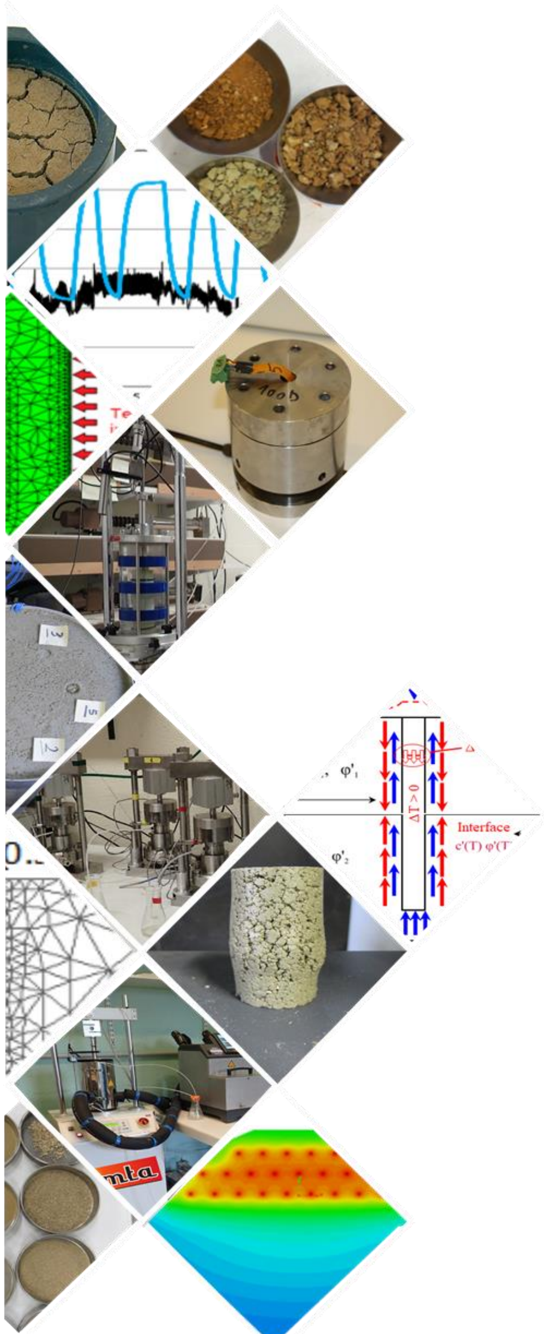

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EGU2020-5622

IN SITU INVESTIGATION OF THE IMPACT OF CYCLIC THERMAL VARIATIONS IMPACT ON THE MECHANICAL PROPERTIES OF A SANDY SOIL

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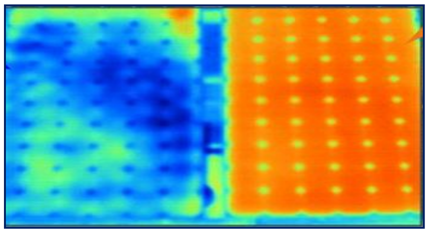
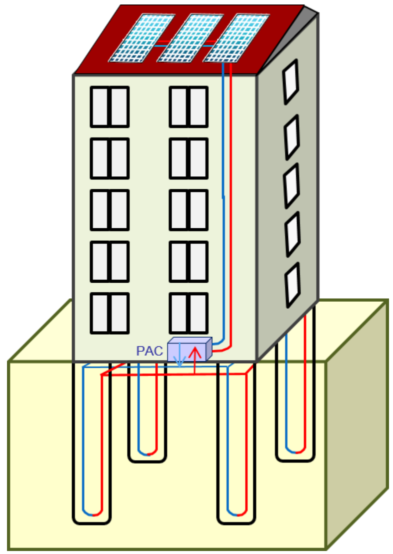
Geo-structures combined with hybrid solar panels and optimized energy storage: solution for Energy-Plus-Buildings (EPB/BEPOS)

Solar panel :
- 0.5% on performance by degree beyond 25°C

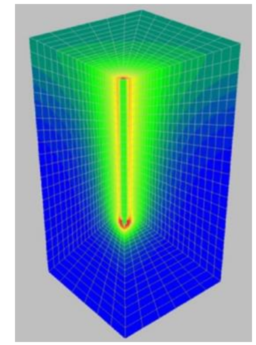


Frozen hybrid solar panel — Classical solar panel



Scientific issue :
Study the combination between geo-structure systems and hybrid solar panels in order to set up an energy system able to provide economic and technical excellence.

Ain of this study :
Measure the impact of temperature variations on the mechanical parameters of the soil in the vicinity of the geothermal piles.



