

From local soil to replicable 3D printed earth panels for low carbon construction in Portugal

From Knowledge to Competitiveness

Portugal-US Partnerships 2026 Summit

MIT Portugal Program



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Digital Transformation in Manufacturing & Sustainable Cities

1 Context and objective

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global floor area to be built by 2060 [1]

Cement based printing mortars remain carbon and cost intensive, with limited thermal performance. Portuguese vernacular earth construction offers time-tested passive strategies yet lacks methods that meet current performance requirements.

Objective: turn locally sourced soil into a functional feedstock for replicable 3D printed wall panels, with thermal and carbon performance predicted before fabrication.

- RQ1** Can local soils in Porto and Boston be processed into a reliable printing feedstock without cement?
RQ2 Can a calibrated thermal model predict the behavior of printed earth walls before they are built?
RQ3 How much embodied carbon does a printed earth panel save against printed mortar and conventional walls?

2 Base study: circular earth printing



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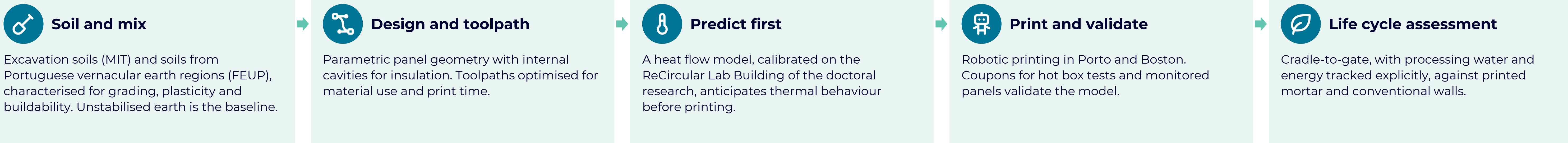
Printed earth has **the embodied carbon of conventional concrete** [2]

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Printed earth has **the embodied carbon of printed mortar wall sections** [2]

Closed material loop for robotic earth printing, adapted from [2]. The same loop enables zero waste earthen formwork [3].

3 Methodology



4 Work conducted and preliminary results

MIT, Boston and FEUP, Porto, 2026

4.1 Material characterisation



Drying shrinkage bars for two soils, following the protocol in [2].

4.2 Mixture preparation



Local soil mixed before printing.

