

Advancing sensing solutions for data-driven seismic damage assessment of non-structural elements: current challenges and future directions

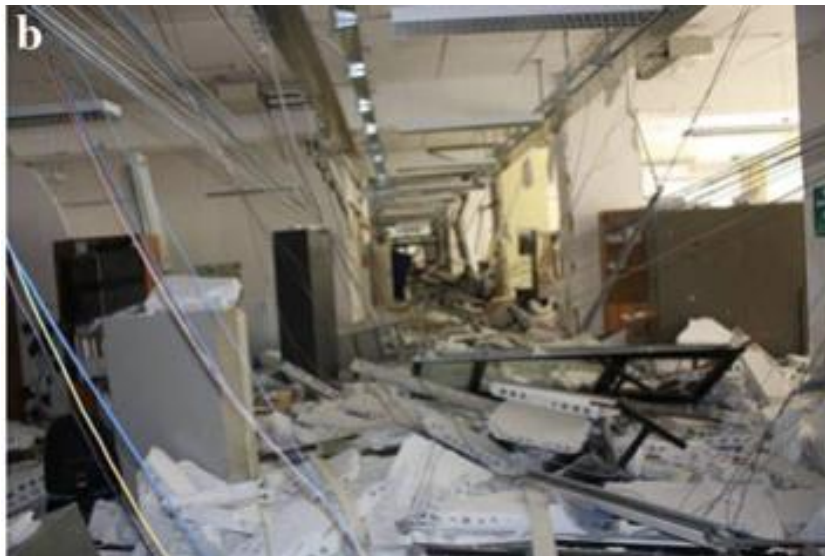
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Non-structural components drive earthquake costs

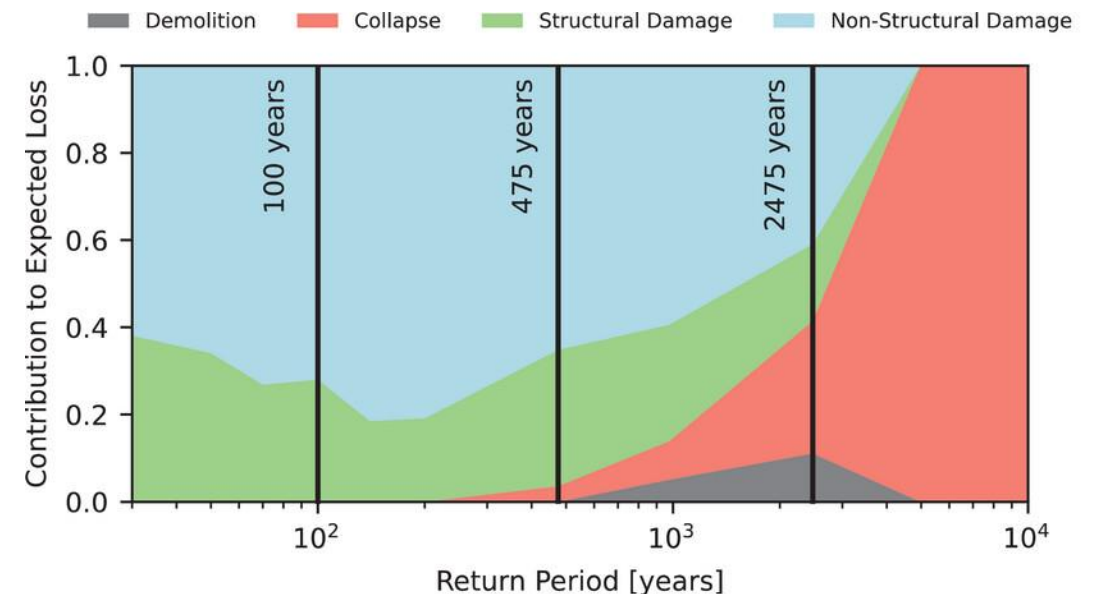
Damage to nonstructural components (partitions, ceilings, facades) can interrupt building use and generate substantial repair costs, even for low shaking intensities and with low structural damage.

Collapse of partitions, L'Aquila eq., 2009



Braga et al. (2011), doi:10.1007/s10518-010-9205-7

Expected repair losses for RC buildings



O'Reilly et al. (2024), doi:10.1002/eqe.4066

And our models struggle to capture their behaviour

Fragility models are driven by laboratory experiments that may not fully represent the actual demands, installation conditions, and damage history of real components.

