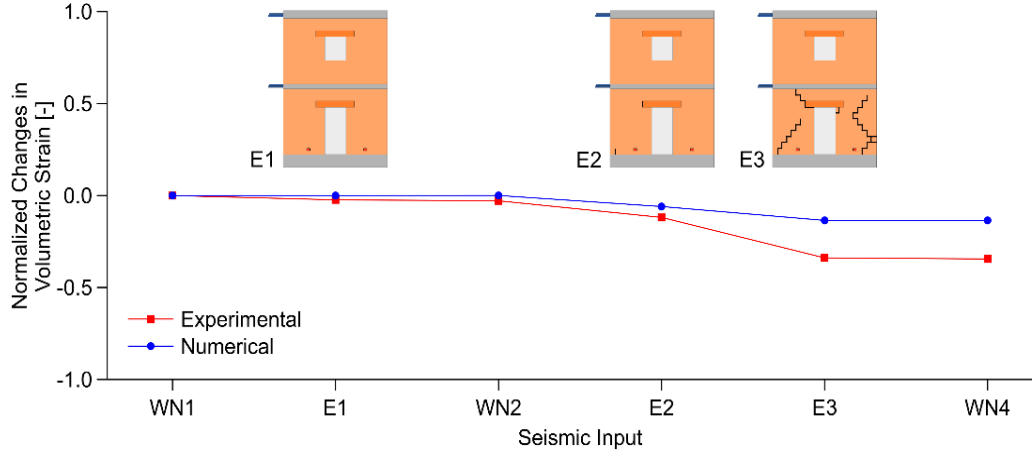
November 15th, 2018

SMART MASONRY: Buildings



Façade 4





November 15th, 2018

CONCLUSIONS

- Novel smart clay bricks doped nano- and micro-fillers with self-sensing abilities and their applications have been investigated.
- Issues are related to the optimization of the preparation procedure (stability of the fillers at high temperature, choice of electrodes and inclusions, proportioning of fillers).
- Electrical and electromechanical tests of the smart bricks demonstrate enhanced gauge factors.
- Tests on walls and on full-scale specimens show that they can identify permanent changes due to progressive damages.
- Smart bricks are promising for a quick assessments of a structural integrity of masonry constructions after important events as earthquakes.

ACKNOWLEDGMENTS

SAFER UP!
Thinking Beyond the Pavement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 765057

PRIN SMART BRICK

"SMART-BRICK: Novel strain-sensing nanocomposite clay brick enabling self-monitoring masonry structures" (protocol no. 2015MS5L27).

UNIVERSITÀ DEGLI STUDI
DI PERUGIA

Thank you for your attention!

antonella.dalessandro@unipg.it