Relevance of modeling insulation layer in ground storage system design

Alberto Lazzarotto
KTH The Royal Institute of Technology
Divsion of Building Technology

Study motivation

Correct system design in GSHP is necessary

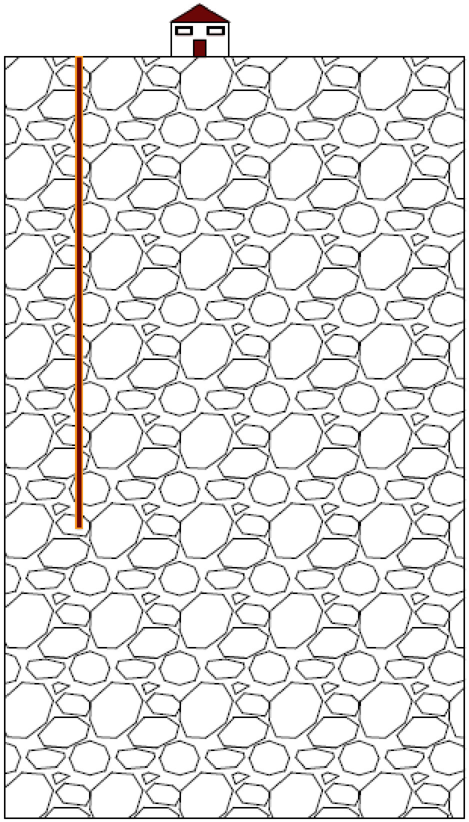
- Oversize → Extra investment cost
- Undersize → Poor performance after few years operation

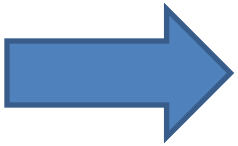
Problem

Design method for ground storage design has been developed for deep borehole application and might be unsuitable for pile storage

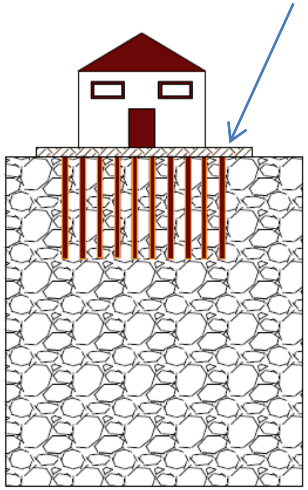
Can I use the same Design tools?