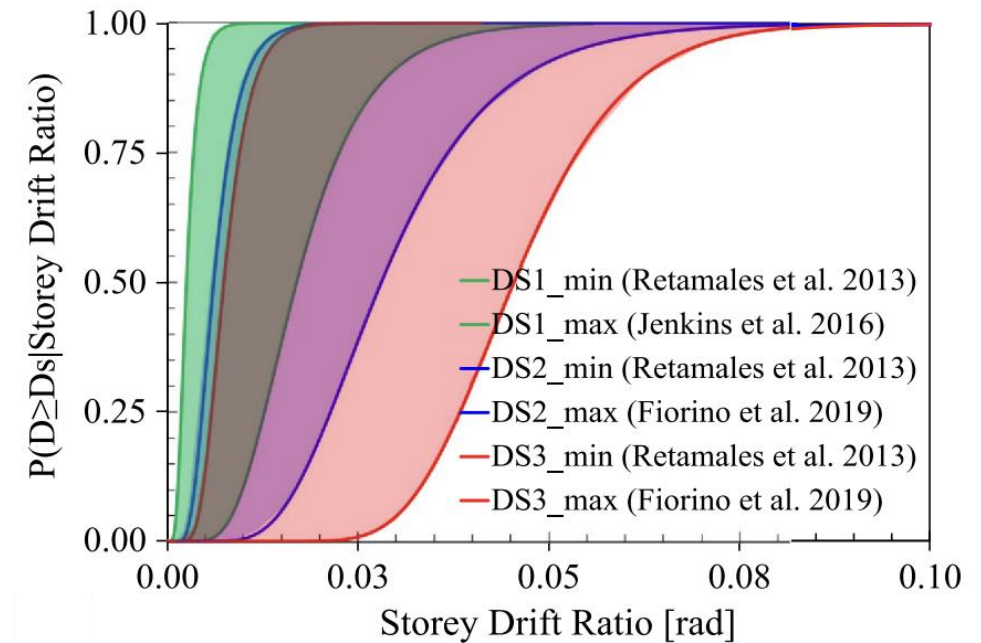
Laboratory vs reality

- Few specimens (with large heterogeneity)
- Prescribed loading histories (e.g. pseudo-static)
- Connections and boundary conditions

Field surveys document damage without measuring the demand!

Monitoring systems measure the demand but do not classify damage!

Fragility domains for gypsum partitions

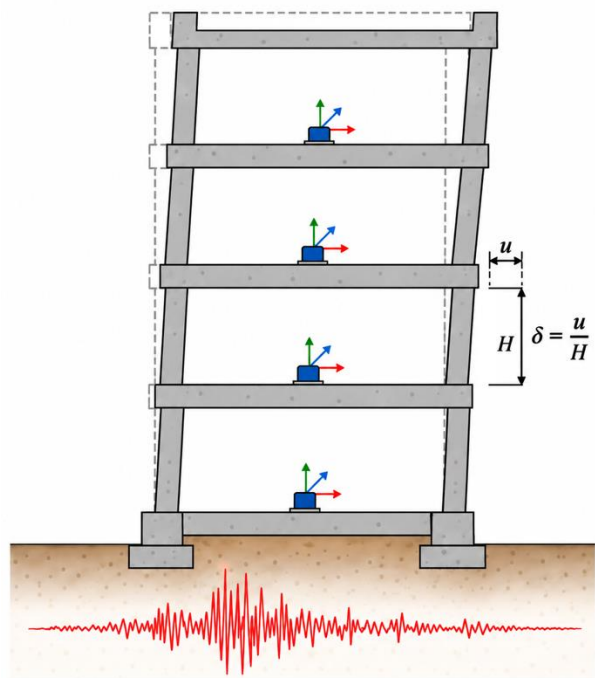


Bianchi & Pampanin (2022), doi:10.1061/(ASCE)ST.1943-541X.0003352

We can improve our models by sensing the structure

Vibration-based structural health monitoring (SHM) systems and cameras provide complementary measurements of seismic demands and images of damaged components.

