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School of Civil Engineering and the Environment

Ground Energy Systems installed in Foundations

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Ground Source Heat Pump Association Seminar
21st January 2009

Outline

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- Overview: uncertainties in ground energy system design
- Proposed research
- Initial numerical modelling
- Some data on differential pile/soil thermal expansion

Uncertainties

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- Design assumptions e.g. end effects for piles, appropriate boundary conditions, variation in heat flux with depth
- Long term effects, especially of unbalanced thermal load cycles
- Interactions between systems
- Role of moisture content, moisture migration, permeability and groundwater flow regime on heat transfer characteristics
- Differences between in situ and laboratory determined geothermal properties: effects of scale and structure

Research approach

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- Numerical modelling: in progress
- Real energy pile site monitoring: planned (two contrasting geological strata, London Clay and Solent Group marls and limestone): planned
- Laboratory and in situ testing of thermal parameters: planned

Initial numerical modelling

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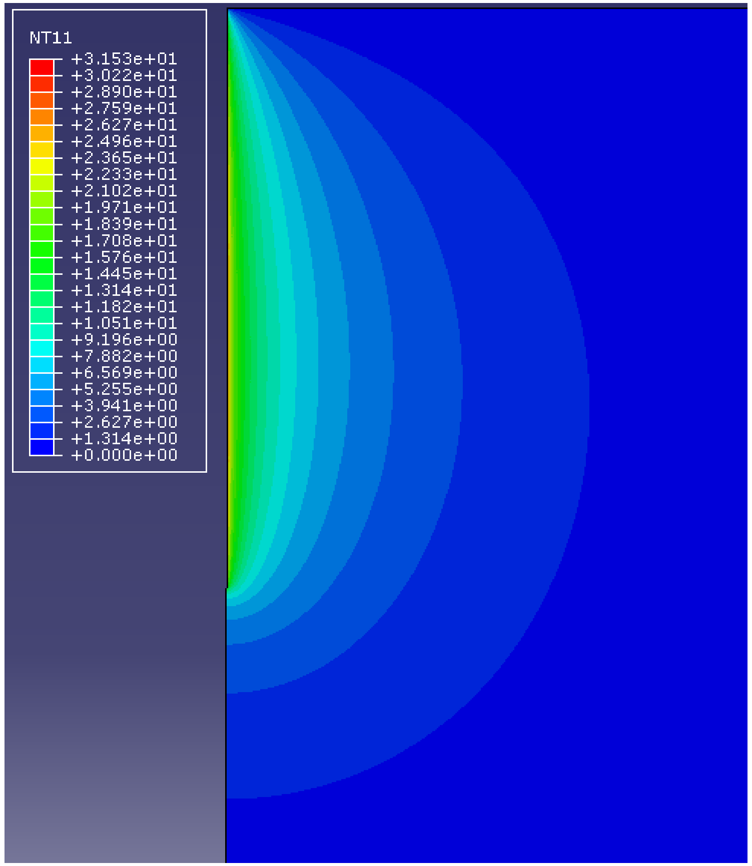
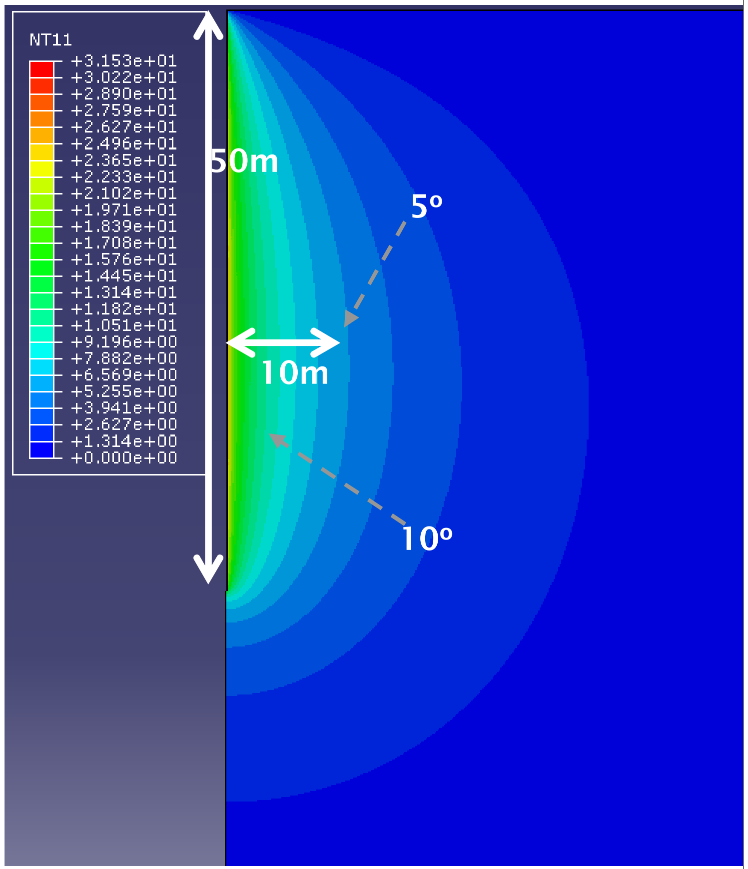
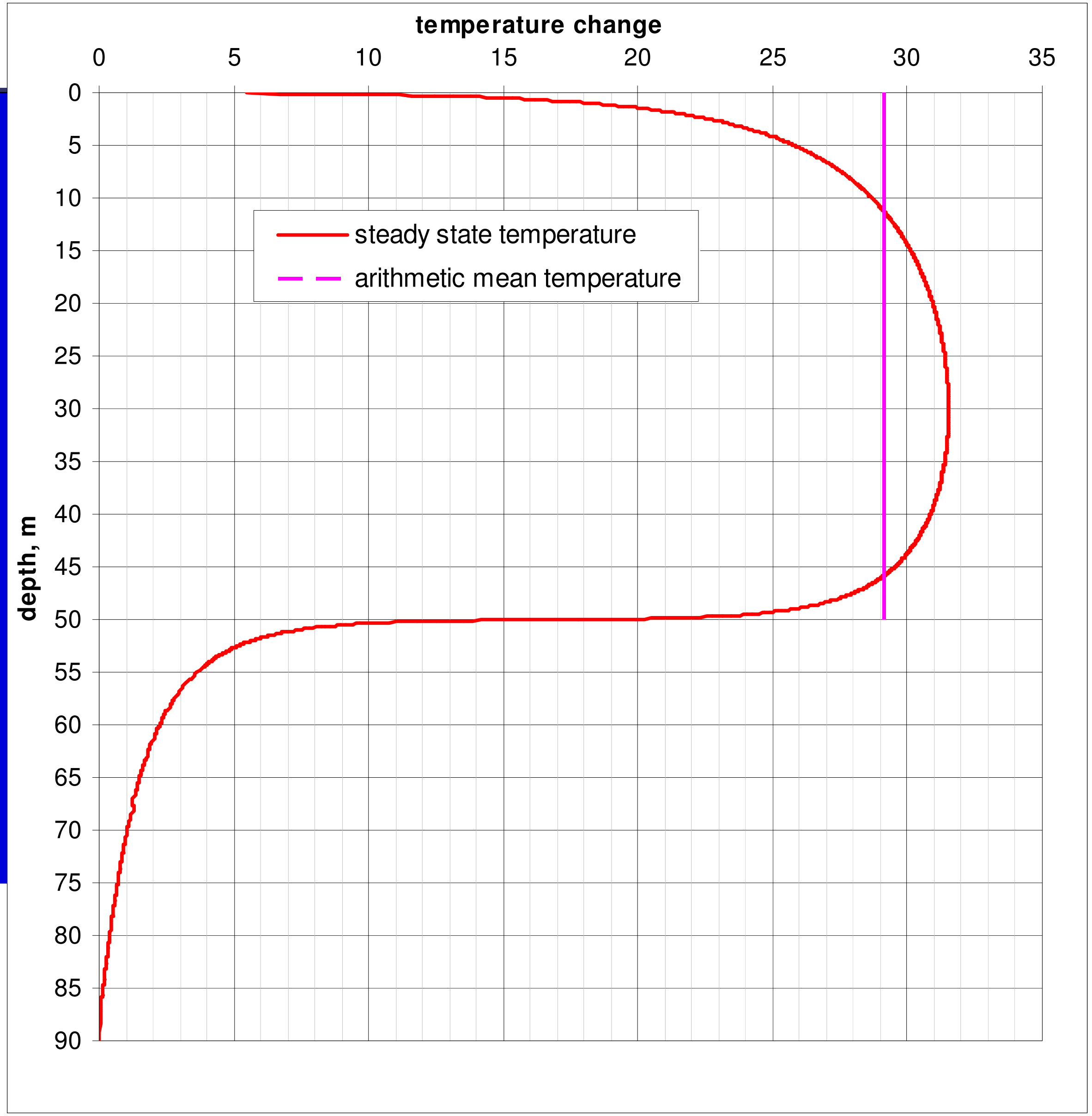
- ABAQUS standard
  - To couple conduction and convection in the ground
  - More complex ground models if required
- COMSOL Multiphysics
  - Less complex ground model
  - Better simulation of pile internal heat transfer







