UNIVERSITÀ DEGLI STUDI DI MILANO

DIPARTIMENTO DI SCIENZE DELLA TERRA ARDITO DESIO
Dottorato di Ricerca in Scienze della Terra

Numerical and Experimental Investigation of Innovative Energy Geostructures

Contact Information

- Principal Investigator: Prof. Francesco Cecinato
  - Email: francesco.cecinato@unimi.it | Website: https://www.unimi.it/it/ugov/person/francesco-cecinato
- Co-Investigator: Prof. Tiziana Apuani
  - Email: tiziana.apuani@unimi.it | Website: https://www.unimi.it/it/ugov/person/tiziana-apuani

UNIVERSITÀ
DEGLI STUDI
DI MILANO

Scientific Problem

- This research investigates how innovative energy geostructures, such as thermo-active sheet pile walls (e.g. Gerola et al. 2025) and micro-piles (e.g. Scuderi et al. 2024), can be optimized for energy efficiency and storage while ensuring structural safety.
- Through numerical modelling, laboratory tests, and field experiments, we aim to explore ways to extend current operational temperature limits—both high and low—to enhance thermal performance while mitigating adverse thermo-hydro-mechanical interactions.

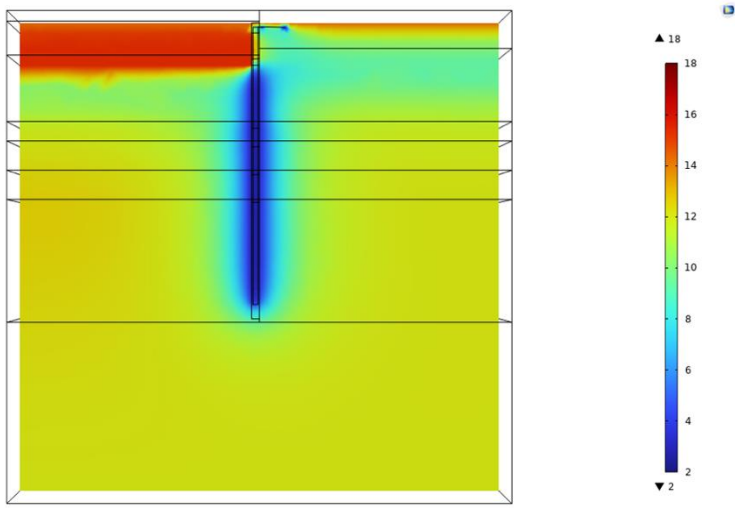

Figure 1. FEM simulation of cross-sectional temperature distribution for an energy quay wall (Gerola et al., 2025)

UNIVERSITÀ
DEGLI STUDI
DI MILANO

Methodology

Examples include:

- Finite Element modelling of the thermal, thermo-mechanical, and thermo-hydro-mechanical behaviour of energy geostructures.
- Thermo-mechanical triaxial and oedometer laboratory testing to evaluate the effects of extreme temperatures on the strength and deformation properties of geomaterials.
- Thermal conductivity measurements in laboratory settings.
- Analysis of monitoring data from selected test and demonstrator sites in Italy.

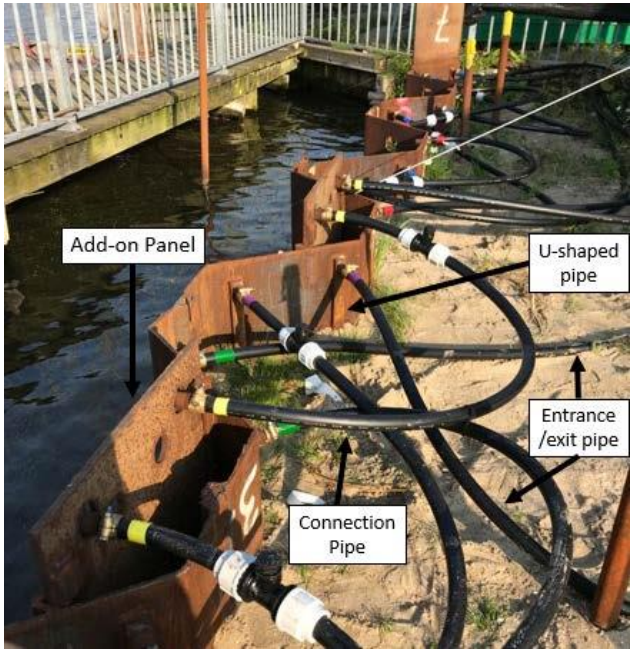

Figure 2. a) UniMI thermo-mechanical apparatus, b) Energy quay wall test site installed in The Netherlands (Gerola et al., 2025)

Potential Impact and Applications

- **Science & Engineering**: Contribute to a deeper understanding of thermo-hydro-mechanical interactions in geomaterials, advancing geotechnical and energy engineering. Improved numerical models and experimental insights can aid in designing more efficient, resilient, and sustainable energy geostructures.
- **Industry**: Enable cost-effective and sustainable thermal energy storage solutions. Applications include urban infrastructure (e.g., building foundations, retaining walls) that integrate geothermal energy, reducing reliance on fossil fuels and lowering operational costs.
- **Policy & Sustainability**: Support the transition to low-carbon energy systems by promoting innovative ways to harness geothermal energy in urban and industrial settings. Inform policy on sustainable building practices, energy efficiency regulations, and climate adaptation strategies.

UNIVERSITÀ
DEGLI STUDI
DI MILANO

Available Resources and Collaborations

- Key numerical resources
  - FEM software for multiphisics analysis (COMSOL)
  - FEM/DEM software for geotechnical analysis (e.g. Rocscience, Flac, UDEC)

- Key equipment at our geotechnical lab
  - Standard rock and soil mechanics element testing apparatus
  - Advanced temperature-controlled oedometer and triaxial apparatus, spanning between -20 and 50 °C
  - Advanced thermal conductivity measurement apparatus for soils and rocks

- Key collaborations
  - Industry: Possible collaboration with a leading Italian geotechnical contractor and an environmental remediation firm to enhance practical applications and scalability.
  - Public Authorities: Possible partnership with water and infrastructure authorities in Northern Italy, supporting the setup of demonstrator sites and facilitating real-world implementation.

Candidate Profile

UNIVERSITÀ DEGLI STUDI DI MILANO

- We seek candidates with a solid background in engineering geology or geotechnical engineering.
- Aptitude for coding and geotechnical laboratory work is highly valued, though prior experience is not required.

References

- Gerola, M., Cecinato, F., Leclercq, V., & Vardon, P. J. (2025). Energy quay walls: Performance analysis and optimisation. Geomechanics for Energy and the Environment, 100664.
- Scuderi, F., Cecinato, F., d'Attoli, M., Gualerzi, D., Occhi, A., & Occhi, M. (2024). Analisi numerica preliminare del comportamento termico di micropali termo-attivi. In XIII Incontro Annuale dei Giovani Ingegneri Geotecnici (pp. 165-168). AGI.