Vibration-based SHM

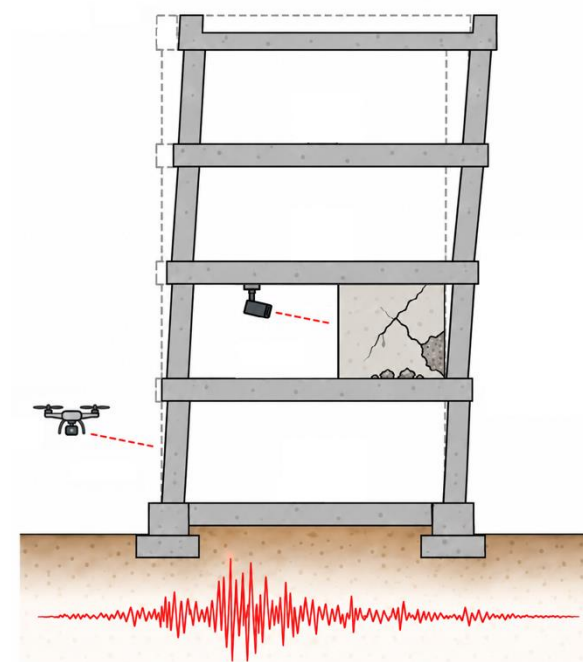


- Modal identification (ambient vibrations)
- Floor accelerations
- Storey drifts

Engineering demand parameter (EDP)

Cameras/Drones + computer vision

- Images of damage ←
- Component detection ~
- Damage classification ~ (automated)



Damage State (DS)

SONATA builds on this idea!

SONATA combines lab experiments with sensing and vision to update fragility models of nonstructural components.

1. Reproduce

→ Shake-table tests of nonstructural components

2-3. Sense and observe

→ EDPs from sensors, DSs from computer vision

4. Update

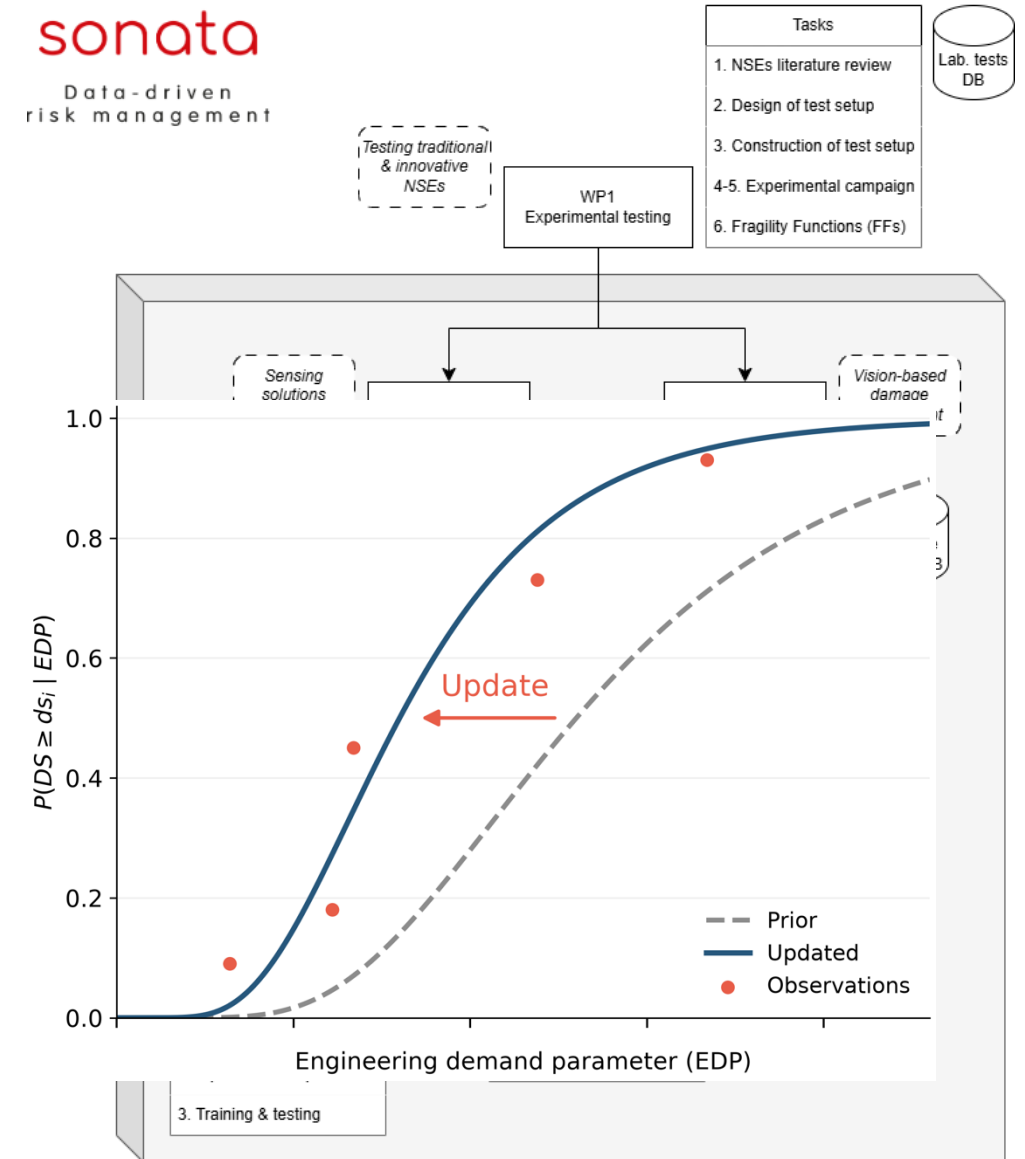
→ Updated component fragility based on data

