A.D. 1308 unipg

DIPARTIMENTO
DI INGEGNERIA
CIVILE E AMBIENTALE

Advanced Grant

SMART MASONRY ENABLING SAFETY-ASSESSING STRUCTURES AFTER EARTHQUAKES (SMS-SAFEST)

Roma 10/07/2023

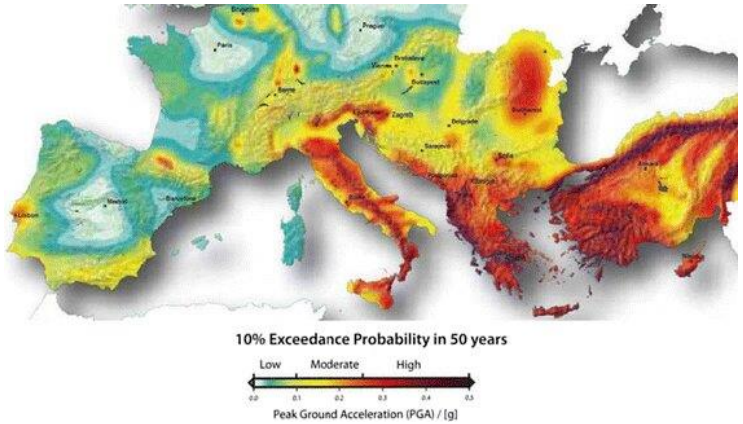
Filippo Ubertini

SMS-SAFEST
reinventing masonry

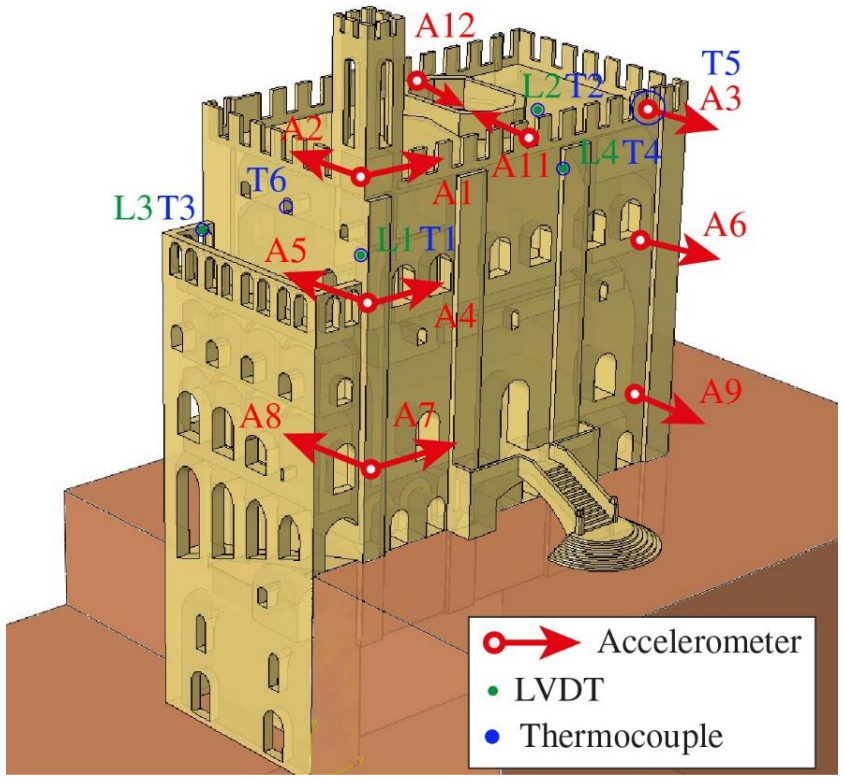
MOTIVATION

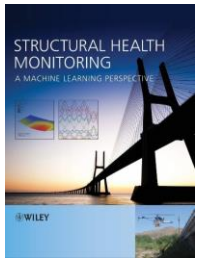
Traditional **SHM hardly applicable to complex masonry buildings**

Earthquakes and masonry



- Majority of European built heritage
- Poor state of preservation
- High seismic hazard





Axiom. Sensors cannot measure damage.

Bottlenecks:

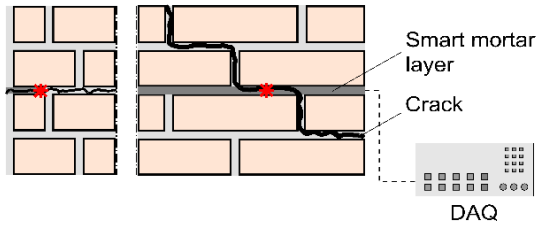
- scalability
- durability
- transmission
- access
- costs
- aesthetics

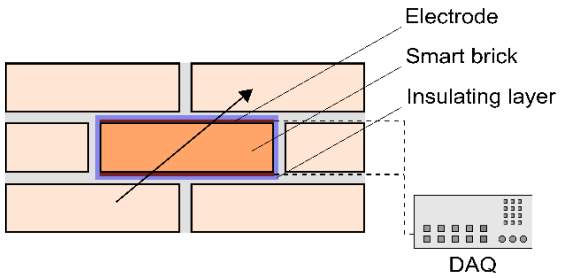
Can we achieve a direct damage-to-decision link?