Modeling of the geothermal piles

Suryatriyastuti et al. 2012

Mini-pressuremeter tests in laboratory

Eslami et al. 2013

Loading tests on geothermal piles

Szymkiewicz et al. 2015

LOCALISATION AND LITHOLOGY OF THE TEST CASE

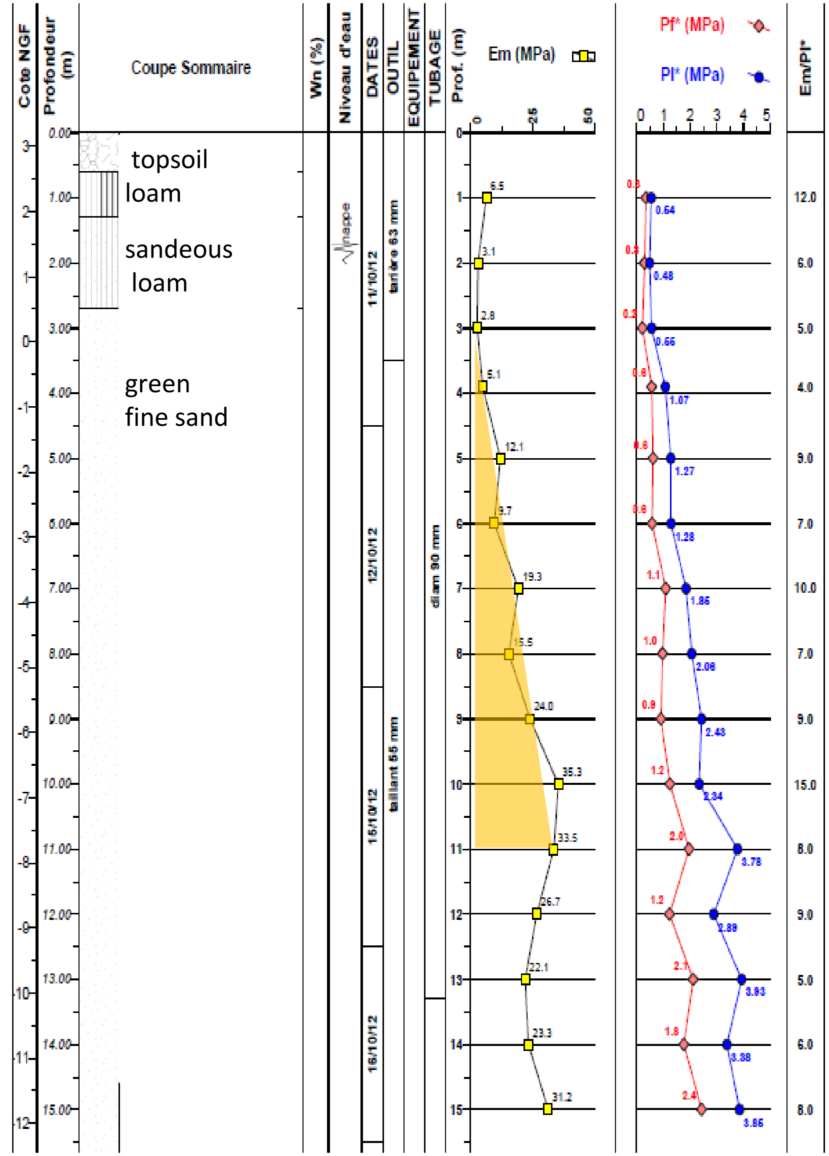
Localisation of the test case

Map modified from www.google.fr

Test site   Pressurmeter test

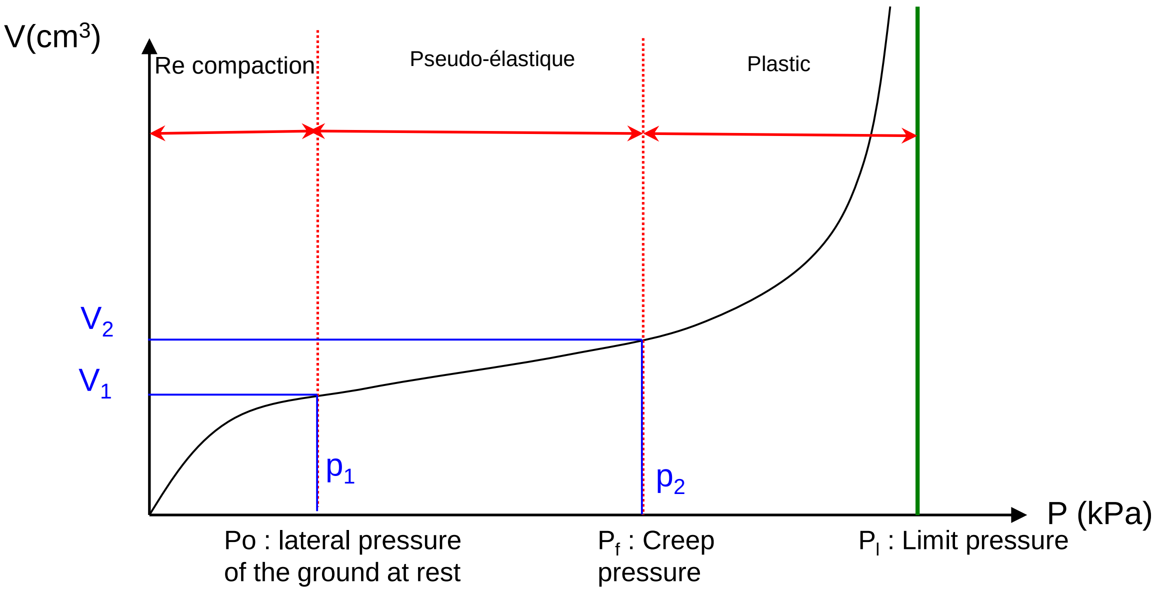
The experimental site is located in the north of France, near Dunkerque in France. The soil is mainly made of sand beneath a three meters' thick silts layer. The water table is found at 1.6 m deep. Szymkiewicz et al. (2011) performed one Ménard pressuremeter test as well as a core to assess the limit pressure, the water content, the grain size distribution, the density, the friction angle and cohesion of the soil up to 15 meters deep.

The presented in this study were performed in the thick sand layer at 3 and 4 meters in depth. Note that in this layer, we clearly see that the pressuremeters parameters are more and more important according to the depth : the soil is densified under the load of the overhead soil
In the following, mini-pressurmeter tests will be compared with these pressurmeter tests.