5. Prototype

→ Integrate SHM, fragility updating and loss assessment



Sensor-driven statistical tools to evaluate risks and manage safety in the built environment



Shaking gypsum partitions

Full-height single- and double-layer gypsum partitions were tested at the Eucentre 9D laboratory in Pavia, Italy, with a setup capable of reproducing differential floor displacements.



Realistic floor-level demands

Bi-directional real ground motions (L'Aquila eq.),
14 scalings propagated into an 8-storey building

Dynamic monitoring

Low-noise MEMS accelerometers to measure floor
EDPs and track stiffness degradation

Cameras & drones

Surveying of visible damage during and after
each run

Seismic demands and observed damage

We paired peak drift with damage states assigned from five independent expert judgements.

Estimate displacement demands

- Double integration of floor accelerations
- Maximum in-plane drift at each run

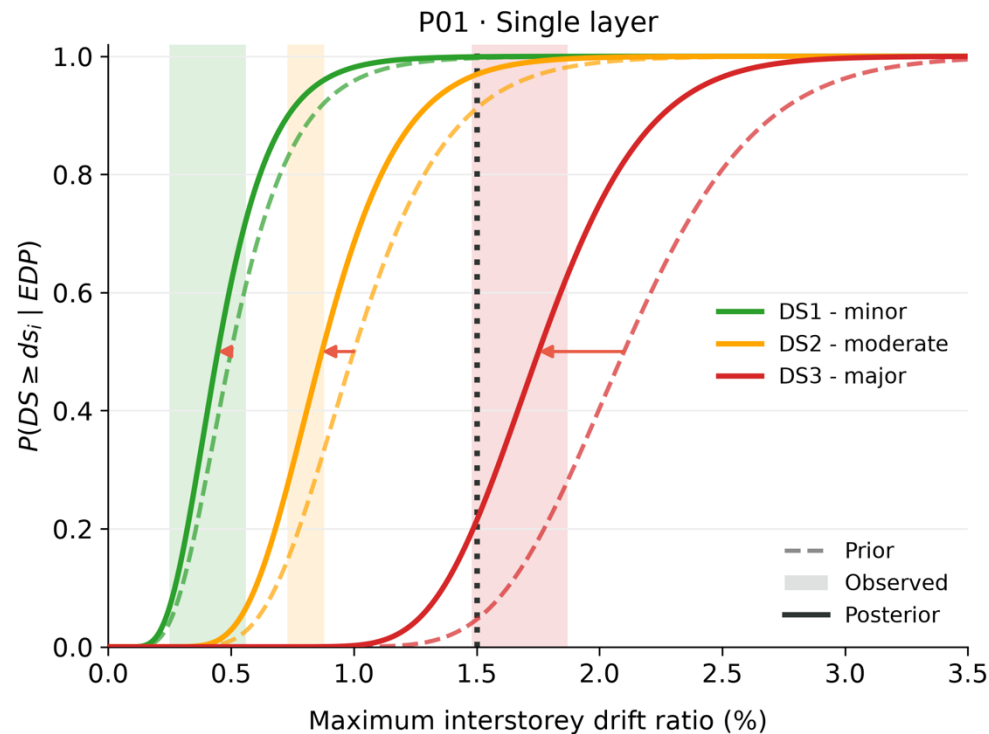
Classify damage

- DS1 – minor, DS2 – moderate, DS3 – major
- ~ Database of (labelled) images
- ~ Training ML algorithm for DS classification