Deep Borehole

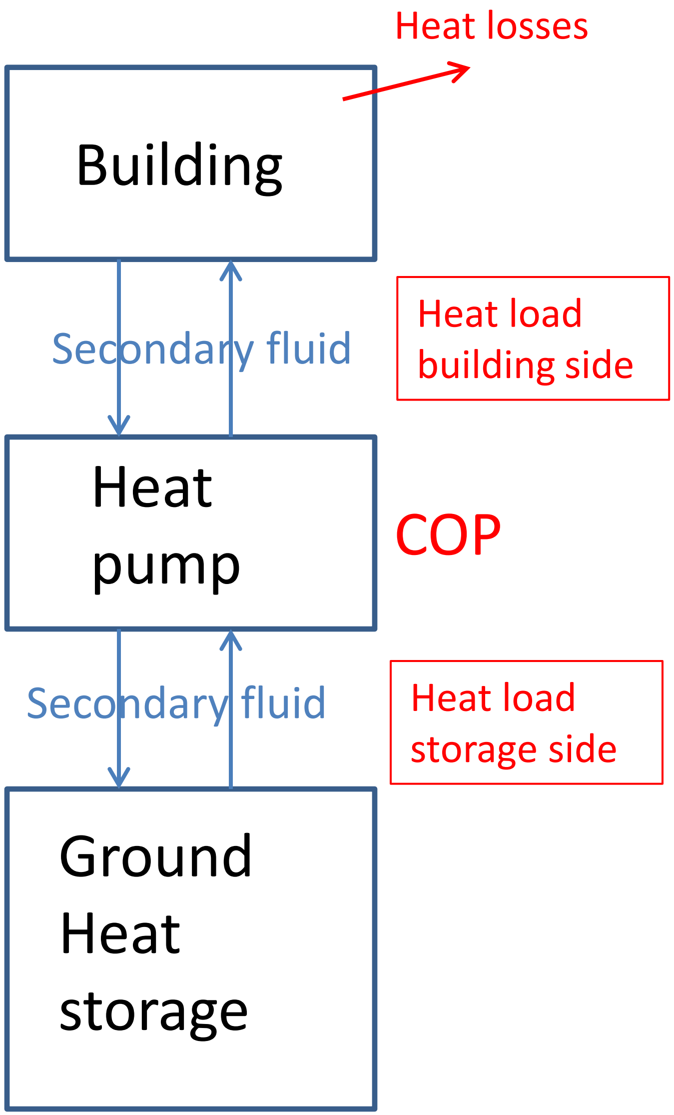




Energy pile system



Background on GSHP System

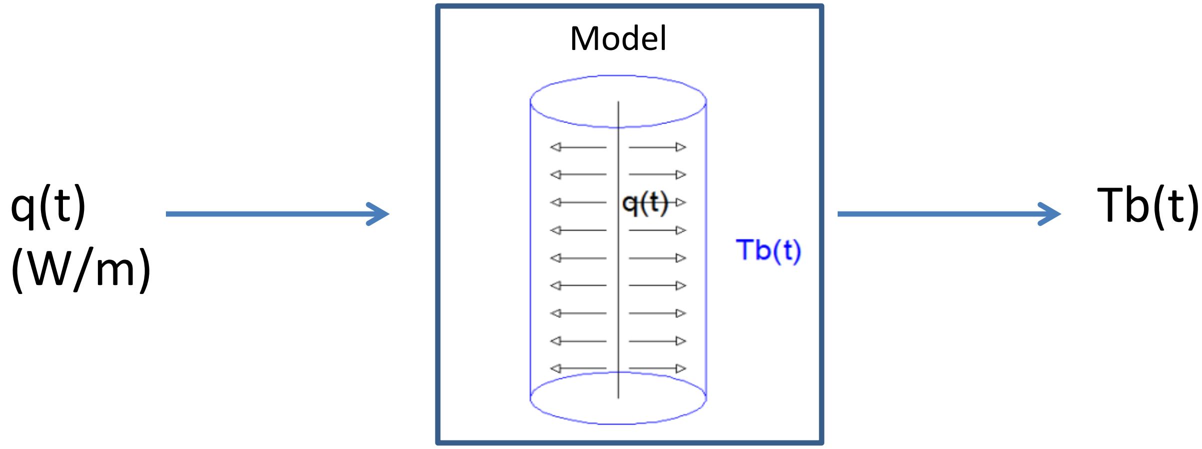


Design of the storage configuration must ensure high performance for the heat pump during operation

- COP depends on the temperature of the fluid from the heat storage
- This is dependent borehole temperature

Average temperature at the borehole surface Tb(t)

Background on classic design methodology



Response function method

1. Decomposition of the load q(t) as sum of step functions.
2. Response temperature Tb calculation for a unitary heat step.
3. Superposition of the effect and recomposition of the temperature Tb for the actual load

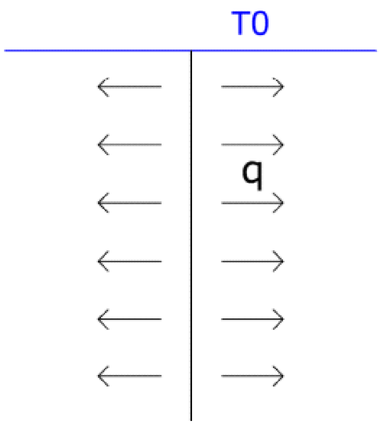
Focusing the attention on the models for response temperature determination

Analytical solutions for the step response determination:

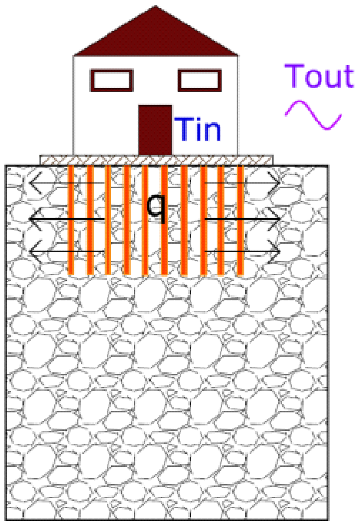
- Infinite line source (ILS)
- Finite line source (FLS)

Finite line source (FLS)

- Each borehole is reppresented as a linear heat source with finite lenght H
- Initial temperature is T0 in the whole domain
- The surface temperature is constant and equal to T0 for every t

