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Development and Validation of a Diaphragm Wall Heat Exchanger Model

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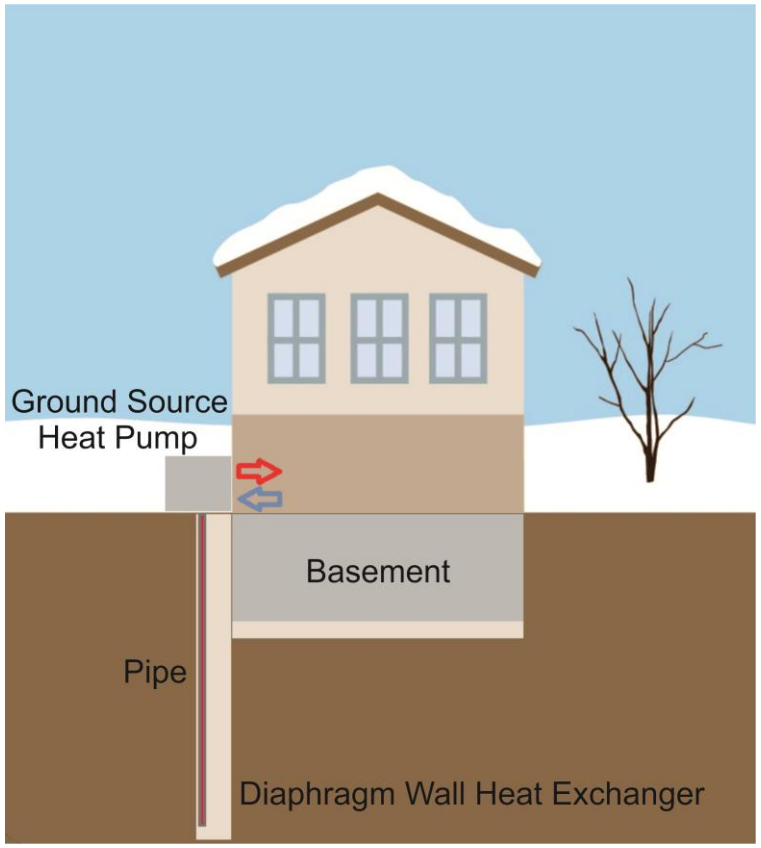
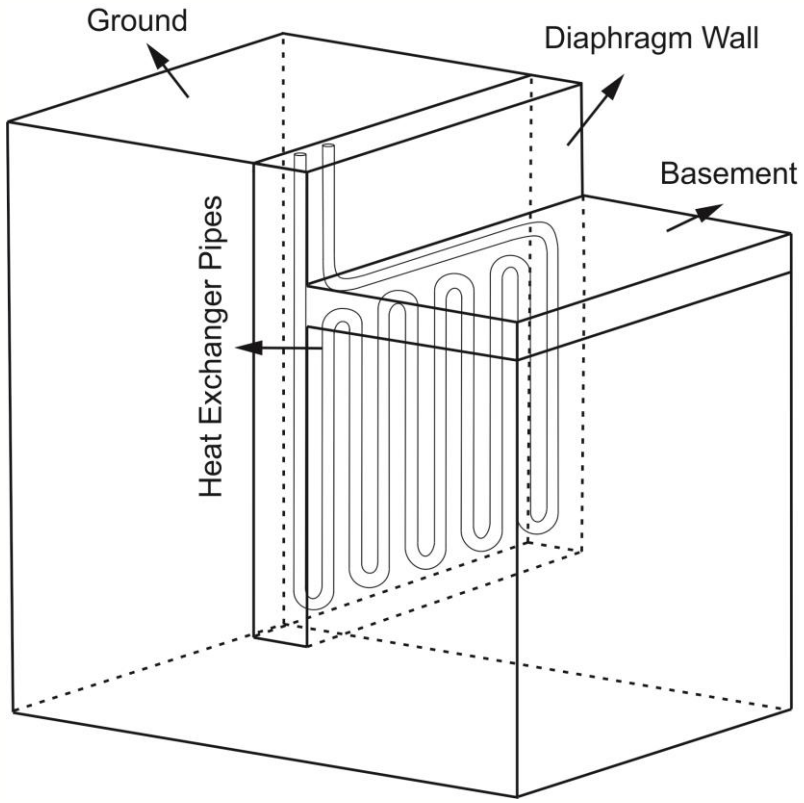
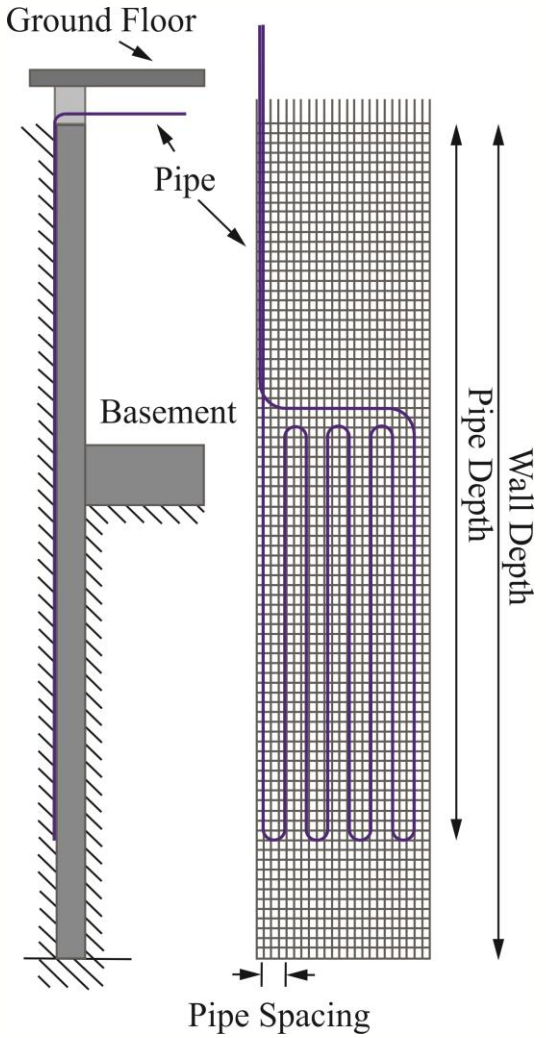
What is a Diaphragm Wall Heat Exchanger (DWHE)?