A pseudo-experiment: update predictions based on data

Imagine the test as a monitored building hit by an earthquake: EDP–DS observations provide the observational evidence — *data* — for the updating of prior fragilities.



Prior

Full-height fully-fixed single-layer gypsum partitions
(Miranda & Mosqueda 2011)

Updating

Bayesian updating of (θ, β)
Interval-censored likelihood

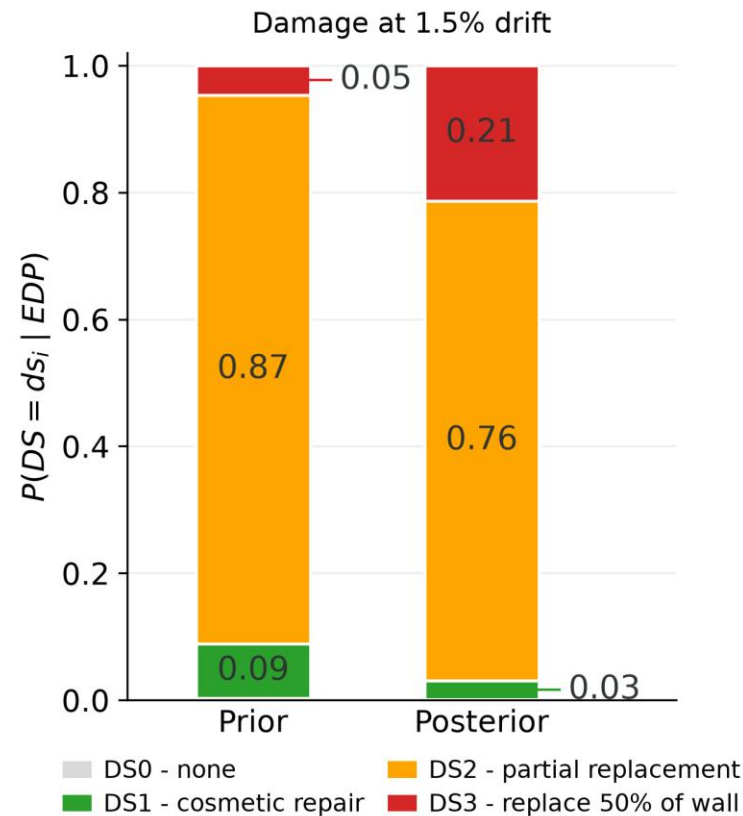
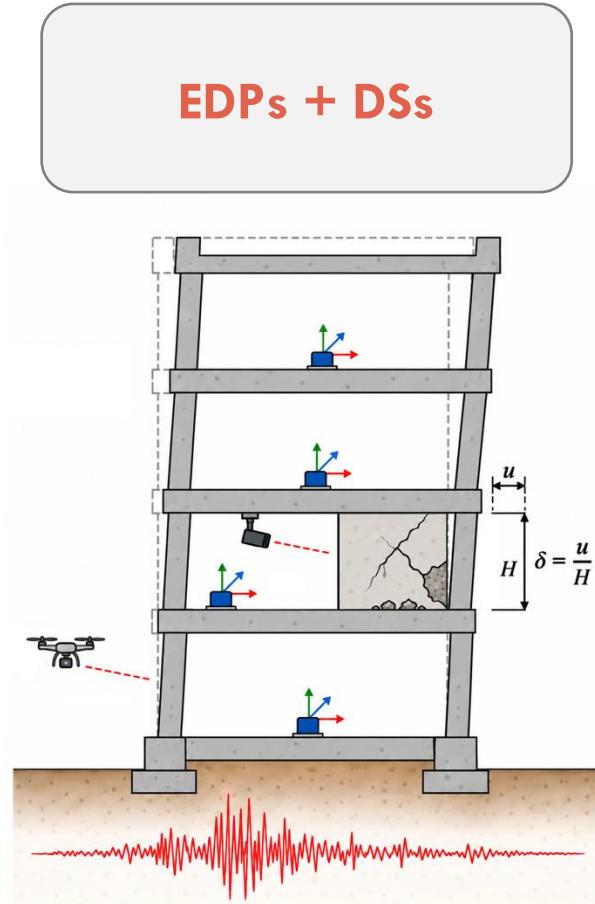
Posterior