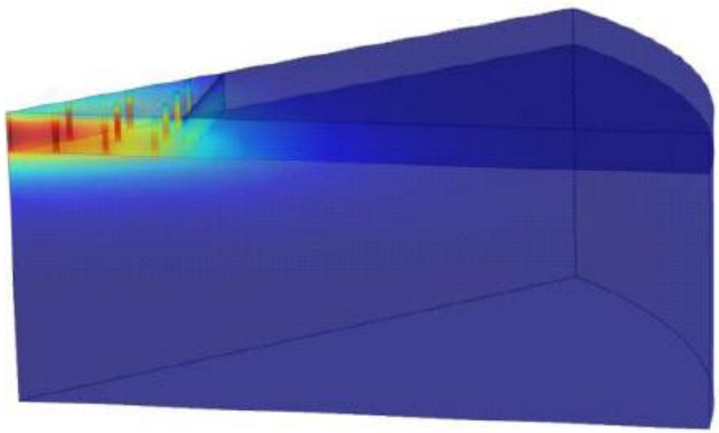


The boundary condition at the surface are much more complex

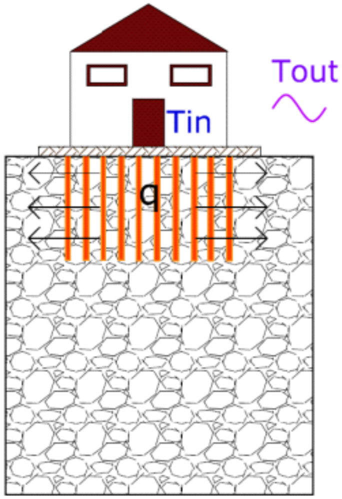


FLS solutions can’t track the behavior of the storage at the surface

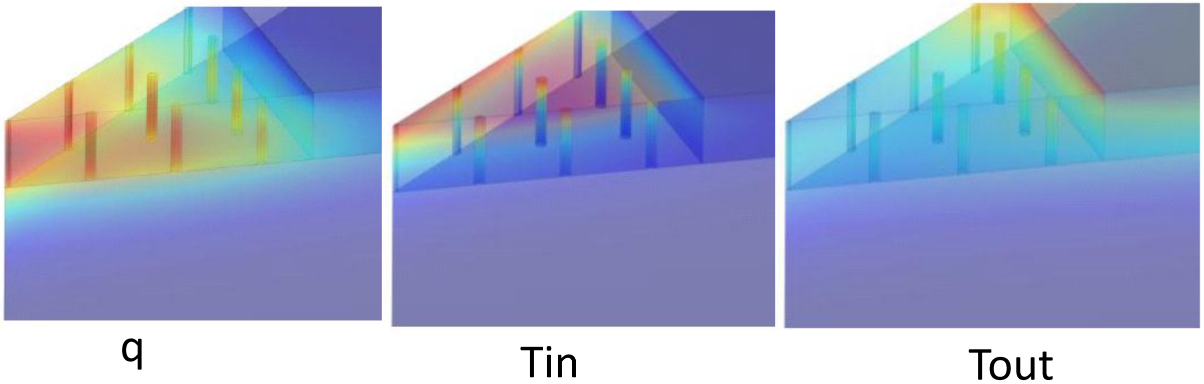
COMSOL model



- The model is utilized to calculate response functions
- Much more flexibility in the boundary conditions is allowed
- Insulation layer can be considered



Evaluation of response temperature for different driving forces



The response temperatures in points of interest is extracted (Borehole surfaces)

Superposition of effects is applied to find the actual temperature evolution due to the load configuration considered

Borehole temperature

MODEL TEST

Geometries

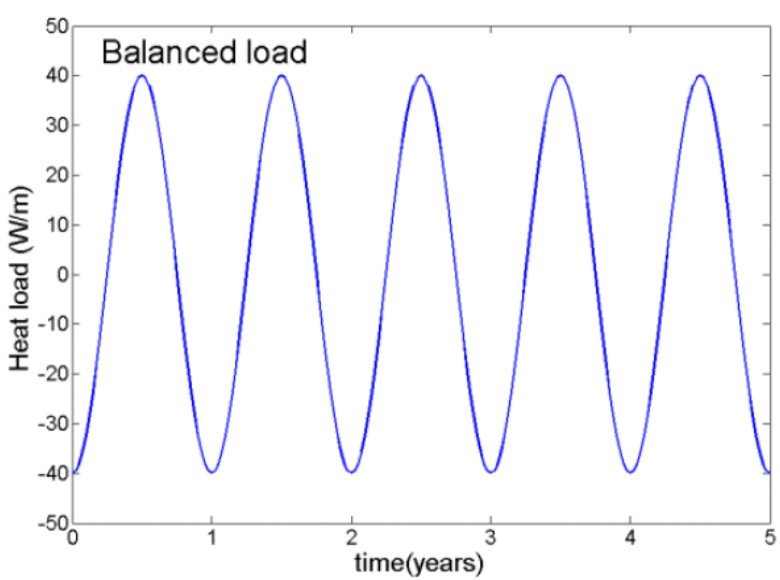
Pattern borehole field : 5×5, 7×7, 13×4
Grid space : 5 m
Depht : 10 m, 20m, 30m
Insulation layer: 300 mm