What is a Diaphragm Wall Heat Exchanger (DWHE)?

How to understand the performance of a DWHE?

Thermal Response Test (TRT): heat energy is injected at a constant rate into one end of the loop and the outflow temperature at the other end is measured.

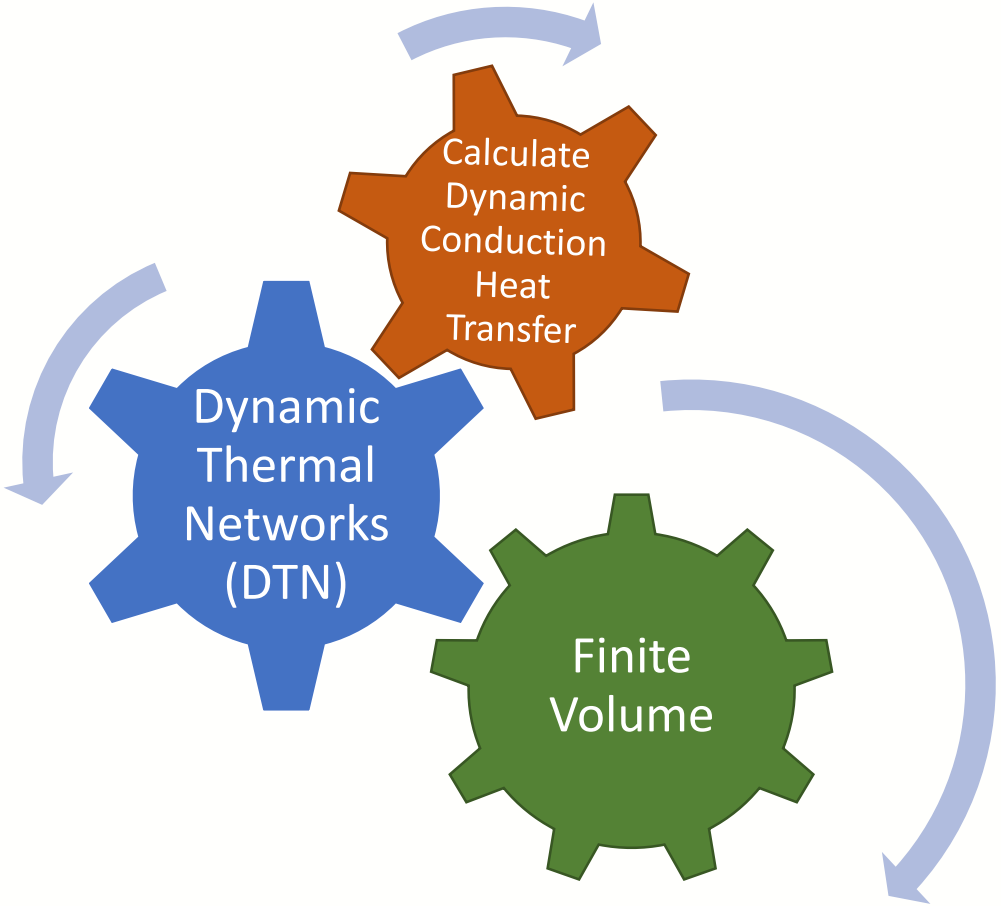
ground and/or concrete thermal properties

How to interpret such temperature data?

A suitable heat transfer mathematical model is required:

few models have been developed for DWHE due to their complexity

Objectives of the Current Research



we have used a TRT apparatus to:

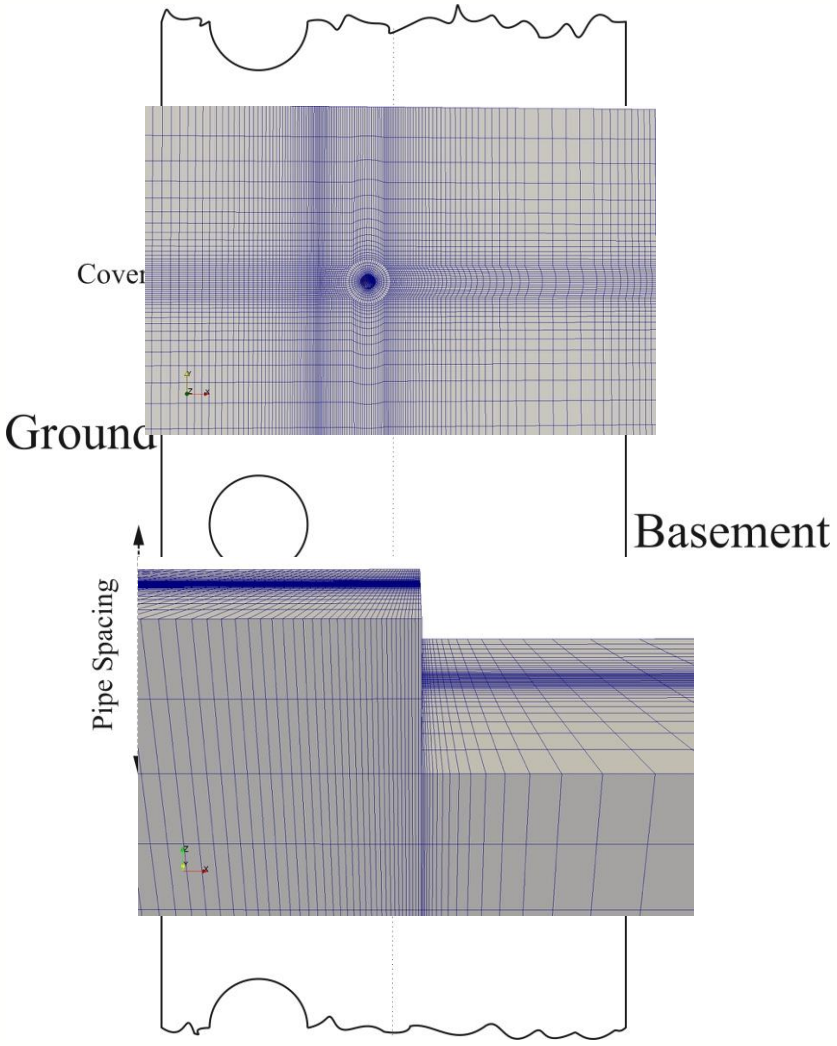
Stimulate the heat exchanger and derive data for model validation