Szymkiewicz et al. (2011)

MINI-PRESSUREMETER TESTS

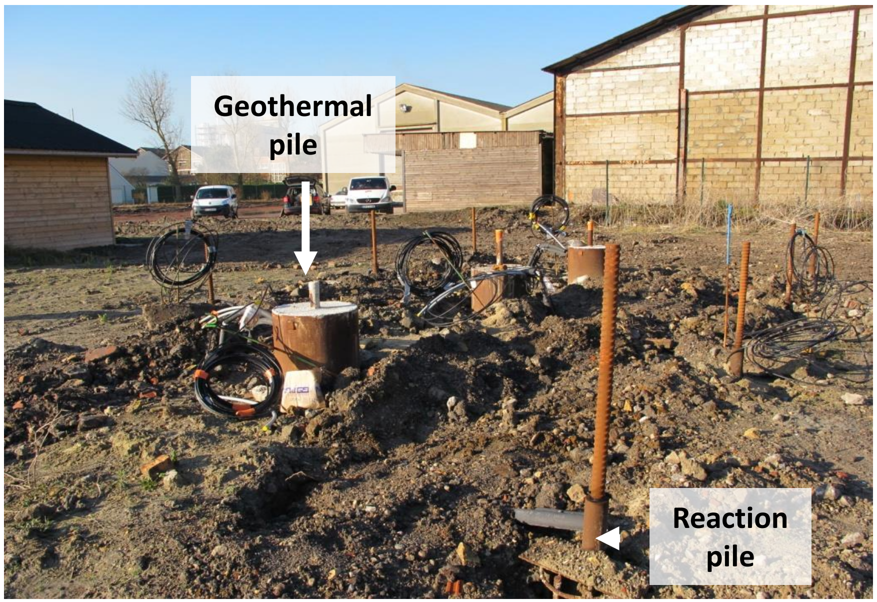


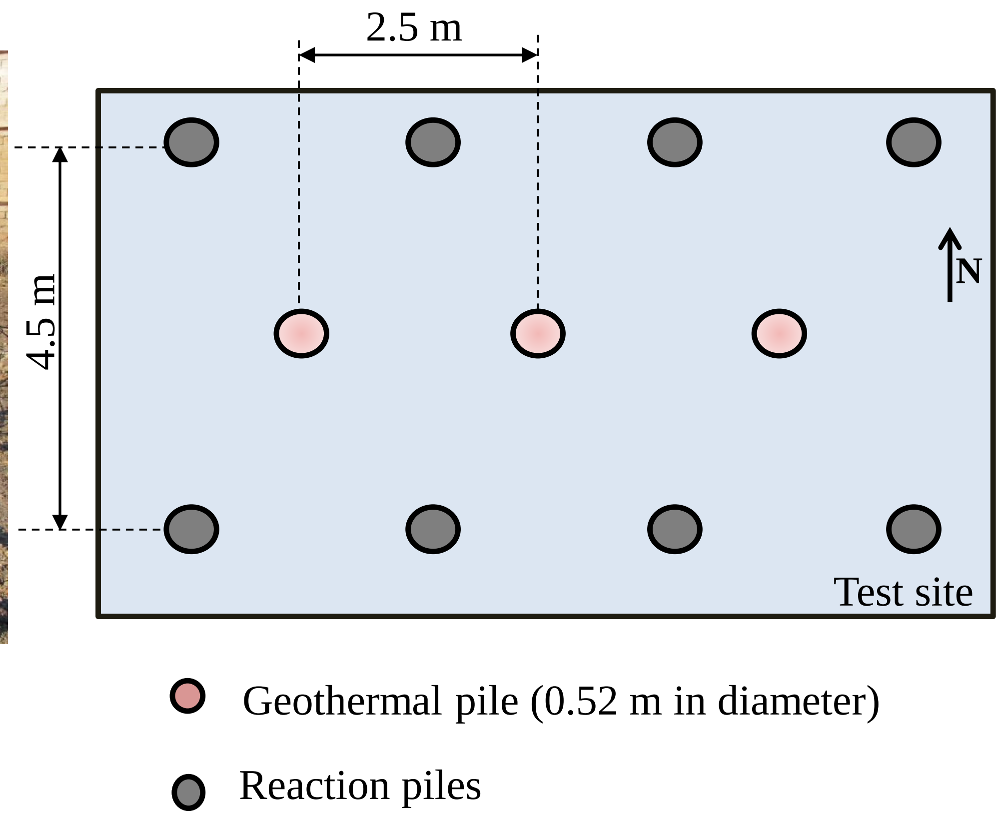
Each pressuremeter curve contains 3 steps :
1- the probe inflates to reach contact with the wall of the hole
2- the volume increases linearly with the increasing pressure allowing for the calculation of **the pressuremeter modulus E_M** (the soil pseudo-elastic reaction against the probe pressure)
3- large displacements take place : plastic deformation
The **creep pressure, P_f** is the boundary between the second and the third steps of the test.
The **limit pressure P_l** corresponds to the masure pressure when the injected volume reaches twice the original volume of the cavity, this value was extrapolated

What is the impact of cyclic temperature variations on these mechanical parameters ?

SET UP OF THE FIELD TESTS

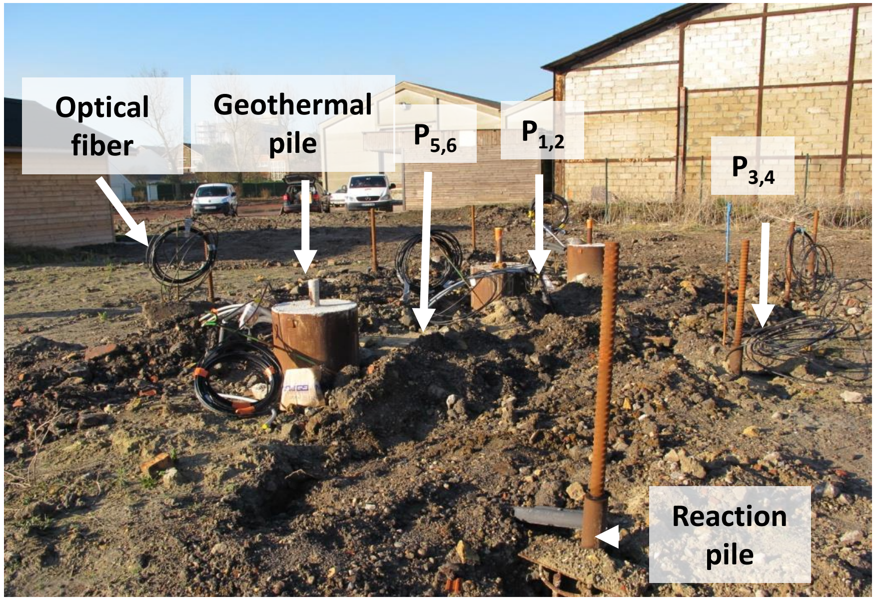
Three geothermal piles of 12 m long and 0.52 m in diameter, spaced of 2.5 m were realized on the experimental site in July 2013.