50m deep, 100mm borehole
q=94W/m
λ=3W/mK α=1.5e10-6m/s^2

Proposed work plan

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- Development of numerical models:
  - Combine a heat flux which varies with depth with variable initial temperature and ground properties
  - Develop 3D models for groundwater advection
- Establish field monitoring sites (two contrasting hydrogeological regimes, London Clay and Solent Group)
  - Monitor ground temperature, air temperatures, fluid temperatures, groundwater conditions, pump energy etc
  - In situ and laboratory testing for thermal response
- Model validation and extrapolation
- Other foundations

Lateral pile slope stabilisation, Grange Hill, London

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Seasonal fluctuations in pile temperature at different depths

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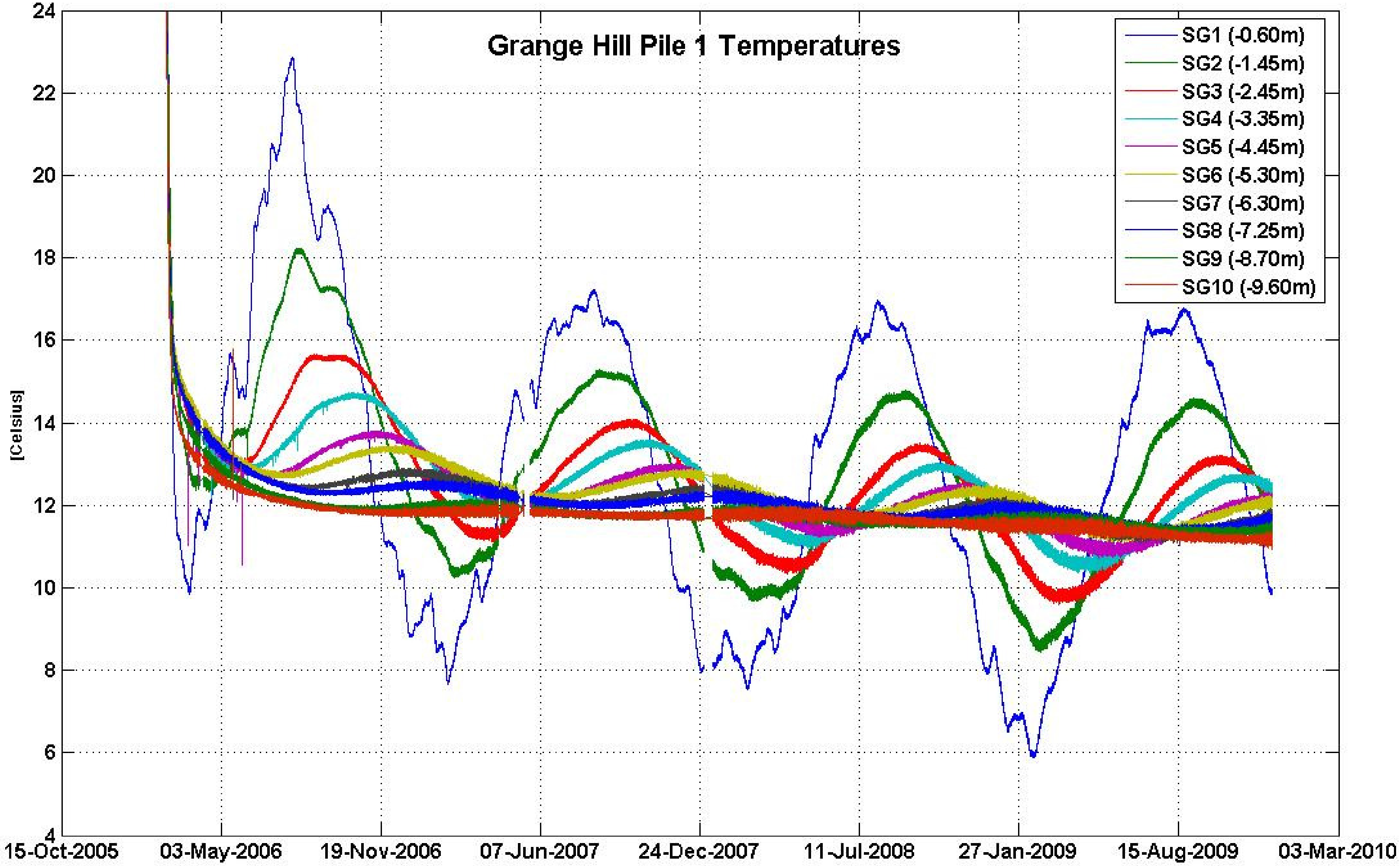