BREAKTHROUGH

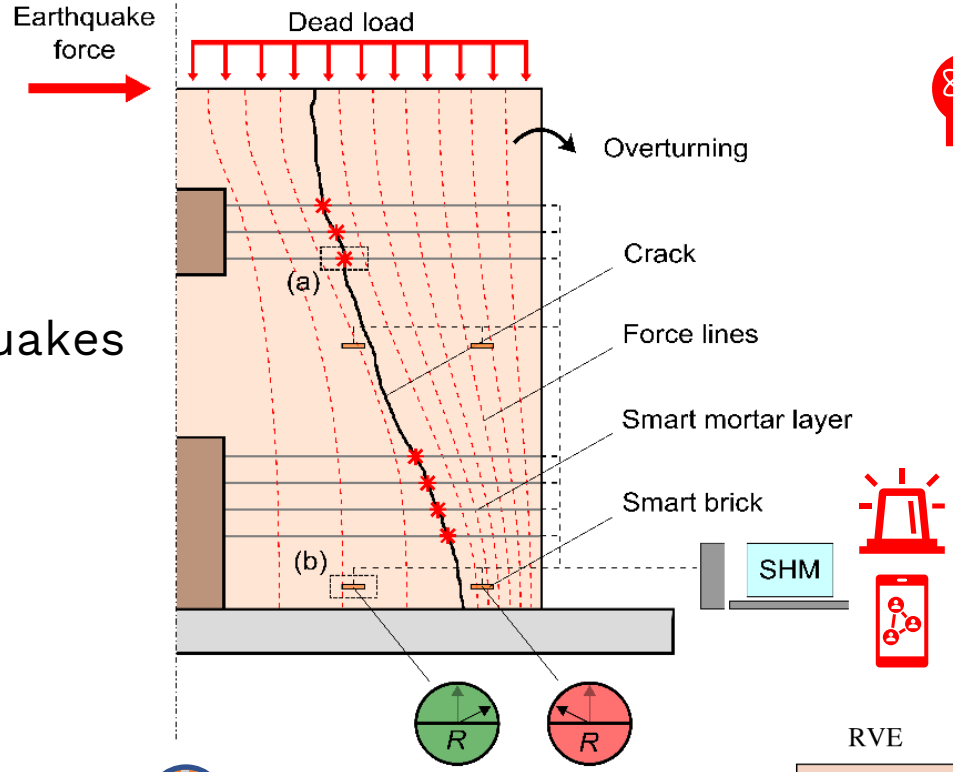
Smart masonry

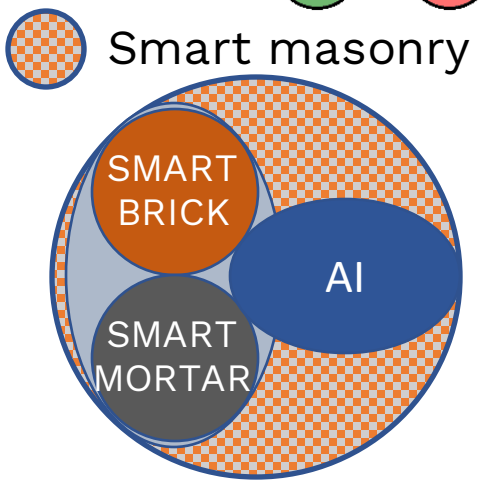
self-assessing masonry structures after earthquakes





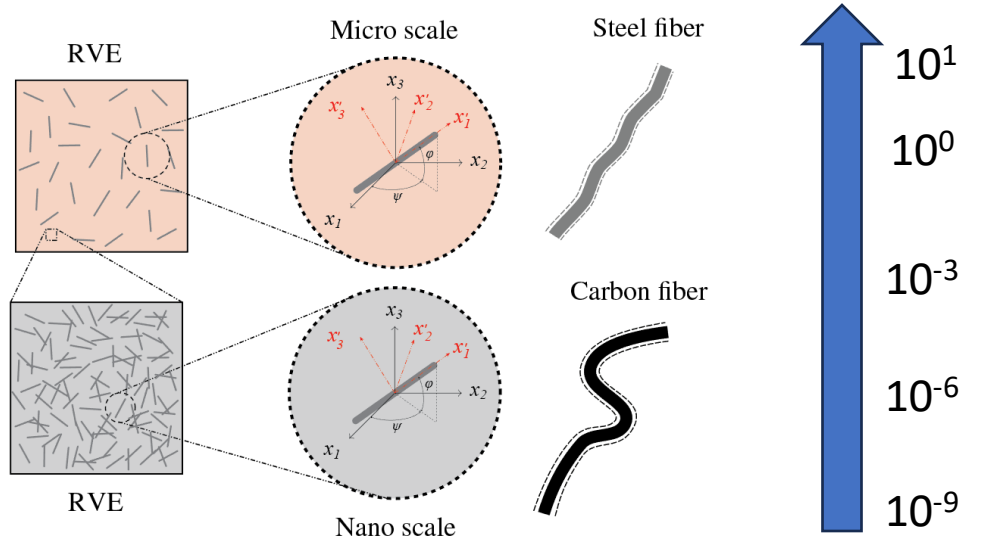
- ✓ Smart bricks – strain changes
- ✓ Smart mortars – crack detection
- ✓ Physics-enhanced AI - Damage ID





Key challenges and advances

- ✓ Sensing units
- ✓ low-cost/low-impact electronics
- ✓ repointing and brick substitution
- ✓ machine learning/AI algorithms
- ✓ full-scale testing