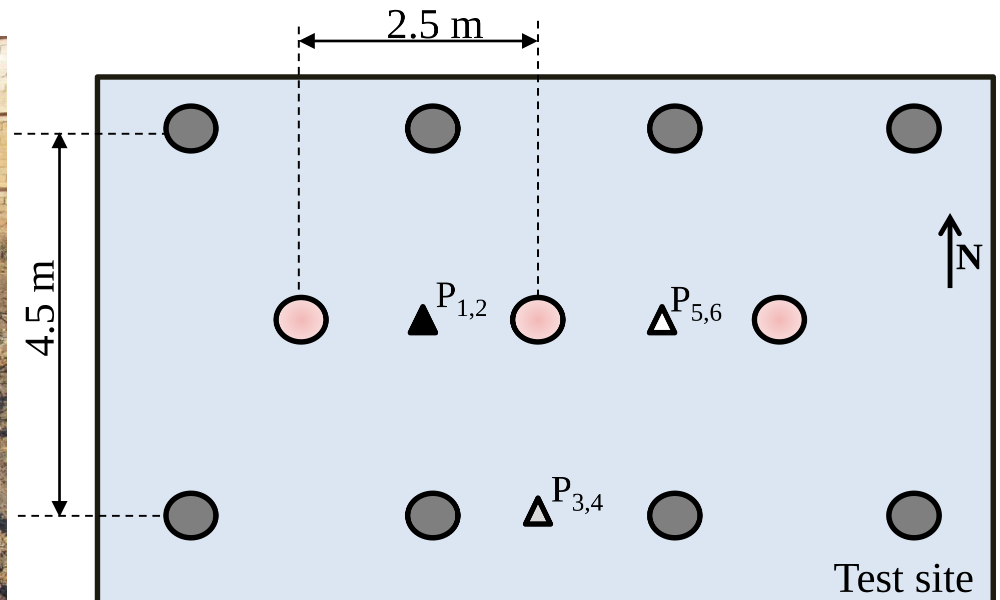




Profil :
0 – 0.6 m : topsoil
0.6 – 1.3 m : yellow brownish loam
1.3 – 2.6 m : greenish sandeous loam
> 2.6 m : green fine sand

SCIENTIFIC SURVEY OF THE GEOTHERMAL PILES





Geothermal pile (0.52 m in diameter)

Reaction piles

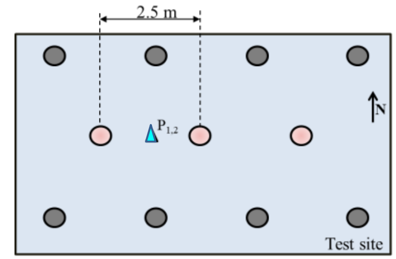
Mini pressuremeter tests at 3 and 4 m in depth :

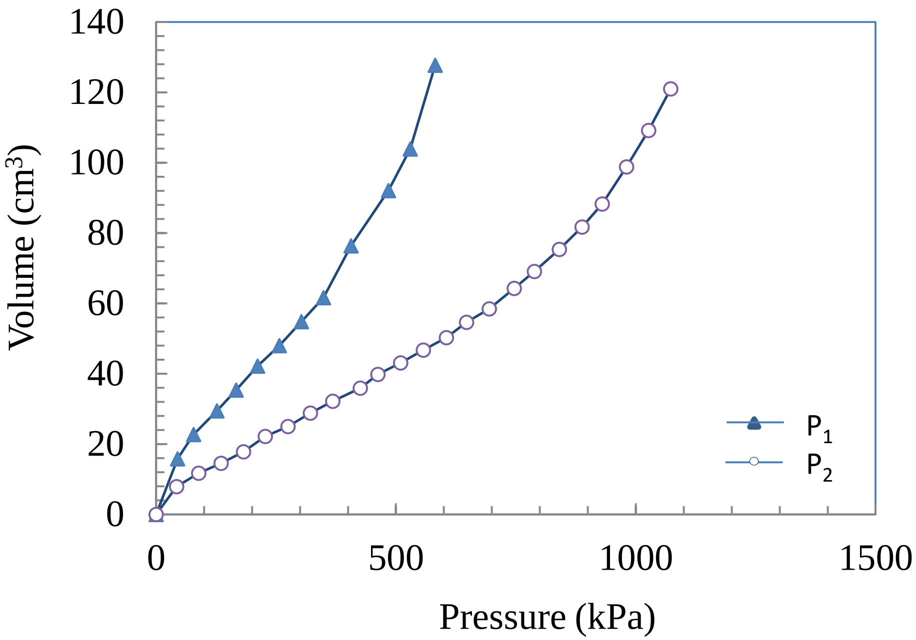
▲ △ $P_{1,2,3,4}$ before the thermal variation (march, 5th 2014)

△ $P_{5,6}$ after the thermal variation (october, 29th 2014)

Six mini-pressuremeters tests were carried out on the test site at three locations and two different depths. Tests P1 to P4 were performed after experimental set-up of the geothermal piles and reaction piles but before their thermal sollicitation, in march. P1 was carried out at a depth of 3m and P2 at 4m. In the same manner, P3 and P4 were respectively carried out at a depth of 3 and 4m but further from the piles (2.25m).
P5 and P6 were placed close to the geothermal pile (1.25 m far from the heat source), but they wer carried out after the thermal sollicitation in october

Comparison of P1 and P2 with the classical pressuremeter tests performed on site :





March 5th : Mini-pressuremeter tests P1 and P2

Distance to the geothermal pile : 1.25 m

Test	Depth	Mini-Pressuremeter parameters E_P (MPa)	P_l (kPa)	P_f (kPa)
P_1	3 m	3.24	573	340
P_2	4 m	5.95	1241	720