Seasonal fluctuation in axial strains at different depths

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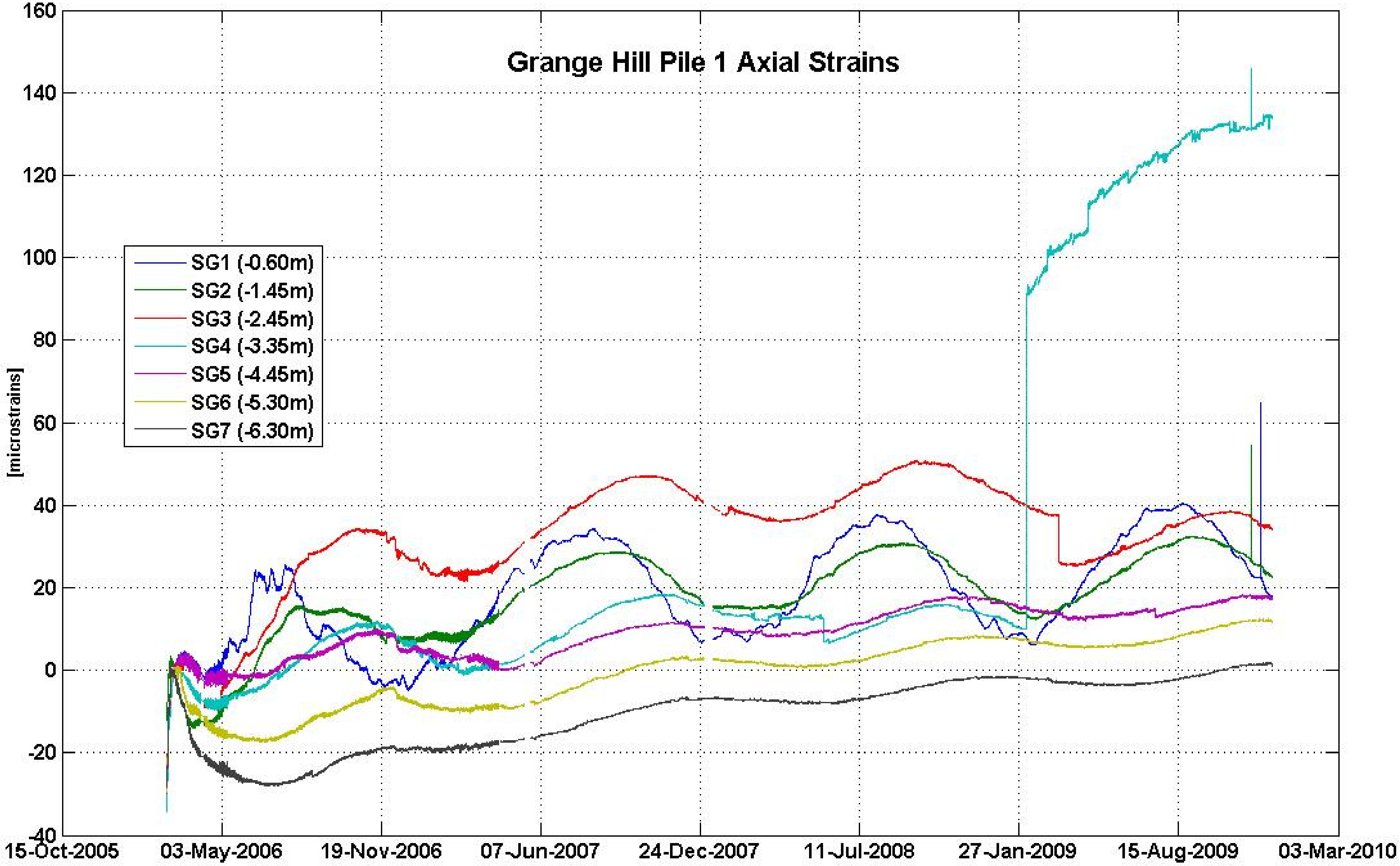