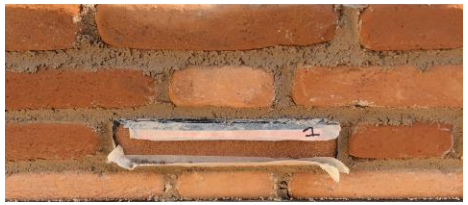
METHODOLOGY

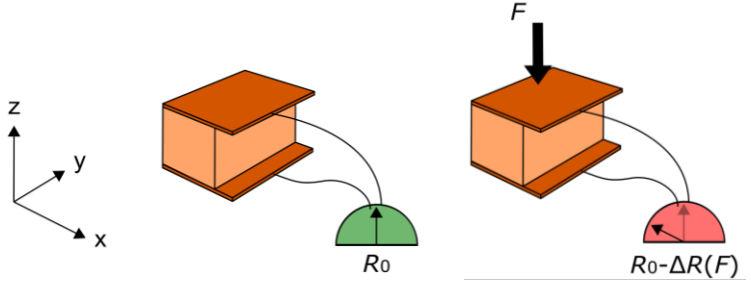
Where do we start from

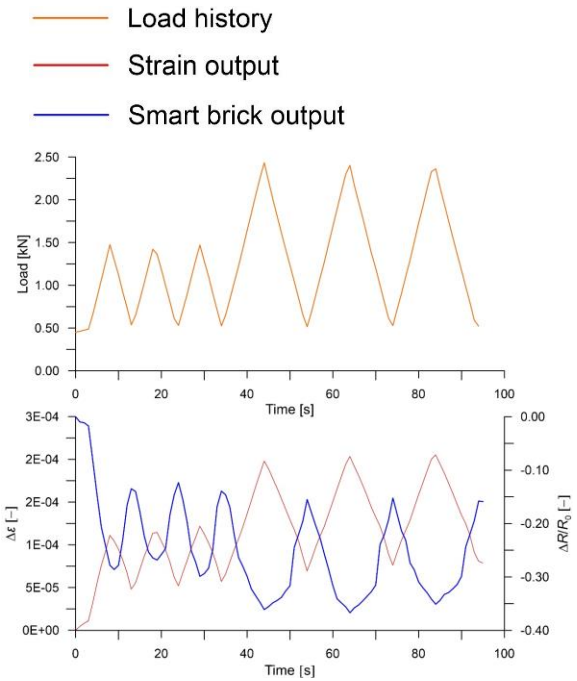
$$\lambda = \boxed{1 + 2v} + \boxed{\frac{\frac{\Delta\rho}{\rho}}{\epsilon}}$$

geometric change — **piezoresistivity**

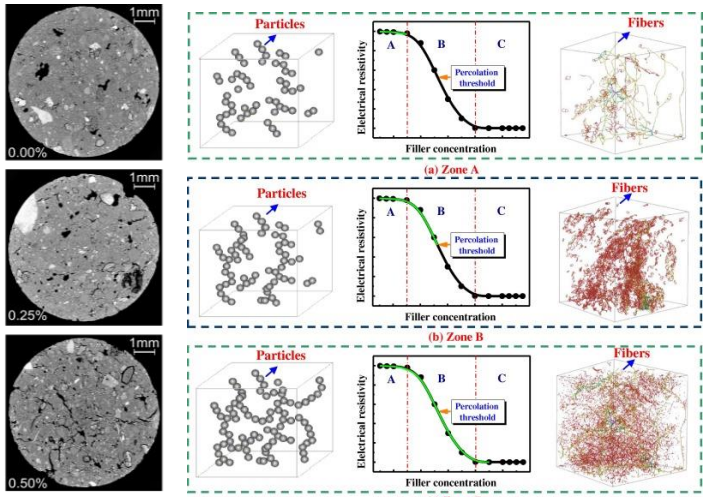
Smart bricks (preliminary design)

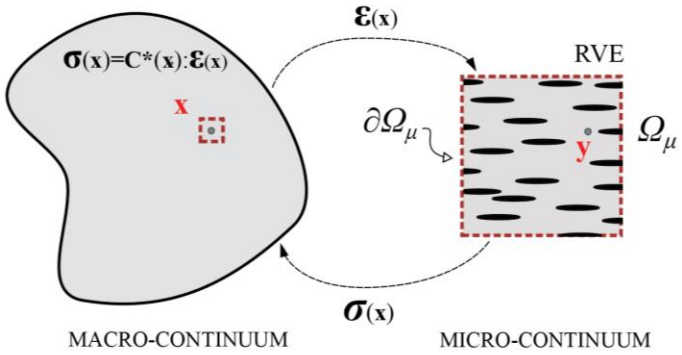


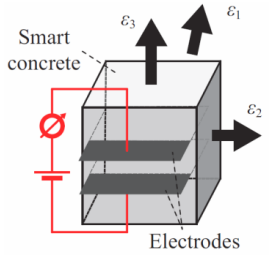




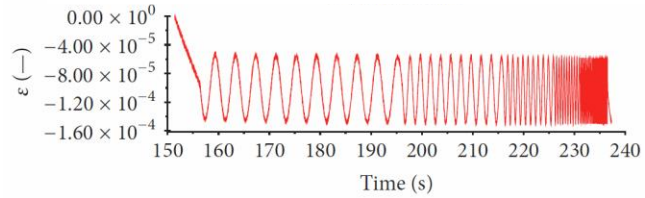
Smart cement paste



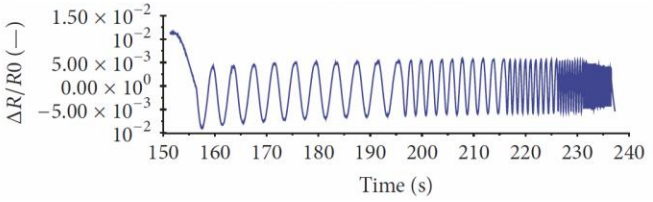




Mechanical input (strain)