4.3 Printed cylinders



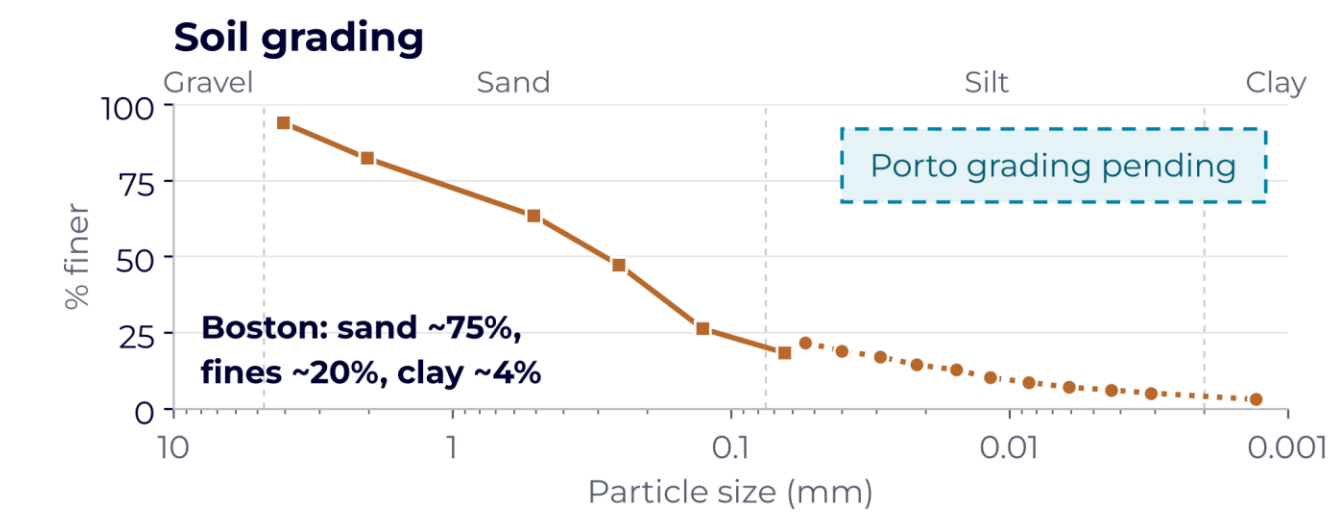
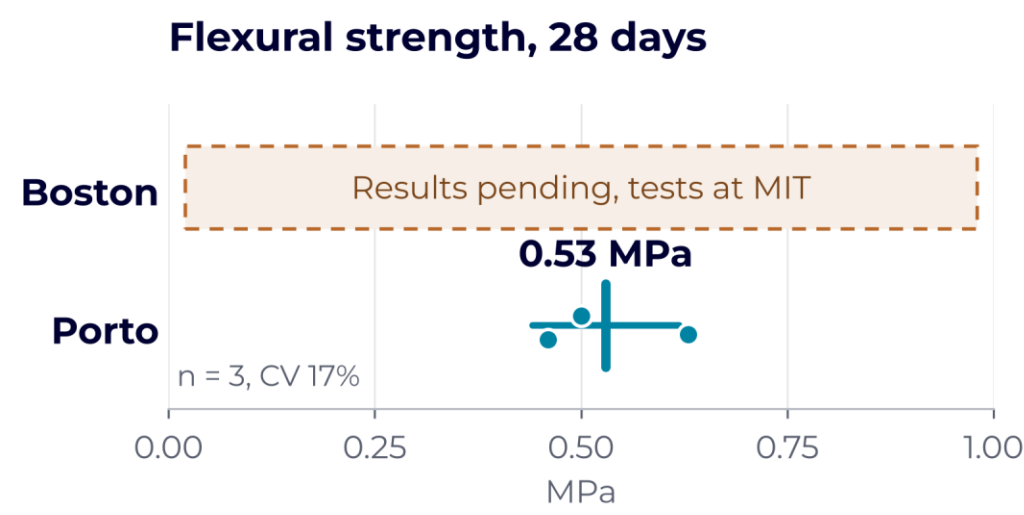
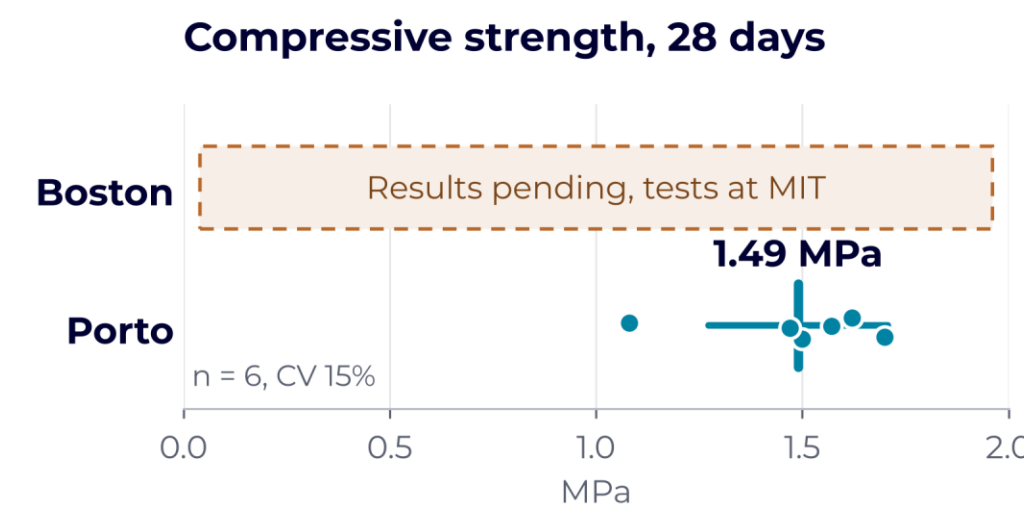
First robotic extrusion trials with the Programmable Mud mix [2].

