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NUMERICAL MODELLING OF ENERGY GEO-STRUCTURES FOR BUILDING RETROFITTING

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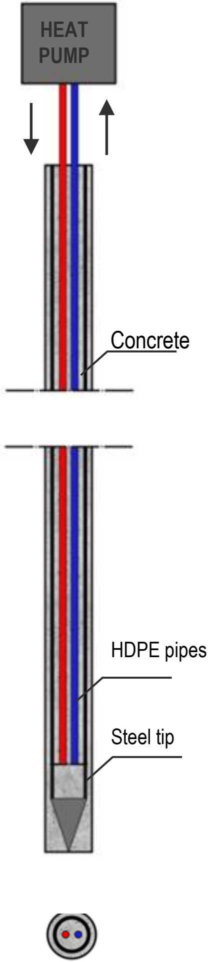

Energy micropiles

Dual function:

1. **Mechanical**
2. **Thermal**

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Innovative application

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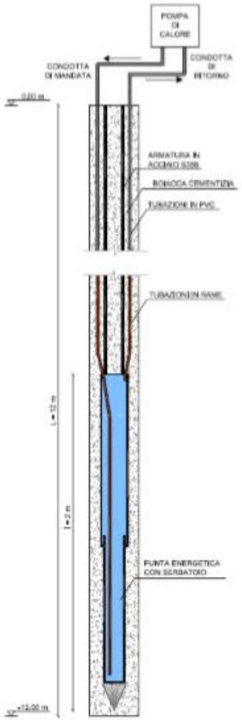
- **Structural retrofitting**
- **Energy retrofitting**

of existing buildings

Materials	Concrete and steel
Typical dimensions	Lmax= 10-20 m Dmax= 0.2-0.3 m
Heat exchanger pipes	A single HDPE/HDPP U-loop
Heat exchanger fluid	HFC (water + antifreeze)
Installation	Cast in place

Ronchi et al., 2018



Problem formulation

Heat exchange processes

- Convective exchange between fluid and pipe walls
- Conduction through pipe material, steel and concrete
- Conduction through soil surrounding the pile.

Aims

Simulate thermal operational conditions of energy micropiles

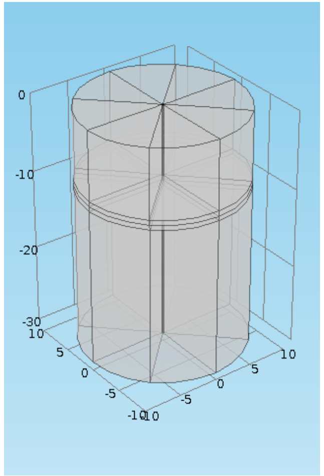
- Long- and short- term performance
- Influence of design parameters
- Comparison with performance of standard energy piles

1. **Pile geometry**
2. **Material thermal parameters**
3. **Fluid velocity**

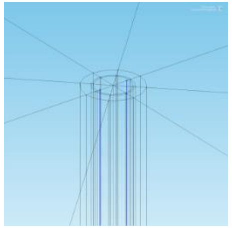
Numerical model

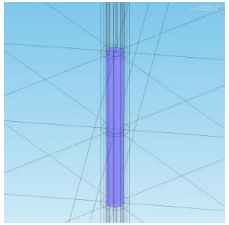
3D FEM model of single micropile

- Cylindrical domain D=20m, H=30m
- Homogeneous fine-grained soil
- Pipes represented as linear elements for computational economy
- Model created with COMSOL Multiphysics