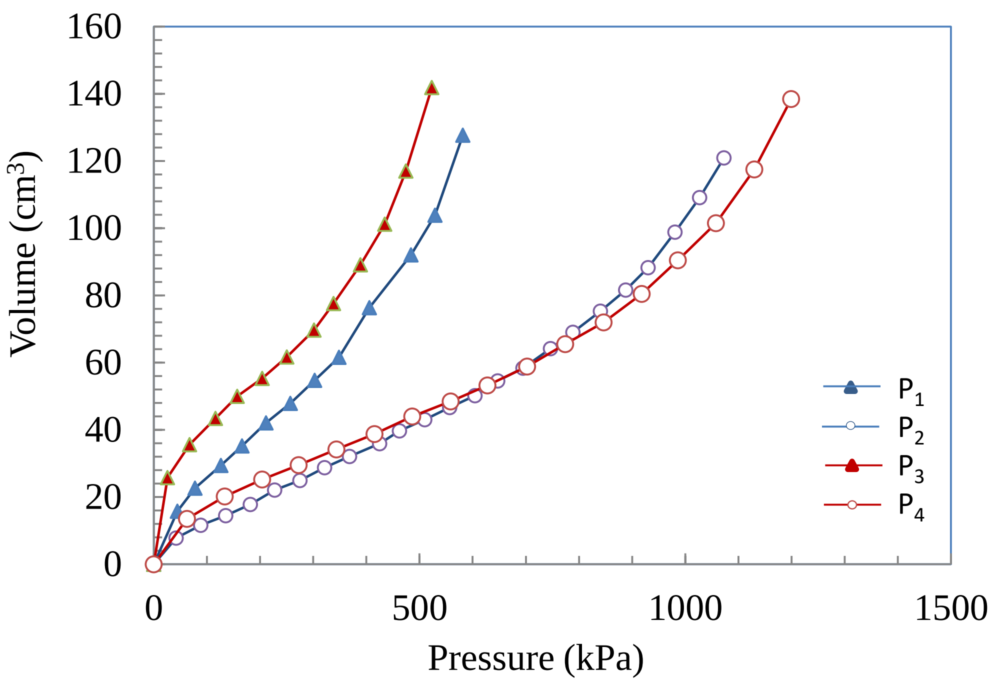
The vertical variation in lithology clearly appears by comparing test at a depth of 3m (P1) with the test at a depth of 4m (P2). The same contrast was evidenced on the pressuremeter results and closed values were reached.

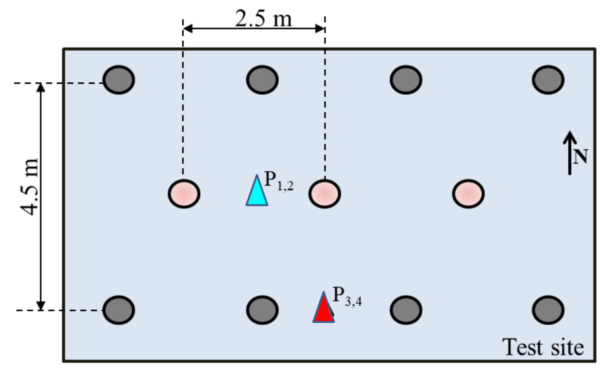
=> good agreement between the two methods for that kind of superficial soils.

Depth	Pressuremeter parameters E_P (MPa)	P_l (kPa)	P_f (kPa)
3 m	2.8	550	200
4 m	5.1	1070	600

Szymkiewicz et al. (2011)

Results measured at 3m and 4 m in depth at two locations
before the application of the cyclic thermal variation (P1, 2,3,4).





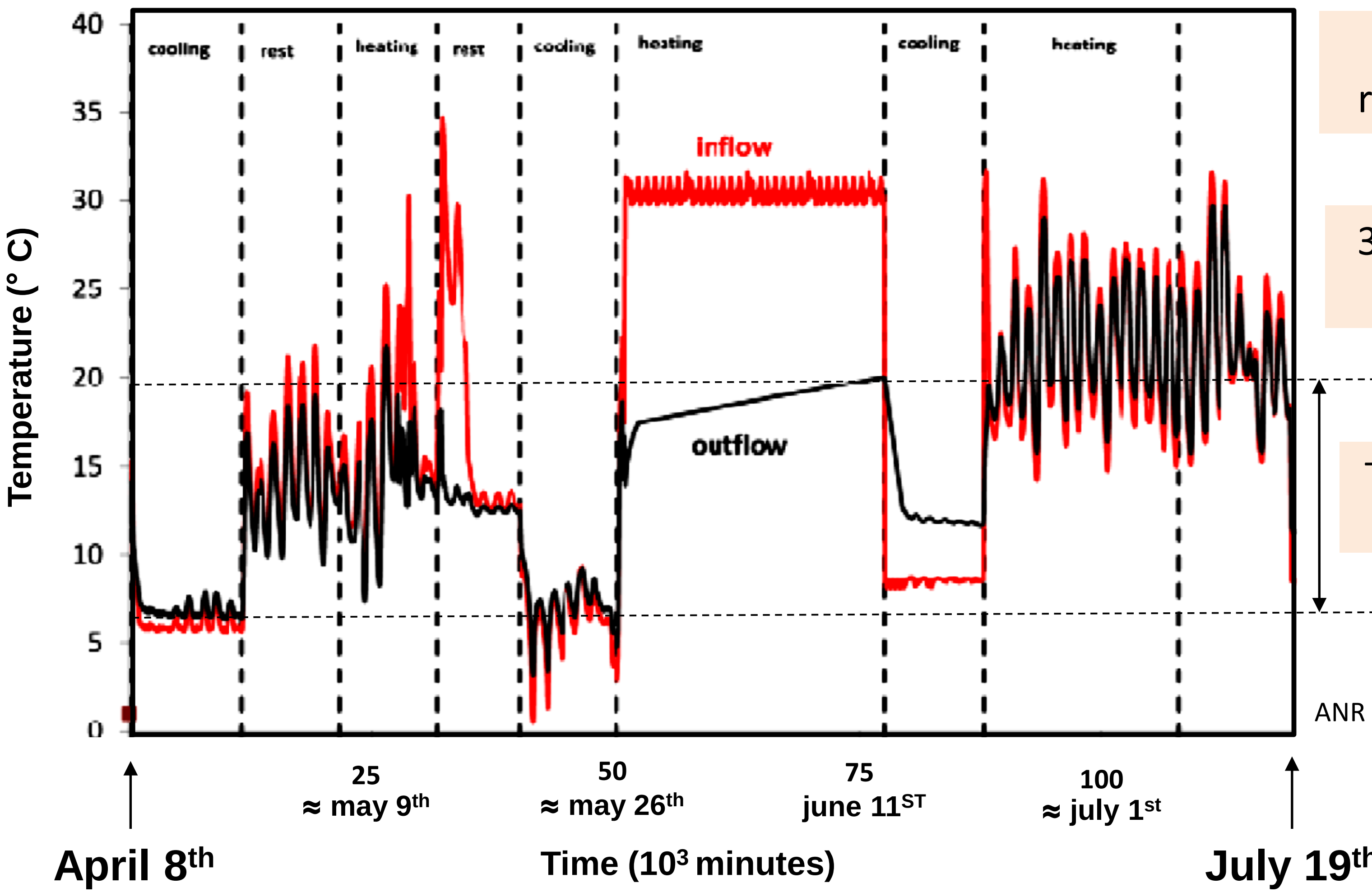
P1 - P3 : thin lateral lithological variation with very low impact on pressuremeter parameters