Material's electrical output



METHODOLOGY

WP1

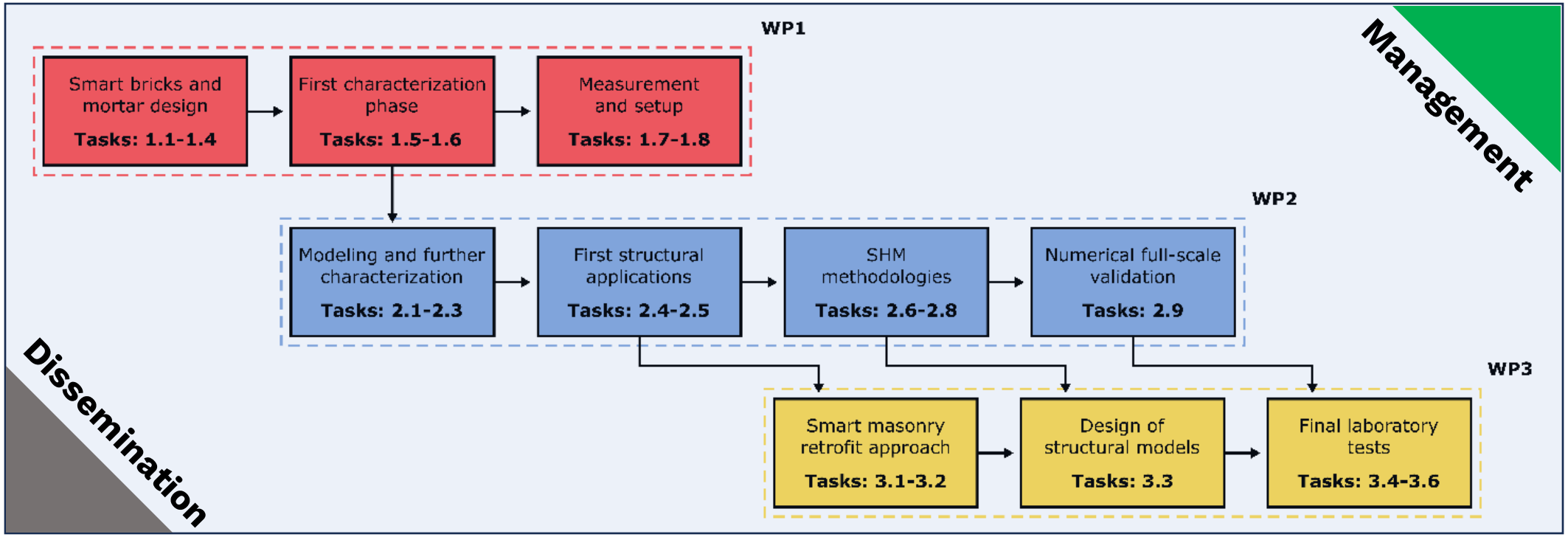
WP2

WP3

WP1: novel smart mortars and smart bricks

WP2: modeling and signal processing

WP3: Full-scale laboratory validations



METHODOLOGY

WP1

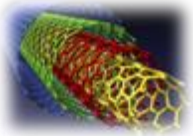
Novel smart mortars and smart bricks

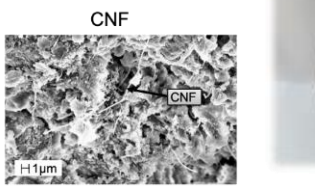
T1.1 Conductive fillers
T1.2 Dispersion of selected fillers
T1.3 Fabrication of smart mortar
T1.4 Fabrication of smart bricks

T1.5 Electrical characterization
T1.6 Strain sensing, damage sensing and mechanical characterization

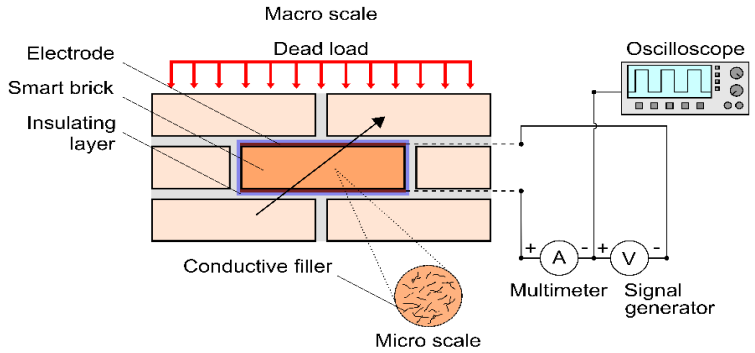
T1.7 Electronics for smart bricks
T1.8 Electronics for smart mortar