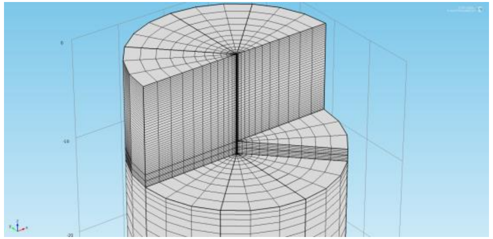


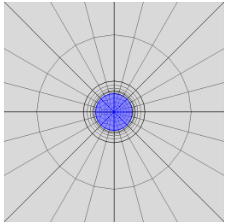
Overview

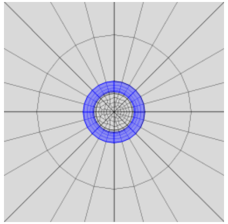

Pipes

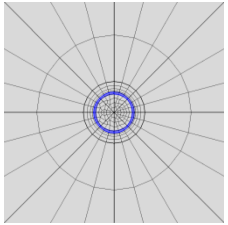

Pile tip

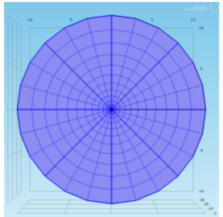
Mesh details


3D view


Internal concrete ring


External concrete ring


Reinforcement


Soil domain

Parametric analysis

PARAMETER SELECTION

- Pile length, L_P,
- Pile diameter, D_P;
- Pipe diameter, D_T;
- Concrete conductivity, λ_{CLS};
- Pipe conductivity, λ_T;
- Fluid conductivity, λ_F;
- Fluid velocity, v_F.

STATISTICAL ANALYSIS

Taguchi method

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7 parameters, 2 levels
(**upper and lower bound**)

Parameters	v_F	λ_T	λ_F	D_P	L_P	λ_{CLS}	D_T
Units	m/s	W/m°K	W/m°K	mm	m	W/m°K	mm
Lower bound	0.4	0.6	0.6	150	10	1.5	12
Upper bound	1.2	20	0.79	200	20	3	20

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8 simulations (Taguchi «L8» array)

Parametric analysis results

Output values of L8 analysis: exchanged power after 180 days

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Level average analysis

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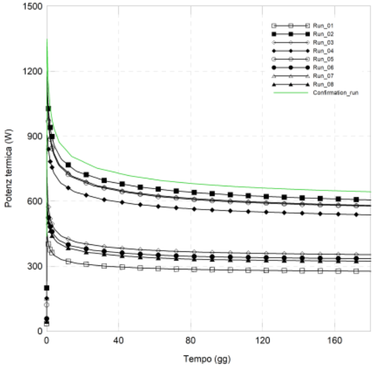
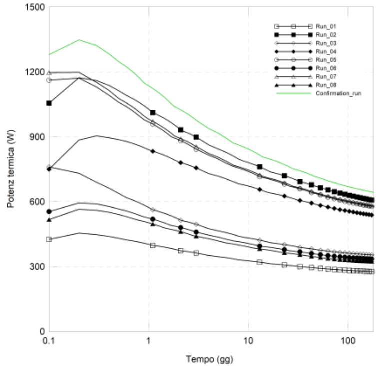
Confirmation Run

Run	v_F	λ_T	λ_F	D_P	L_P	λ_{CLS}	D_T
	m/s	W/m°K	W/m°K	mm	m	W/m°K	mm
01	0.4	0.6	0.6	150	10	1.5	12
02	0.4	0.6	0.6	200	20	3	20
03	0.4	20	0.79	150	10	3	20
04	0.4	20	0.79	200	20	1.5	12
05	1.2	0.6	0.79	150	20	1.5	20
06	1.2	0.6	0.79	200	10	3	12
07	1.2	20	0.6	150	20	3	12
08	1.2	20	0.6	200	10	1.5	20





Conclusion

- A numerical model was employed to perform a parametric study to assess the most important parameters to maximize the energy performance of EMPs
- The three most important factors in EMP energy performance are
    - pile length
    - concrete conductivity
    - pipe diameter
- Results show that thermal design of EMPs should not be based on the same criteria as those used for EP design
- The energy performance of energy micropiles is comparable to that of standard diameter energy piles

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References

Ronchi, F., Salciarini, D., Cavalagli, N., & Tamagnini, C. (2018). Thermal response prediction of a prototype Energy Micro-Pile. *Geomechanics for Energy and the Environment*, *16*, 64-82.

Salciarini, D. & Cecinato, F. (2020). Numerical modelling of thermo-active micropiles. Proceedings of the 16th International Conference of IACMAG (in press).