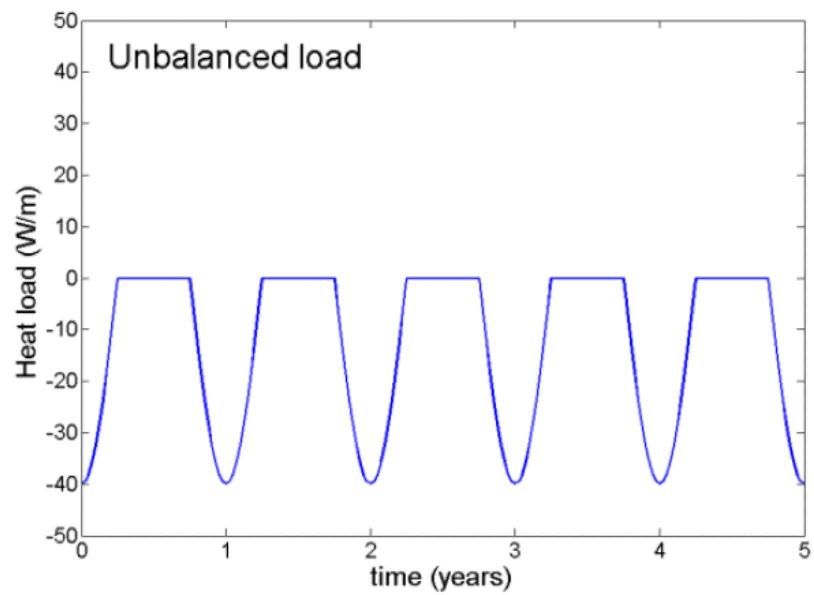
Soil characteristics

Thermal condutivity : 1.5 W/mK, 2.5 W/mK
Density : 1000 kg/m3
Specific heat capacity : 2600 J/kg K