Important Parameters in the Design of the DWHE

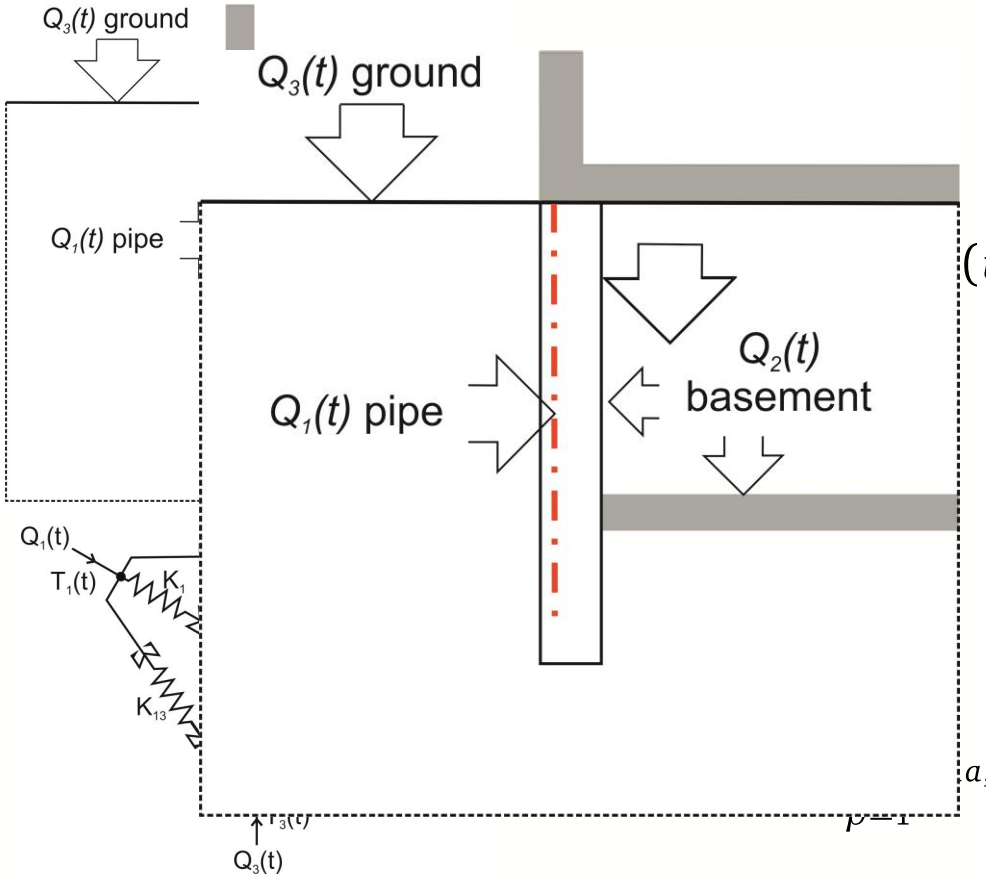
- Depth of the wall
- Width of the wall
- Depth of the basement area
- Thickness of the basement floor
- Depth of the buried heat exchanger pipe
- Pipe spacing
- Cover (space between the outer surface of the pipe and the ground)
- Heat exchanger pipe diameter