P2 = P4 : homogeneity of the massif

Test	Date	Distance to geothermal pile	Depth	Mini-Pressuremeter parameters		
				E_P (MPa)	P_l (kPa)	P_f (kPa)
P_1	march, 5th	1.25 m	3 m	3.24	573	340
P_2	march, 5th	1.25 m	4 m	5.95	1241	720
P_3	march, 5th	2.25 m	3 m	2.93	625	360
P_4	march, 5th	2.25 m	4 m	5.02	1106	610

Inflow and outflow variation of the temperature in the geothermal piles
From April 8th to July 19th

Heating-cooling cycles in the range 5 to 40°C were applied for 5 months using a thermoregulator (May 2014 to September 2014). The resulting temperature is measured in the pile using an optical fibre placed inside the different piles.



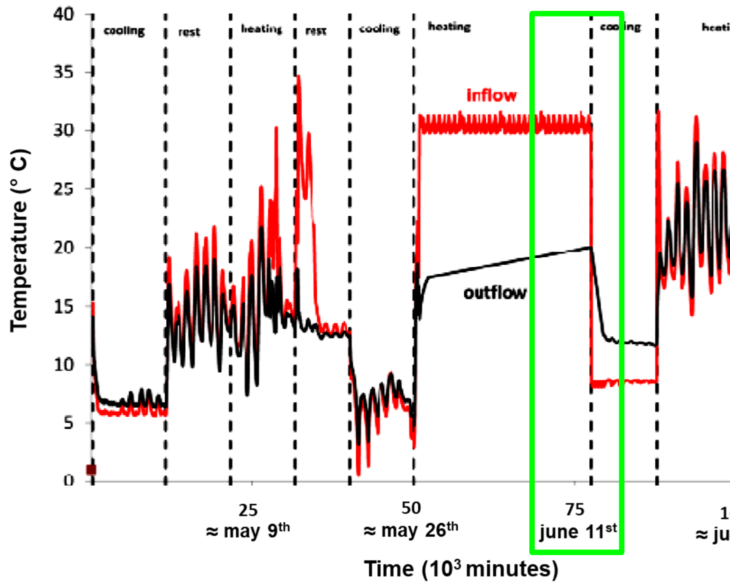
Heat pump running: 87 days

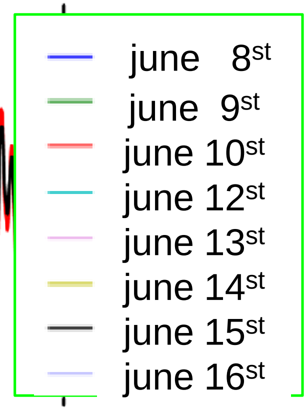
3 heating-cooling cycles

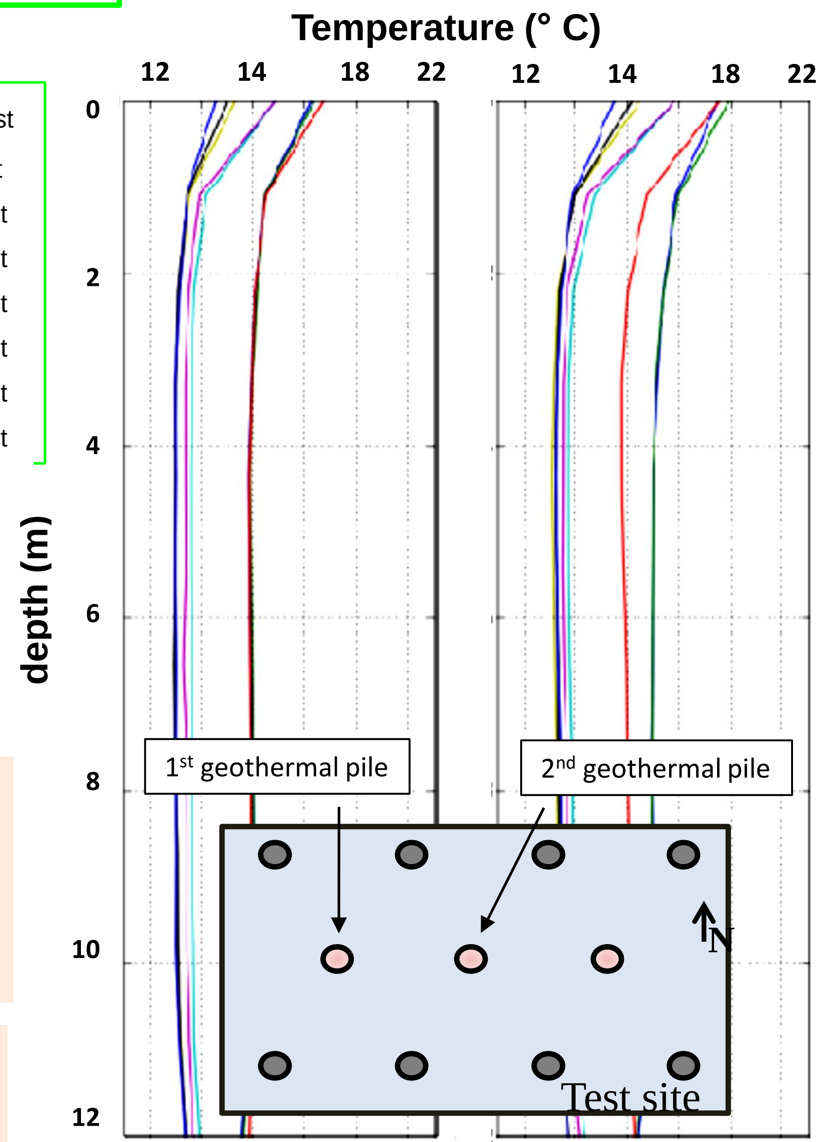
Temperature range from 8° to 19°C

ANR GECKO Report (2015)

Example of variation of the temperature in two geothermal piles from June 8th to 16th