Loads

Amplitude:40 W/m
Period: one year

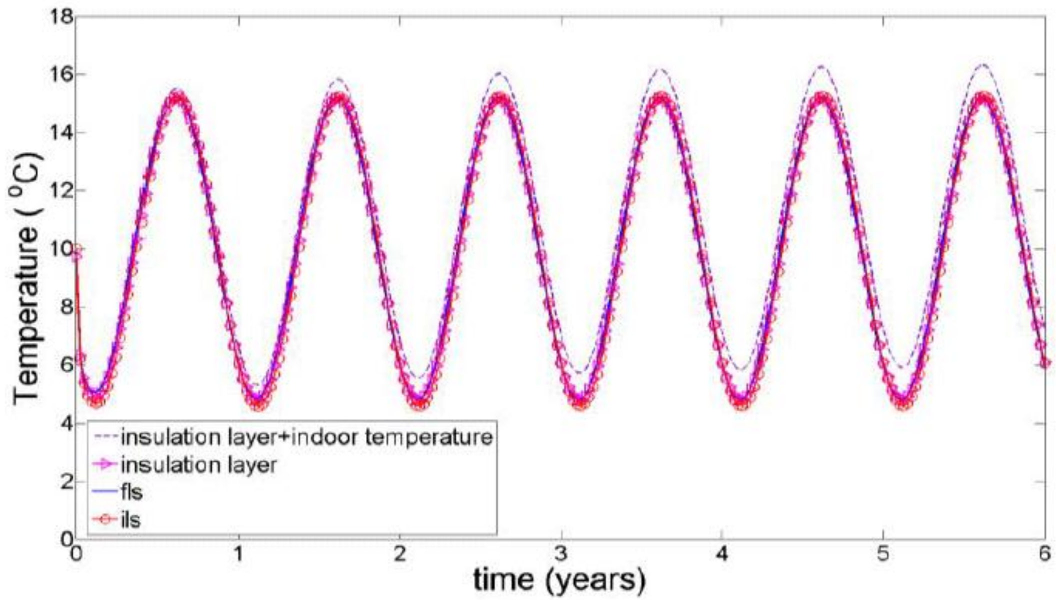




Results

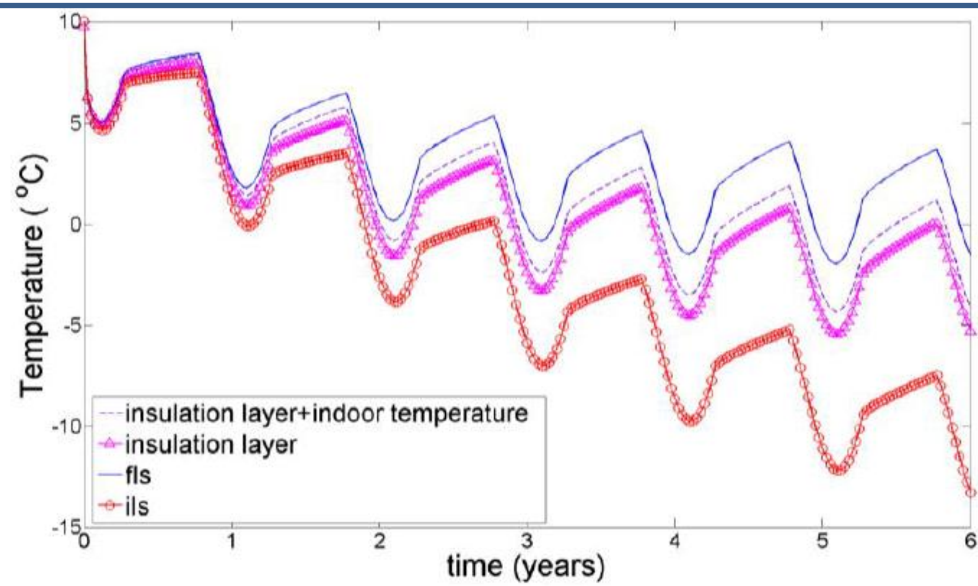
Balanced load

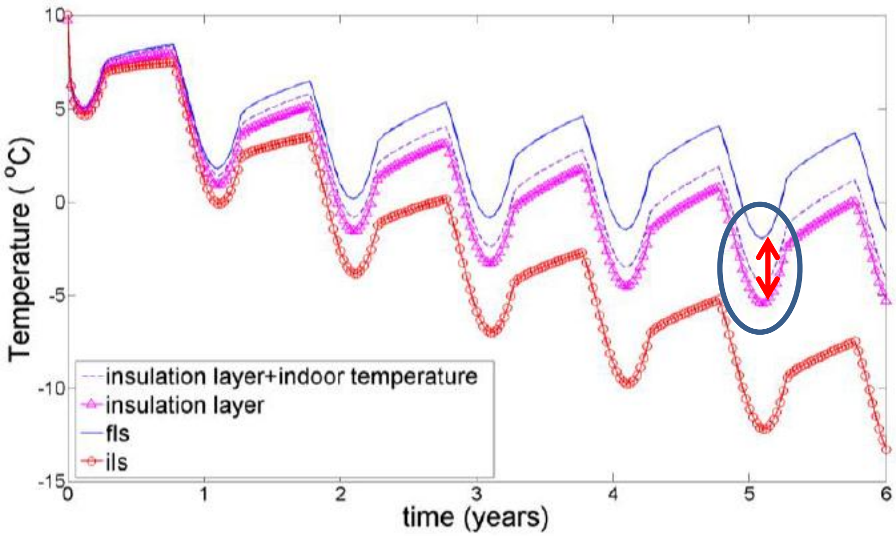
The analytical model and the numerical model show comparable behavior



Unbalanced load

In this case the investigated models yield to different results





Temperature difference between fls and numerical model after 10 years operation

		25piles		49piles		52piles	
k_g (W/mK)		1.5	2.5	1.5	2.5	1.5	2.5
H (m)	10	-4.57	-3.33	-6.27	-4.91	-5.03	-3.75
	20	-3.67	-2.86	-5.39	-4.69	-4.11	-3.36
	30	-2.63	-2.18	-3.93	-3.71		

- The more the system is large and compact, the greater is the difference between the models

- When Increasing the lenght of the piles, the difference between the FLS solution and the insulation layer model decreases

Less importance of the conditions at the surface

Conclusion

- When the load is balanced the results obtained with the traditional methodology are consitent with a more detail analysis.

- When the load is unbalanced traditional methodologies deviate compare to a detail analysis and could be interesting considering the methodology presented