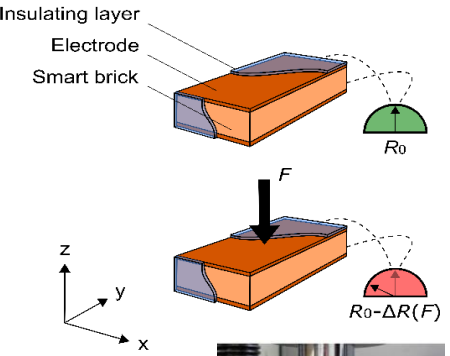
T1.1-4



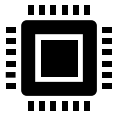


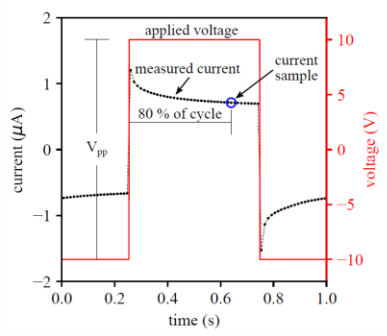
T1.5-6

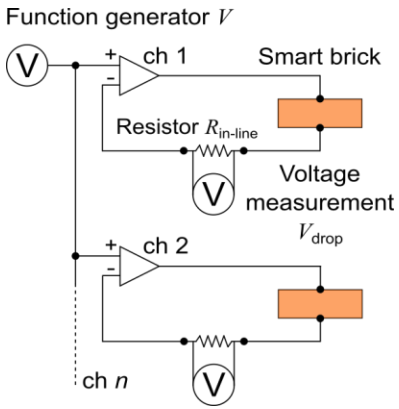


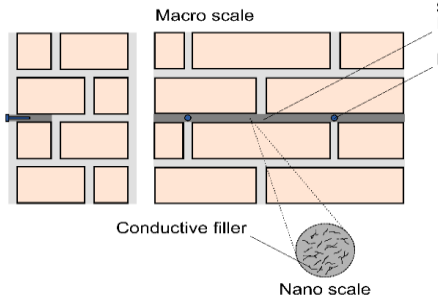


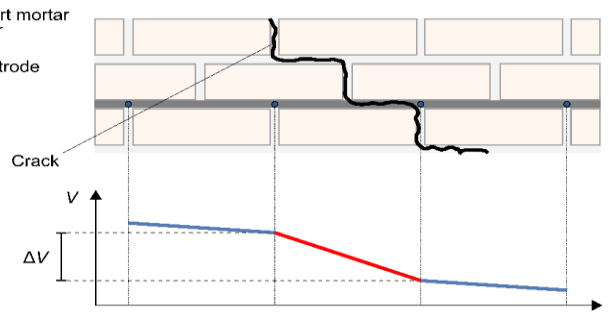
T1.7-8

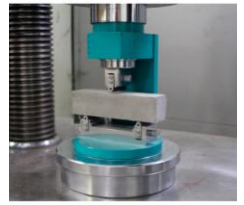












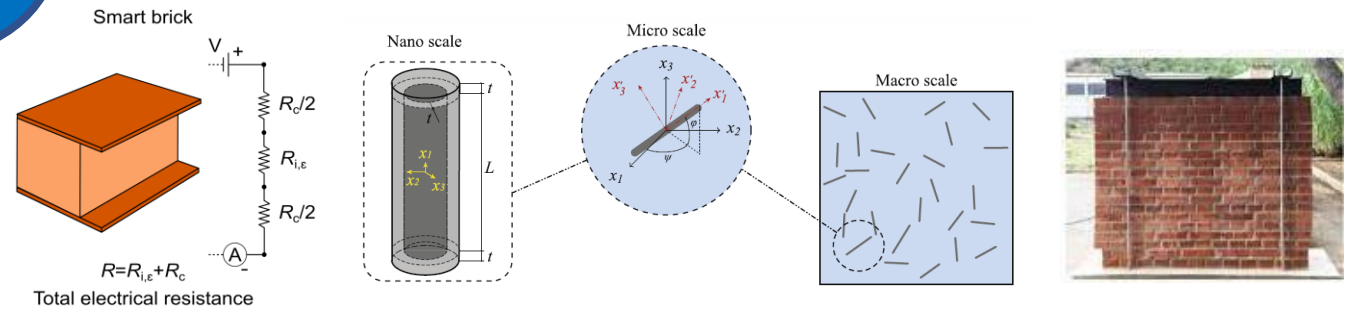
METHODOLOGY

WP2

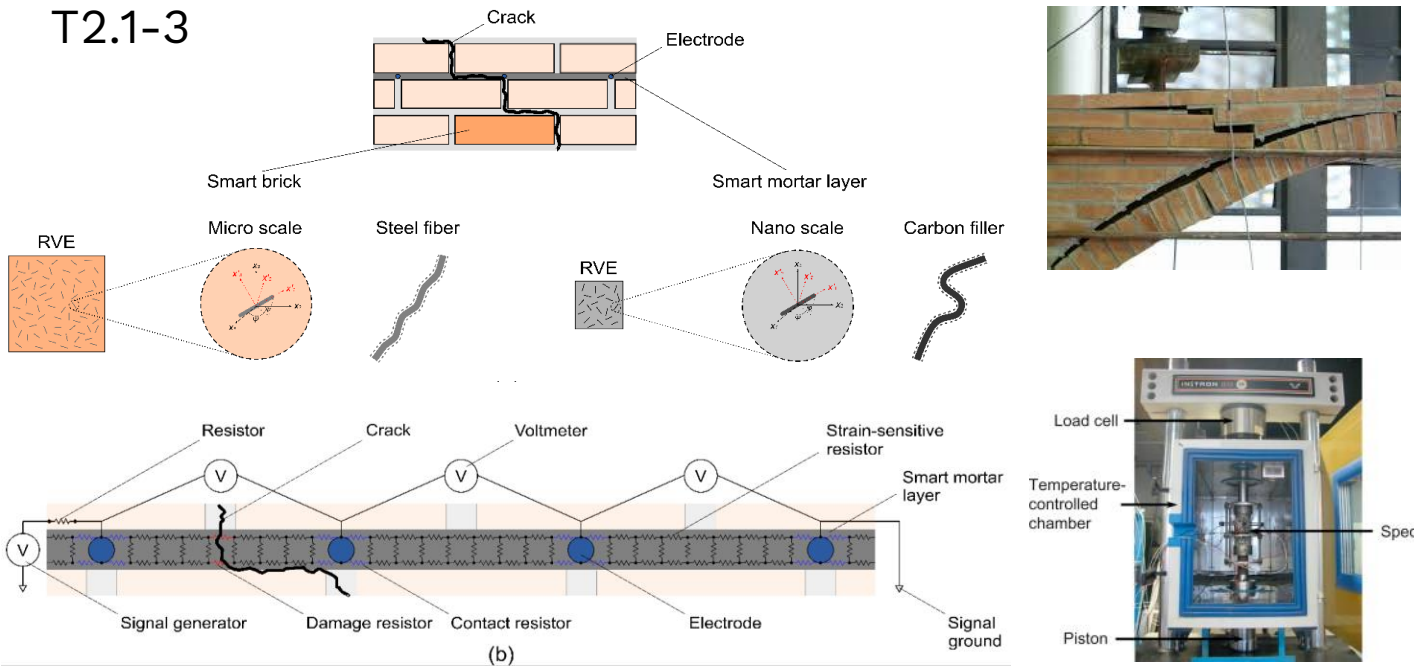
Modeling and signal processing

T2.1 Modeling of smart bricks
T2.2 Modeling of smart mortars
T2.3 Electromechanical and environmental characterization