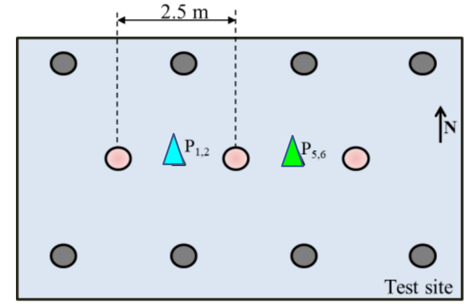
Temperature variation of the external part of the pile according to the depth for one cooling step.

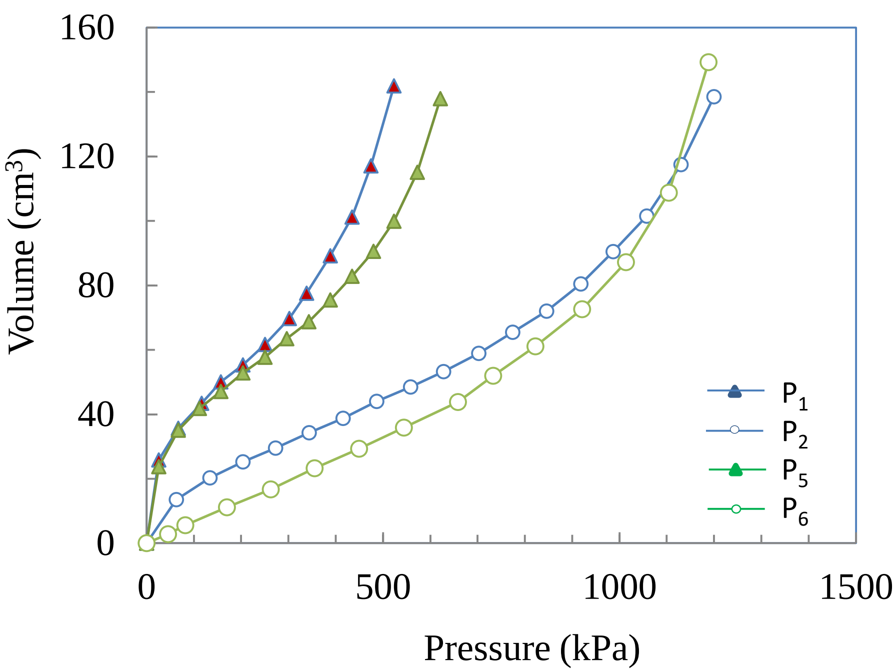
Maximum outflow temperature : 19°C
Maximum temperature of the external part of the pile : 16°C after 15 days of heating
=> Δ_t of the surrounding soil is of only + 3.5°C after 15 days of heating

The values for the lowest temperatures (during the first cooling step) are not available. The following tests were performed before and after the 3 heating-cooling cycles.

ANR GECKO Report (2015)

Mini-Pressuremeter curves at 3 and 4m in depth **before and after the application of the cyclic thermal variation**





Test	Date of test	Depth
P_1	March, 5th 2014	3m
P_2		4m
P_5	October, 29th 2014	3m
P_6		4m

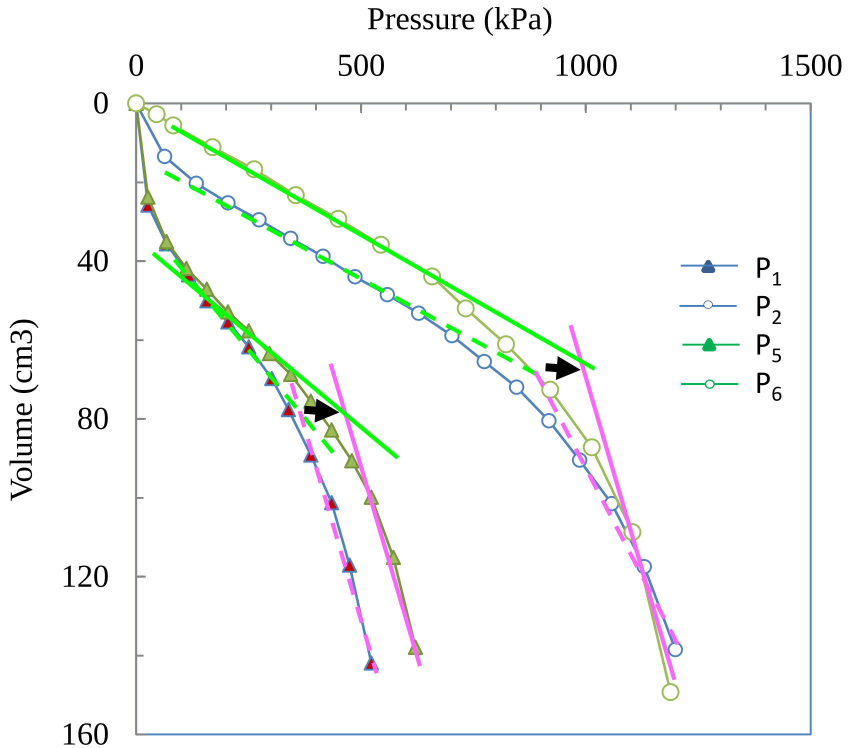
Conditions		**Evolution due to cyclic thermal variation**		
		ΔE_P	ΔP_l	ΔP_f
In situ	3 m	+ 14 %	+ 27 %	+ 18 %
	4 m	- 6 %	- 10 %	+ 28 %