DEFINING THE BOUNDARY LAYERS

Weighing Factors required by DTN model



Dynamic Thermal Networks Model (DTN)

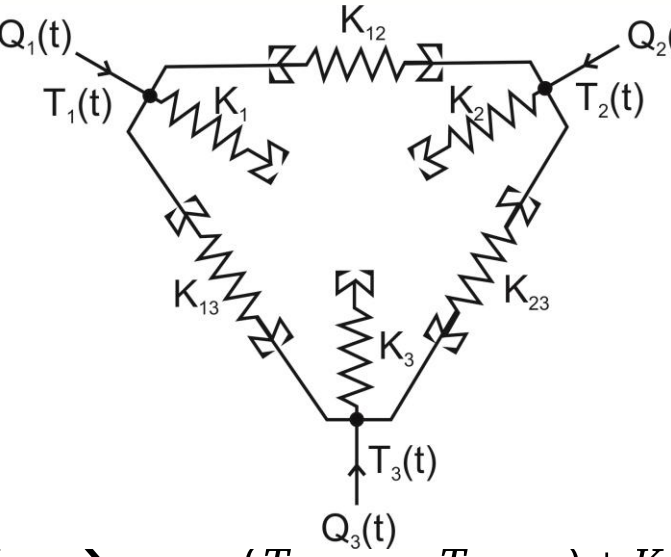


$$Q_1(t) = Q_{1a}(t) + Q_{12}(t) + Q_{13}(t)$$

$$(t) - \bar{T}_{1a}(t)\big] + \qquad (t) - \bar{T}_{31}(t)\big]$$

$$\bar{T}_{ia,}$$

$$\bar{T}_{ij,}$$

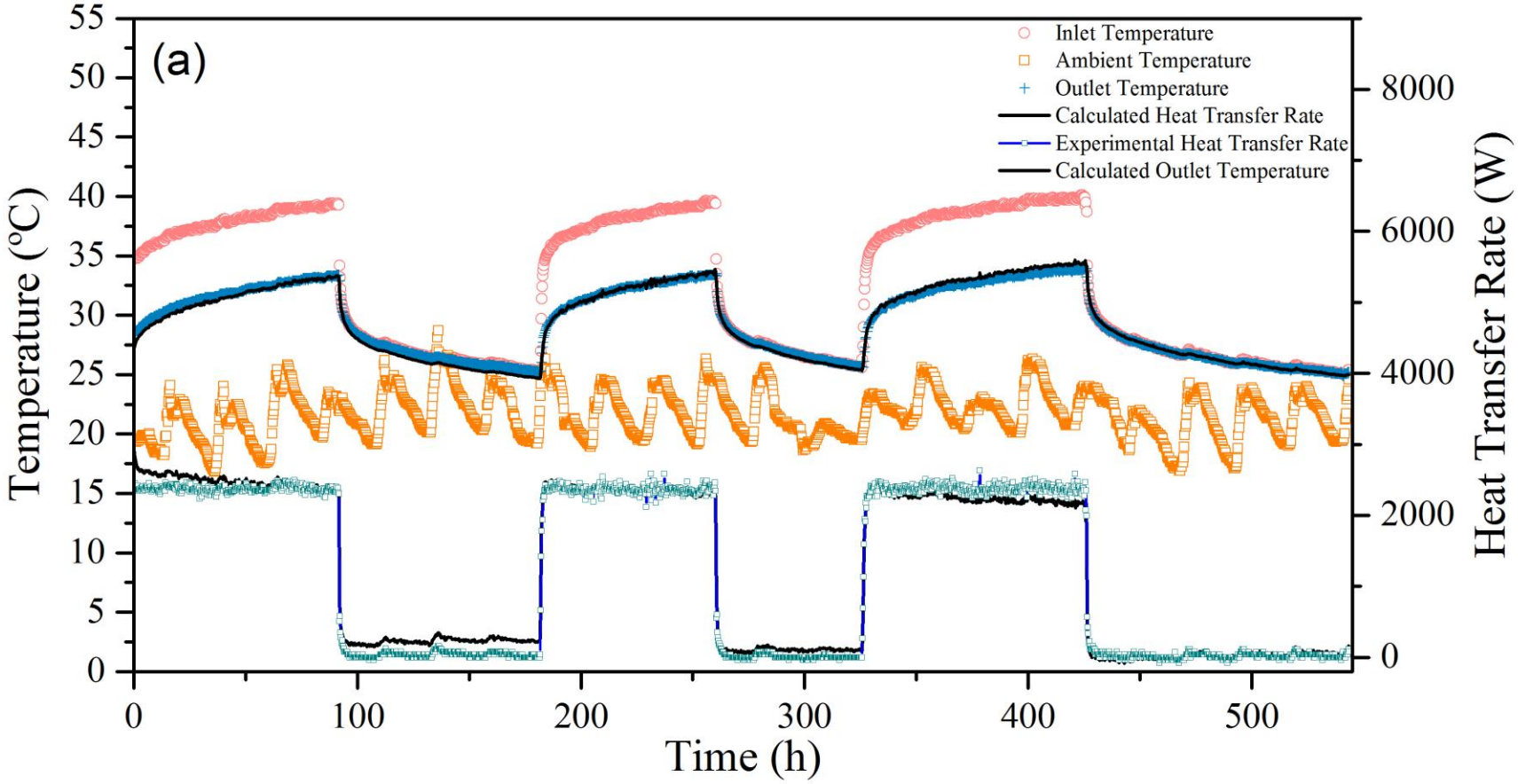


$$a,\rho\, T_{1,n-\rho}\big] + K_{12} \cdot \sum_{\rho=0} \kappa_{12,\rho}(T_{1,n-\rho} - T_{2,n-\rho}) + K_{13} \cdot \sum_{\rho=0}^{\rho_s} \kappa_{13,\rho}(T_{1,n-\rho} - T_{3,n-\rho})$$

Validation of the Model

DTN DWHE Model Parameters for the TRT Test Conditions		
Model Parameters	Value	Units
Wall Depth	17.0	m
Pipe Depth	15.6	m
Basement Depth	6.5	m
Pipe outer diameter	25	mm
Pipe inner diameter	21	mm
Pipe horizontal spacing	0.40	m
Pipe circuit length	93.0	m
Number of loops	4	-
Pipe thermal conductivity	0.39	$W\ m^{-1}K^{-1}$
Fluid conductivity	0.625	$W\ m^{-1}K^{-1}$
Fluid specific heat	4178	$J\ kg^{-1}K^{-1}$
Fluid density	994.0	$kg\ m^{-3}$
Fluid viscosity	0.000714	Pa