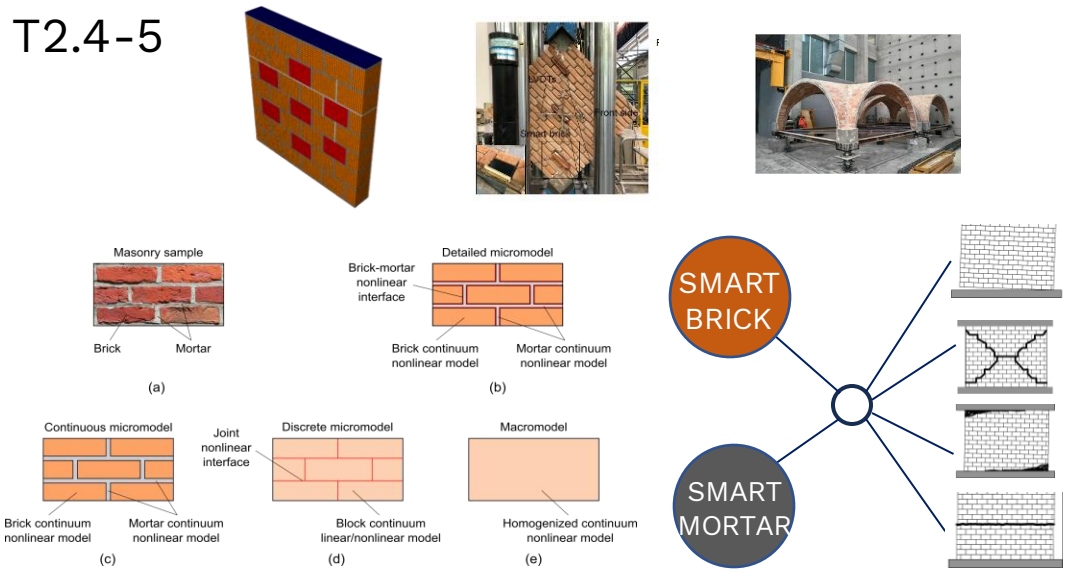
T2.4 Numerical validation
T2.5 Experimental tests on small-scale structural specimens



T2.1-3



T2.4-5



METHODOLOGY

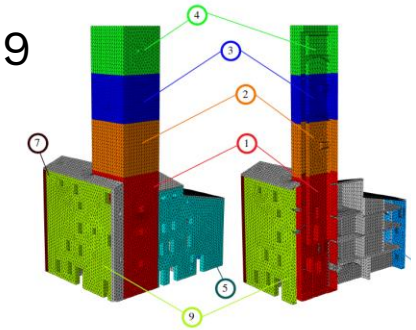
WP2

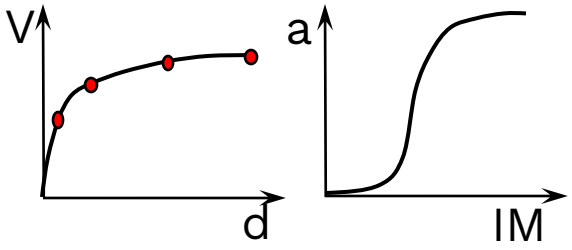
Modeling and signal processing

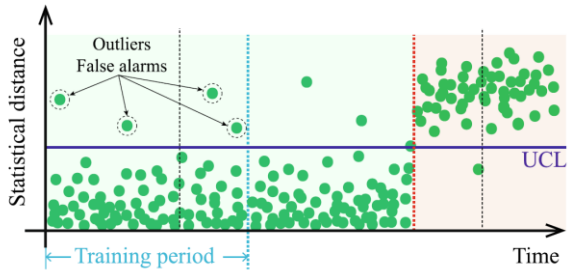
T2.6 AI-based damage identification algorithms using smart mortars
T2.7 AI-based damage identification algorithms using smart bricks
T2.8 SHM strategy using smart masonry