4.4 Test printing, MIT and Porto



Test print at MIT (left) and earth specimen printed in Porto (right).

Preliminary results soil grading at MIT (ASTM D6913, D7928) and strength at FEUP (EN 196-1)



Progress to date

- Review of Portuguese vernacular earth techniques and their passive climate strategies
- Soil characterisation in Boston
- Earth and mortar coupons in Porto and Boston
- Heat flow model on the MIT dataset of shape optimised walls [4], in progress
- Earth specimens printed in Porto and Boston

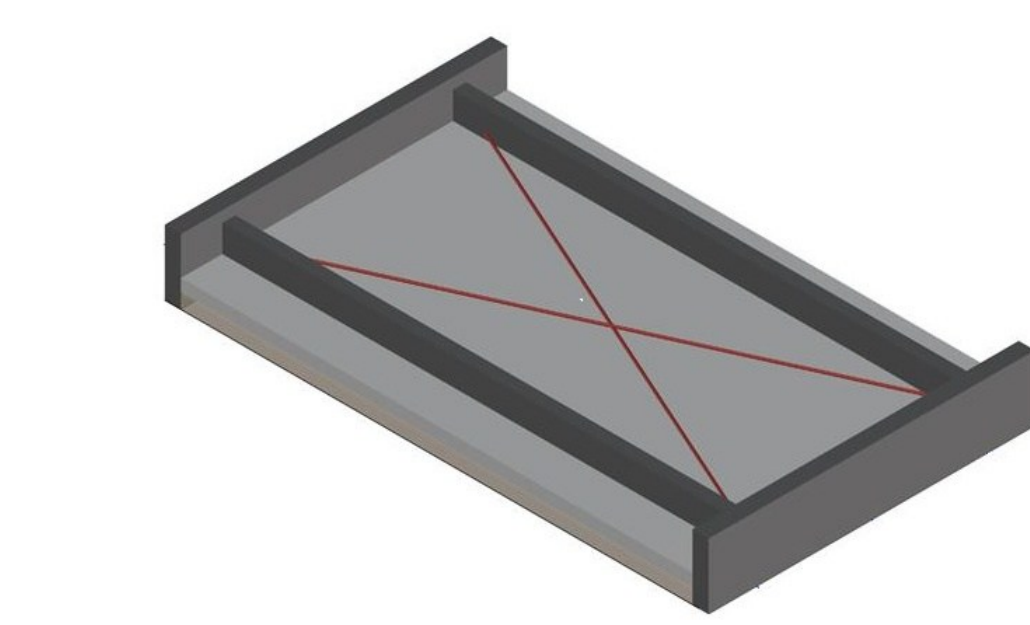
5 Future development: tilt up modular earth wall



Printed earth wall and columns with threaded steel rods, first post tensioning trials



Printing flat avoids the self weight deformation of tall vertical prints



Module concept: X cross bracing between bond beams

Concept

Earth is printed flat as permanent formwork for insulation, unbonded cables and concrete bond beams. The X cross bracing compresses the earth for lifting and braces the building in service. At end of life the earth is rehydrated and reprinted, cables and concrete frame are reused.

6 Impact

Climate

Cement free walls from local and excavated soil, at a fraction of the carbon of concrete.

Circularity

Unstabilised earth is rehydrated and reprinted at end of life. No material becomes waste.

Portugal

Replicable panels for Portuguese housing demand, with an open workflow and a validated thermal model ready for industry transfer.

References

- [1] UNEP, 2017 Global Status Report: Towards a zero-emission, efficient, and resilient buildings and construction sector, GlobalABC, 2017.
[2] A. Curth et al., 3D printing earth: Local, circular material processing, fabrication methods, and life cycle assessment, Constr. Build. Mater. 421 (2024) 135714.
[3] A. Curth et al., EarthWorks: Zero waste 3D printed earthen formwork for shape-optimized, reinforced concrete construction, Constr. Build. Mater. 449 (2024) 138387.
[4] E. Gascón Alvarez et al., Enhancing the dynamic thermal performance of wall components through shape optimization, Build. Environ. 290 (2026) 114193.

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