Utilising Soil for Heat Storage in
Local Space Heating Applications

Yasameen Al-Ameen
Yasameen.alameen@ntu.ac.uk
Outline

- Motivation
- Underground Thermal Energy Storage
- Research Aim & Methodology
- Experimental Work & Results
- Future Applications
MOTIVATION

‘MEETING THE FUTURE NEEDS OF ENERGY CONSUMPTION’

Available sustainable energy sources:

- Solar; Electricity and Heat
- Wind; Electricity
- Geothermal; Heat (and Electricity)
- Biomass; Electricity and heat
- Waste Heat; Heat
- Others…
The Solar Problem

Solar panels convert sunlight into clean green electricity

Only 20-30% of generated Solar Energy is used from PV panels

During the night/cloudy weather, electricity is imported from the grid
Current Heat Storage Systems
Aim

TO DESIGN A NOVEL INSULATED SOIL STORE FOR LOW TEMPERATURE LOCAL HEATING

- To create a heat storage using soil
- Establish the efficiency of the storage
  - Optimise the efficiency of the storage
Research Methodology

01 | Literature Review
02 | Laboratory testing
03 | Numerical Simulation
04 | Compare and Optimise storage design
Preliminary Testing

- Soil
- Insulation
- Storage pit Layout
- Equipment
Storage Set-Up

Plan View

Side View
Storage Set-Up

- **Network 1:** Electric Heating Element
  - 10mm Copper Tube containing water
- **Network 2:**
  - Soil Volume 0.25m³
  - Soil Capacity = 400kg
  - Water Capacity = 0.5L
  - 50mm Insulation
  - 25mm MDF Lining
Experiment Set-Up

Key:

- Heating Storage
- Extracting Heat from Storage

Storage Rig

- Power Supply
- Thermostat
- Electric Heating Elements
- Water Supply
- Tank
- Cold Water In
- Drain
- Flow Control
- Flowmeter
- Hot Water Out
Temperature Readings

- 54 Temperature sensors
- 12 Sensors on each sand layer
- 4 Sand Layers (A-D)
- 4 Sensors on Insulation
- Water Inlet & Outlet

Layers:
- Layer A
- Layer B
- Layer C
- Layer D
Experimental Results (0.1L/min)

Storage Temperature vs. Time graph with a 0.1L/min Flowrate

Key:
- Sand Layer B
- Sand Layer C
- Sand Layer A
- Sand Layer D
- Insulation
- Water Inlet
- Water Outlet
Analysis


- **0.1 L/min**: Temperature (°C) over time (days)
- **0.2 L/min**: Temperature (°C) over time (days)
- **0.4 L/min**: Temperature (°C) over time (days)
- **0.7 L/min**: Temperature (°C) over time (days)

Store Discharging
Analysis

# Calculating Storage Efficiency

<table>
<thead>
<tr>
<th>Flowrate (L/min)</th>
<th>Max. Output Temperature (°C)</th>
<th>Complete Discharge Time (hr's)</th>
<th>Hot water Discharge Time (hr’s)</th>
<th>Total Quantity Hot water (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>69</td>
<td>36</td>
<td>16</td>
<td>96</td>
</tr>
<tr>
<td>0.2</td>
<td>50</td>
<td>24</td>
<td>8</td>
<td>96</td>
</tr>
<tr>
<td>0.4</td>
<td>45</td>
<td>19</td>
<td>4</td>
<td>96</td>
</tr>
<tr>
<td>0.7</td>
<td>42</td>
<td>12</td>
<td>2</td>
<td>84</td>
</tr>
</tbody>
</table>
Calculating Storage Efficiency

\[ Q = mC_p \Delta T \]

- **SAND CHARGING PROCESS**, \( Q_{\text{CHARGE}} = 14400 \text{ KJ} \)
  
  \[ C_{p,\text{sand}} = 800 \text{ J/kgK} \quad \rho_{\text{sand}} = 1600 \text{ kg/m}^3 \quad \Delta T = 45 \text{ K} \quad \text{Volume} = 0.25 \text{ m}^3 \]

- **WATER DIS-CHARGING PROCESS**, \( Q_{\text{DISCHARGE}} = 11693 \text{ kJ} \)
  
  \[ C_{p,\text{water}} = 4200 \text{ J/kgK} \quad \rho_{\text{water}} = 1000 \text{ kg/m}^3 \quad \Delta T = 29 \text{ K} \quad \text{Volume} = 0.096 \text{ m}^3 \]

- **STORAGE EFFICIENCY** = \( \frac{Q_{\text{DISCHARGE}}}{Q_{\text{CHARGE}}} = 0.8 = 80 \% \)
Improving Storage Efficiency

OR

...............
Conclusion and Applications

- Soil storage created and tested with various flows
- Efficiency of the storage at 80% and acceptable
- Need to increase the storage discharging period using additional enhancing materials
- Applications include retrofitting local homes for low temperature heating systems (e.g. Underfloor)
- Uses the natural soil and available materials which makes application cheaper, easier & sustainable
THANK YOU FOR LISTENING
Any questions?

E-mail: yasameen.alameen@ntu.ac.uk