T2.9 Large-scale numerical tests

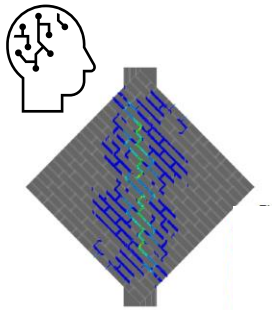
T2.9

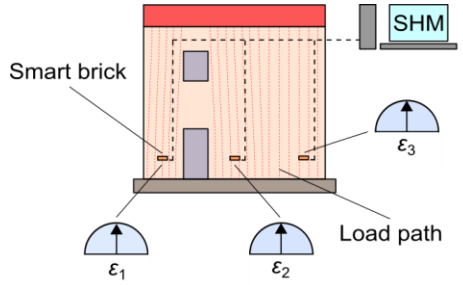


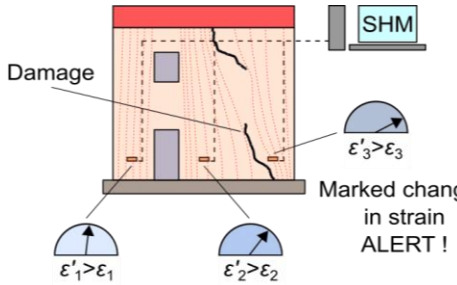


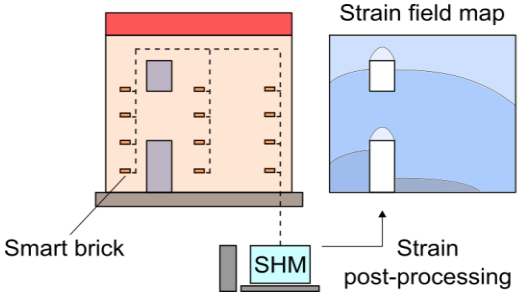


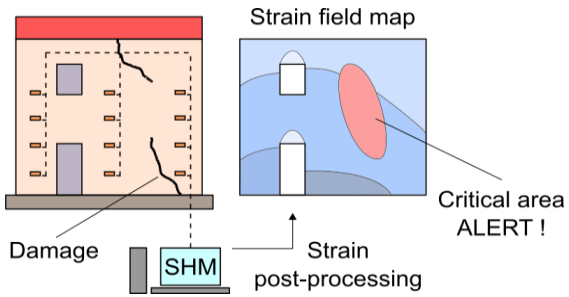
T2.6-8

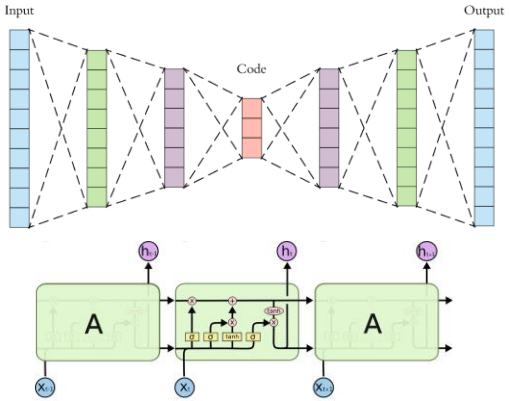


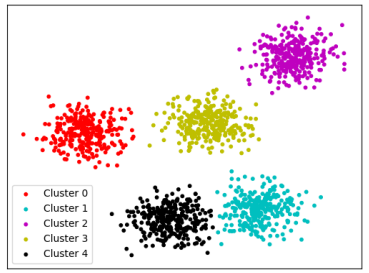


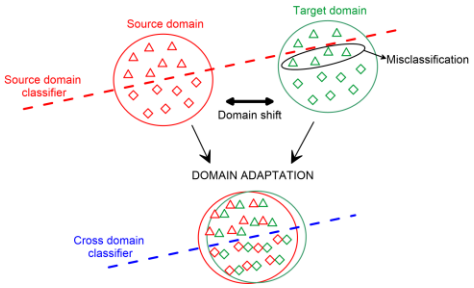












METHODOLOGY

WP3

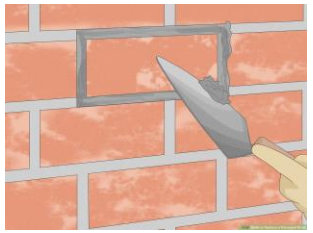
Full-scale laboratory validations

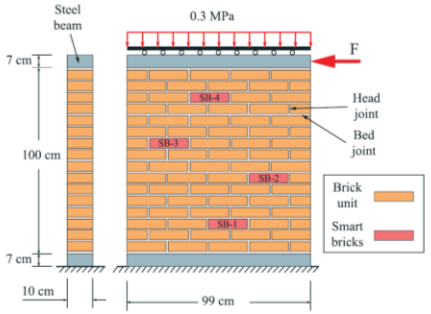
T3.1 Post insertion of smart bricks
T3.2 Masonry repointing using smart mortar layers

T3.3 Design and construction of smart masonry structural models

T3.4 Static tests
T3.5 Numerical simulations of destructive tests
T3.6 Destructive tests