Axial tension in phase with temperature

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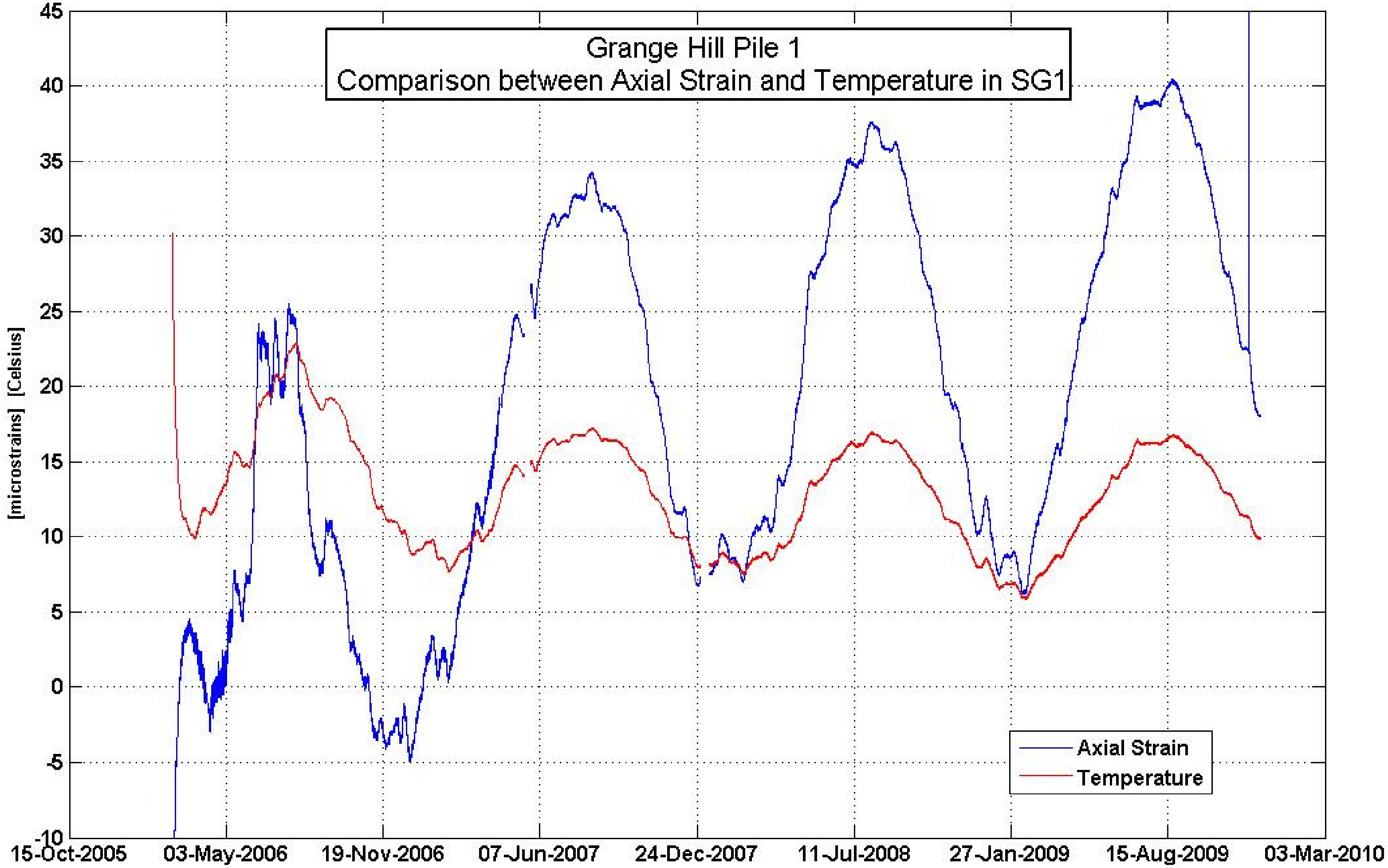

Commentary on data

- o/c clay has a coefficient of thermal expansion ~7 times greater than concrete, so an increase/decrease in temperature causes tension/compression in the pile
- The jump in axial strain is due to cracking, but the general behaviour of the strain gauges doesn't change
- The peaks in axial strains follow the temperature, with a small time lag which increases with depth
- Strain range ~ 20$\mu\varepsilon \Rightarrow$ axial load ~200 kN for a 0.6 m dia. pile (~20% of skin friction capacity of a 10 m deep pile?)

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Thank you to our project partners

- Mott MacDonald
- Cementation Skanska
- Golder Associates
- WJ Groundwater
- Vienna Technical University