At 3m in depth, a clear soil thickening is recorded after the heating-cooling cycles

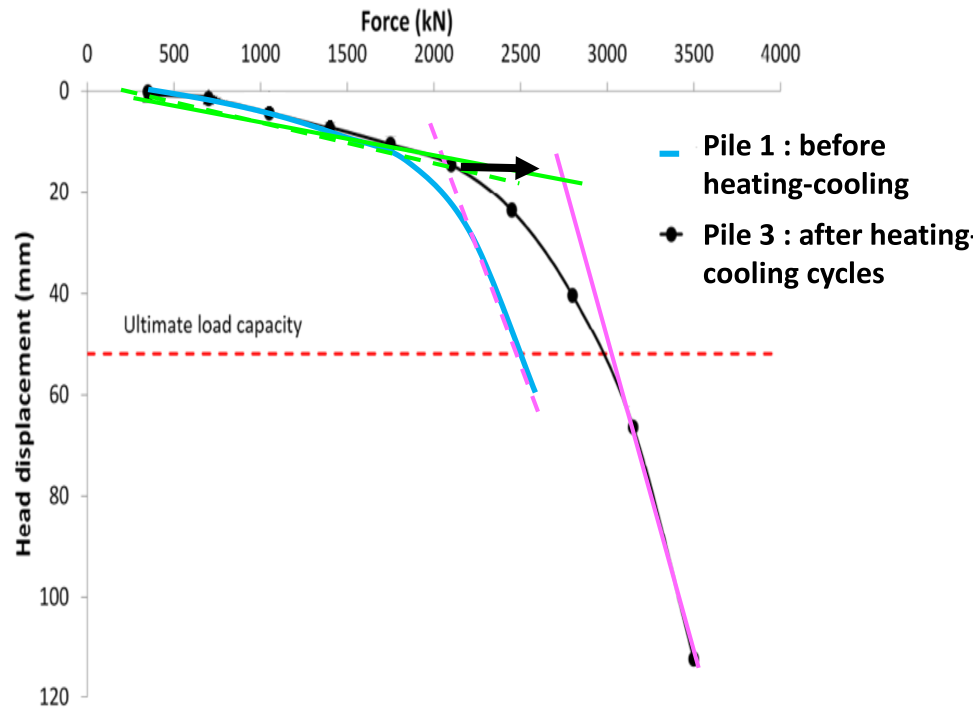
Tests P5 and P6 were carried out at a depth of respectively 3m and 4m and at distance of 1.25m from the geothermal piles but after the thermal solicitation of the piles. In accordance with the narrow range of pile temperature variation, the difference between curves is low.

The comparison of the pressuremeter parameters calculated at a depth of 3m (P1 and P5), shows a discernable increase of the pressuremeter modulus, the limit pressure and the creep pressure. For deeper tests (P2 and P6), the difference between tests is lower.

COMPARISON WITH IN-SITU BEARING TESTS



This study



Impact of heating-cooling cycles on the bearing capacity of CFA piles in sandy soils
(modified from *Szymkiewicz et al. 2015*)

Elastic part	Moderate evolution of the elastic modulus (E)	The beginning of the curves are closed together
Elasto-plastic limit	Increase of the creep pressure (Pf)	The yielding occurs under an higher vertical force

F. Szymkiewicz, S. Burlon , F. Guirado, C. Minatchy and G. Vinceslas, 2015. Impact of heating-cooling cycles on the bearing capacity of CFA piles in sandy soils. XVI ECSMGE, Paris, France

CONCLUSIONS

Several mini-pressuremeter tests were performed close to geothermal piles, they are consistent with classical pressuremeter tests.

The comparison of the mechanical parameters before and after heating-cooling cycles shows :

- an increase of the mechanical parameters indicating a soil thickening;
- For the deeper results, a increase of the P_f is measured but E_M and P_l were not affected in the same way : the temperature variations may have various impact according to the initial soil density.

The heat-cooling cycles had a positive influence on the bearing capacity of the piles due to :

- densification of the soil at the interface soil-pile (*Szymkiewicz et al. 2015);*
- thickening of the soil around the geothermal piles.

The soil thickening is recorded even after only three heating-cooling cycles.

TO BE CONTINUED :

Long-term impact of the heating-cooling cycles.
Impact of the heating-cooling cycles on loading piles.
Impact of the heating-cooling cycles on more sensitive soils (clayey soils).

Thank you for your kind attention

ACKNOWLEDGEMENTS

This study was part of the GECKO research program funded by ANR.
The partnership has been driven by JB. Bernard (ECOME)

Geothermal piles were executed by IFSTTAR and CEREMA as well as the bearing tests (under the supervision of S. Burlon, F. *Szymkiewicz and J. Habert*)

The optical fiber survey was reported by BRGM (under the supervision of C. Maragna, X. Rachez)