Updated fragilities account for the actual demand
and the observed response in operating conditions

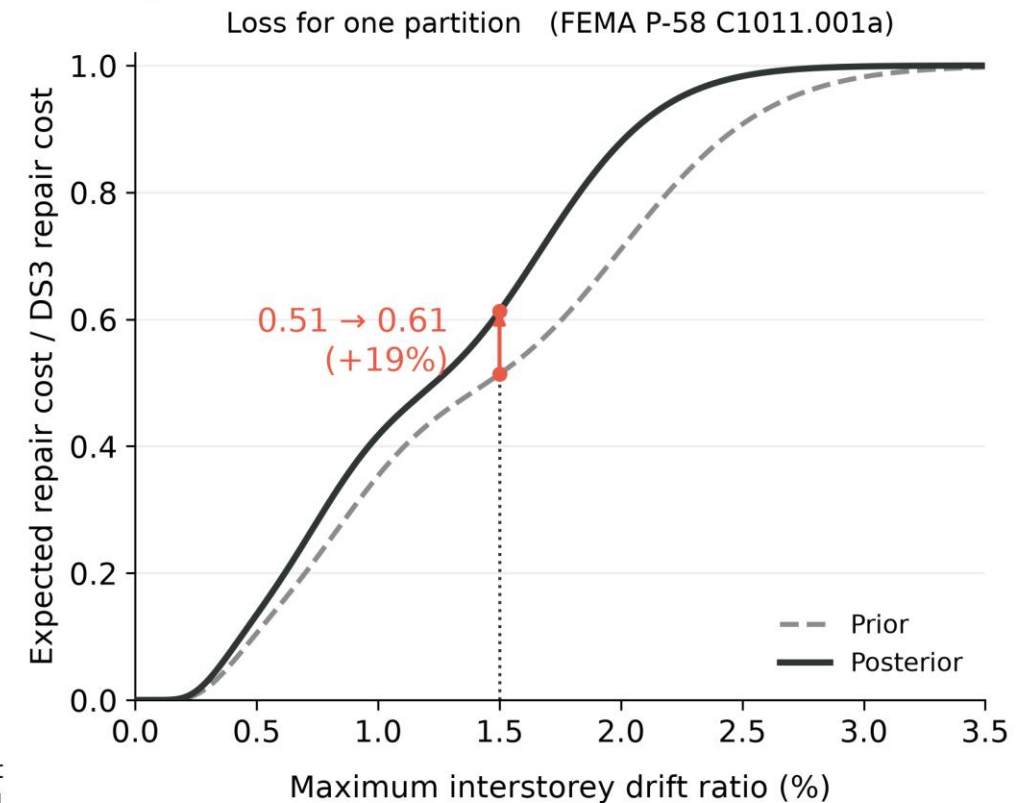
For this component observations shift the estimated fragilities towards lower drift demands!

From fragility to repair costs

Updating component fragilities may significantly affect the estimate of repair losses (and downtime)!



P01 · Single layer



Towards data-driven assessment

Modern sensing technologies and machine-learning capabilities are readily available to support loss and downtime assessment for nonstructural components by using:

Sensors. Low-noise MEMS are the link between operational SHM and seismic response

Computer-vision. Specialized models can identify components,
but need dedicated training databases to classify damage

Updating. Integrating the two technologies allows to update
fragility and loss estimates based on data



Sivori, Daniele; Guamán, Mauricio; Todaro, Marco; Özsaraç, Volkan; Shahnazaryan, Davit; O'Reilly, Gerard J. (2026) "Advancing sensing solutions for data-driven seismic damage assessment of non-structural elements: current challenges and future directions"

18th European Conference on Earthquake Engineering, Berlin, Germany