Validation of the Model



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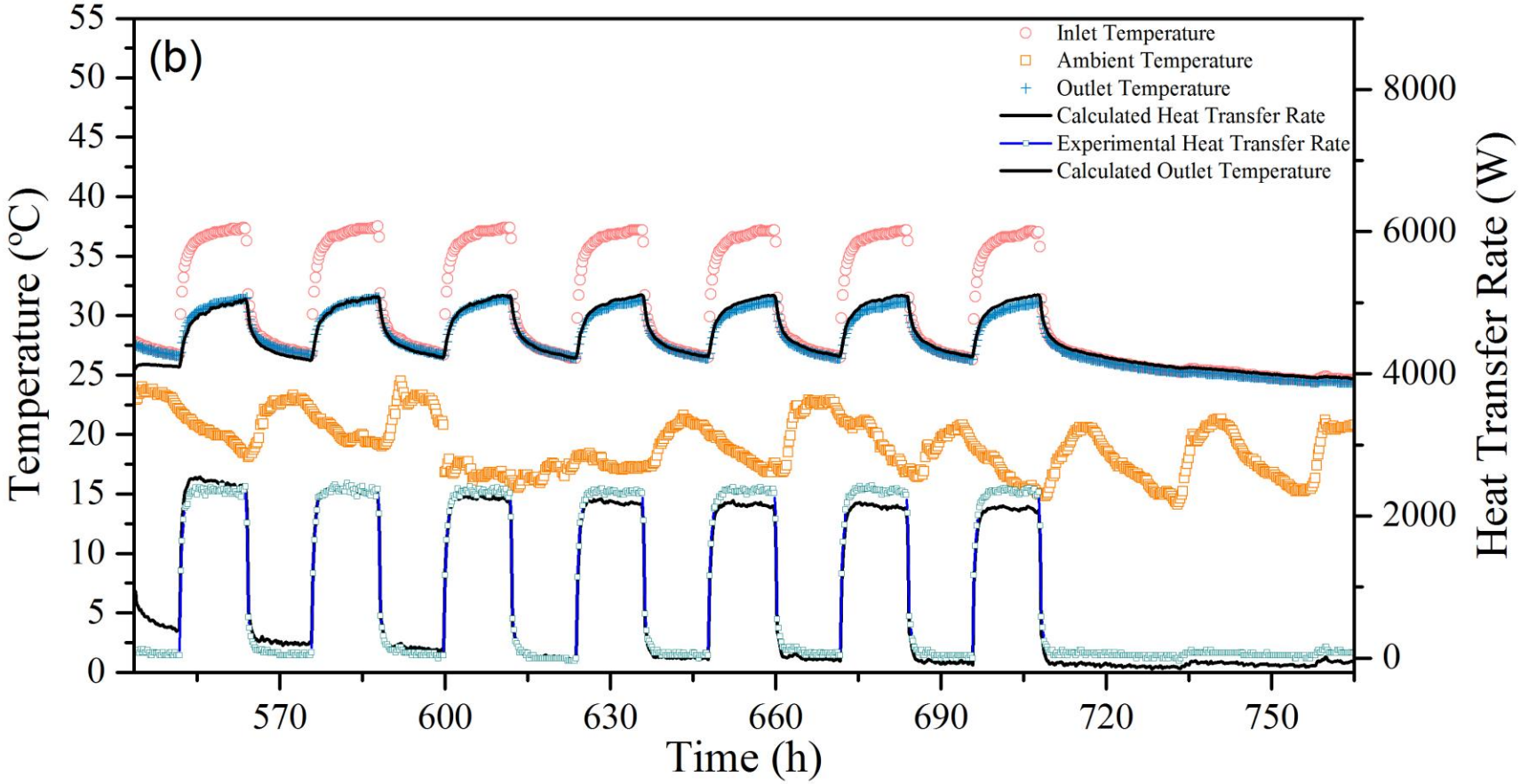
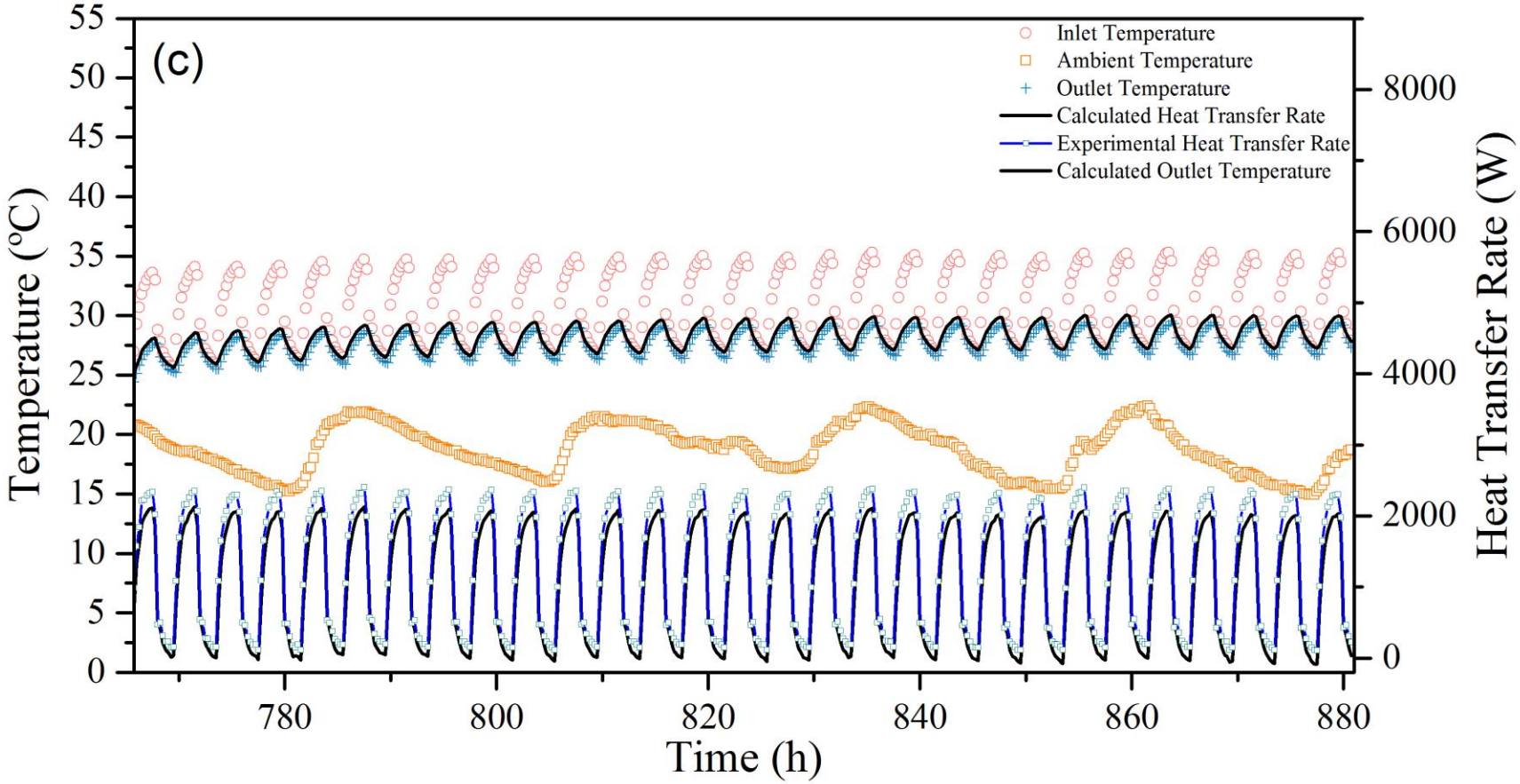


Validation of the Model



Validation of the Model

Thermal Properties of Concrete and Ground used in Model		
Thermal Properties	Value	Units
Concrete thermal conductivity	2.25	W $m^{-1}K^{-1}$
Ground thermal conductivity	1.6	W $m^{-1}K^{-1}$
Concrete volumetric heat capacity	3.5×10^{6}	J $m^{-3}K^{-1}$
Ground volumetric heat capacity	1.6×10^{6}	J $m^{-3}K^{-1}$

- RMSE between the calculated and measured outlet temperatures over the 6 weeks operation period is 0.4K.
- Closest agreement is found with higher values of ground and concrete thermal conductivities and relatively high value of concrete volumetric heat capacity.
- Measured heat rejection over the whole period is 999.7 kWh and this compares with a predicted value of 988.7 kWh which corresponds to a 1.10% relative error.

Thank You!