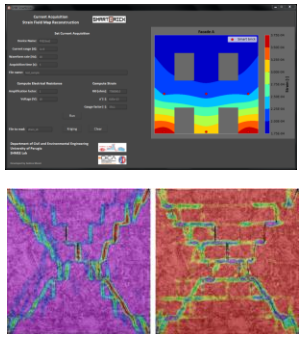
T3.1-2

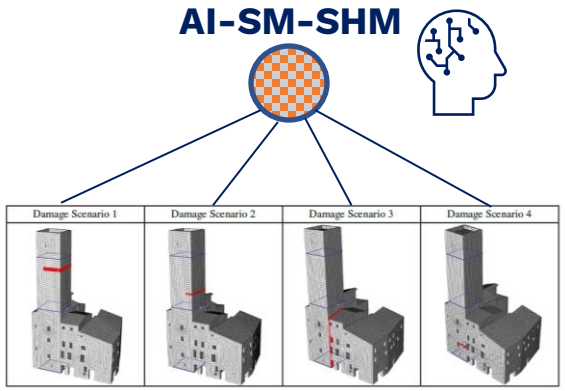


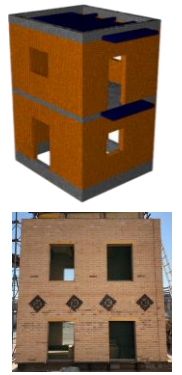


T3.3

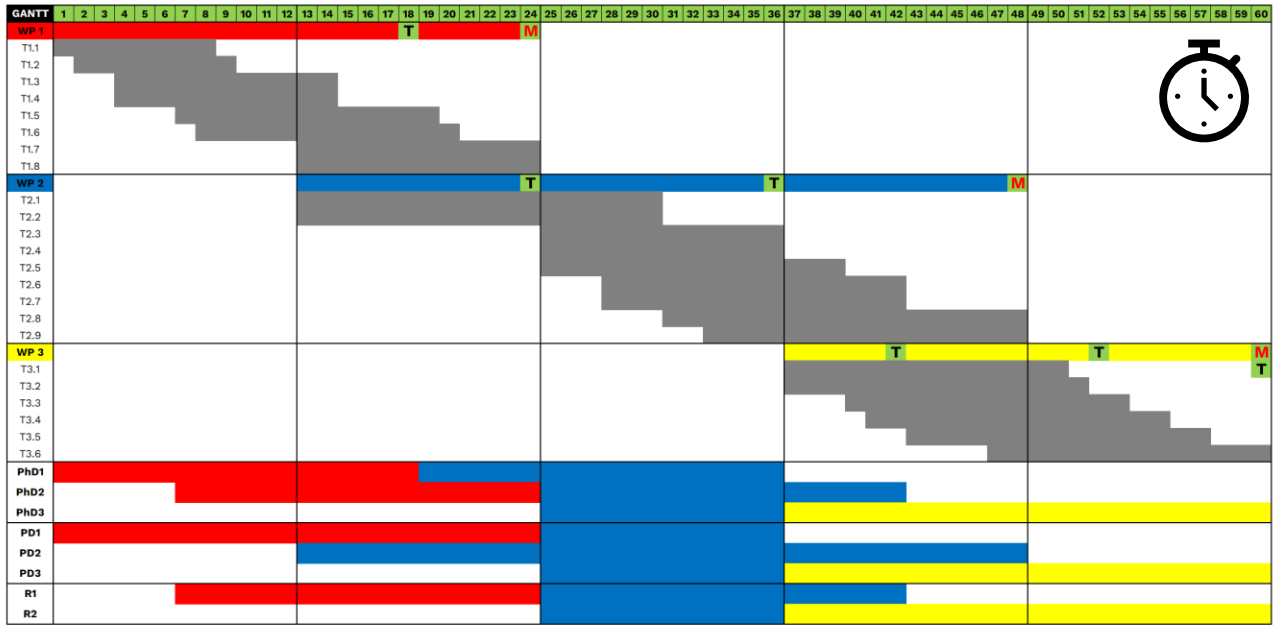
T3.4-6

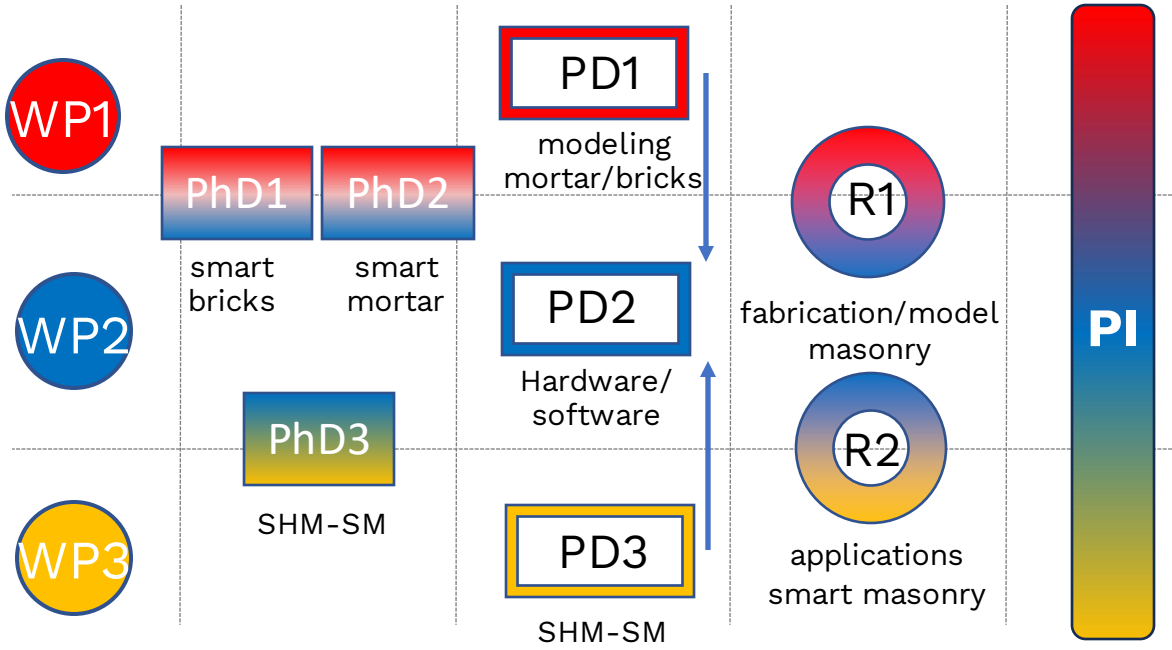






TIME SCHEDULING & BUDGET





Milestones (M) and Targets (T)

- ❑ **M1** New smart mortar and integration with smart bricks
- ❑ **M2** New SHM-AI-SM algorithms and software
- ❑ **M3** Full scale demonstration
- ▪ T1 Fabrication procedures smart bricks and smart mortar
- ▪ T2 Smart mortar and bricks preliminary models
- ▪ T3 Smart mortar and bricks final models with electronics
- ▪ T4 AI algorithms developed and validated
- ▪ T5 Retrofit strategy through Smart Masonry
- ▪ T6 Lab validation of smart masonry

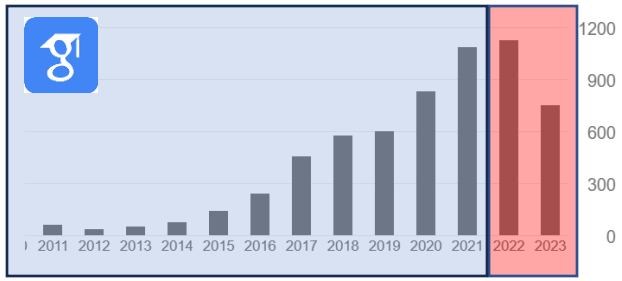
Project costs

- Personnel (880 k€)
- Equipment (300 k€)
  - Mechanical testing
  - DAQ systems + off-the-shelf sensors
  - Monitoring station + Software licenses
- Additional funding (500 k€)
  - Completion of new lab (started July 4th 2023)
- Indirect + Consumable + Travels + OA fees (420 k€)

PI AND HOST

Filippo Ubertini (PI)
Full Professor

Research
- structural analysis and design
- smart construction materials
- vibration-based SHM

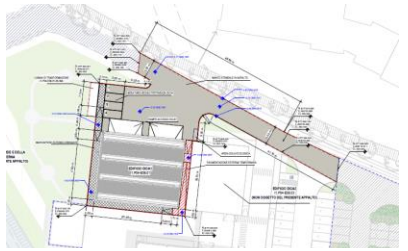


Updated track records (post submission in red)

Coordinator	PRIN 2015 + ERIES	
Local PI 2019	MSCA ITN 2018-2022 + RIA H2020 2016- + PRIN2017 + FISR2019 (co-PI) + PRIN 2022	
Local co-PI	PNRR Vitality + PNRR STRIC	
Other coordination	1 MEur funding SHM 2020-2023	
Plenary / keynote	IOMAC2024 + CMMOST2023	
Journal articles	**119 (150, +31)**	
h index	**36 (45, +9)**	**33 (41, +8)**
Citations	**4203 (6213, +2010)**	**3387 (4886, +1499)**
Main author 10yrs	**61 (83, +22)**	

HOST

LABS



SOFTWARE

PEOPLE

SHMee LAB