NHBC - Energy piles for houses

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Ground Source Heat Pump Association –

Research Review

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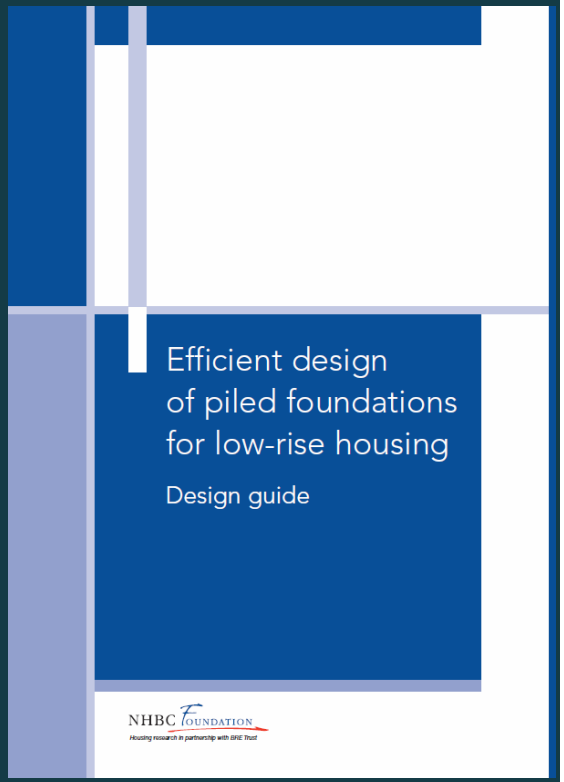
ARUP

Overview

- **Based on Arup study for Roger Bullivant Ltd**
- **Used in NHBC Piling Guide - Section 6.**
- **Design - Code for Sustainable Homes**
  - Emission targets
- **House – heating energy requirements**
- **Energy pile design**
  - Geotechnical – pile capacity
  - Geothermal design
- **Comparison with other heating systems**
  - Carbon
  - Costs
- **Contractual responsibilities**



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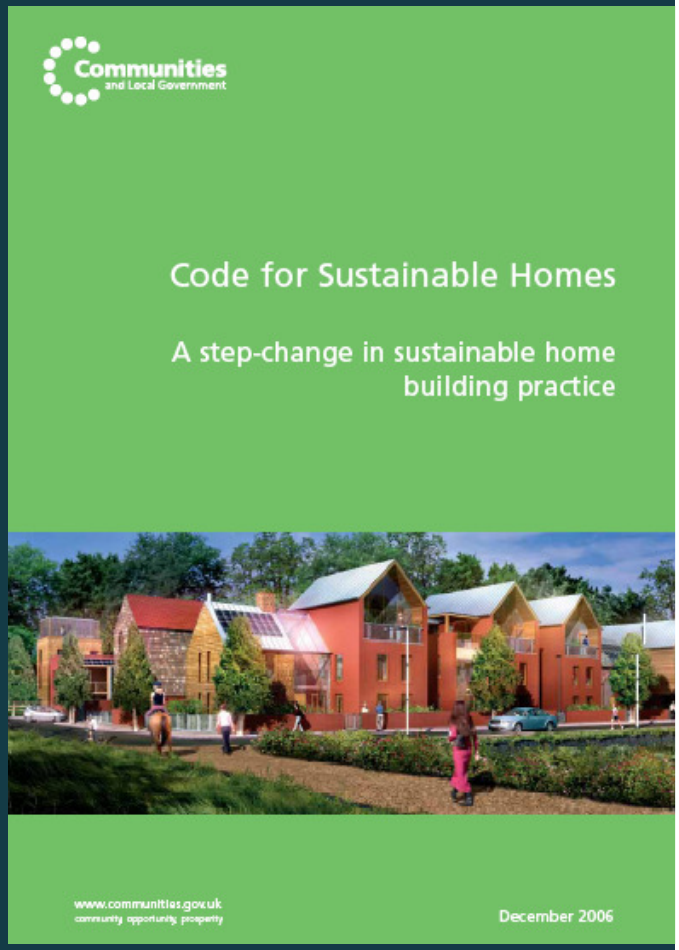
Code for Sustainable Homes

- Launched 2006
- Assessment process and performance standards
- National standard for sustainable design and construction
- Interim code levels for energy and CO2 emissions targets



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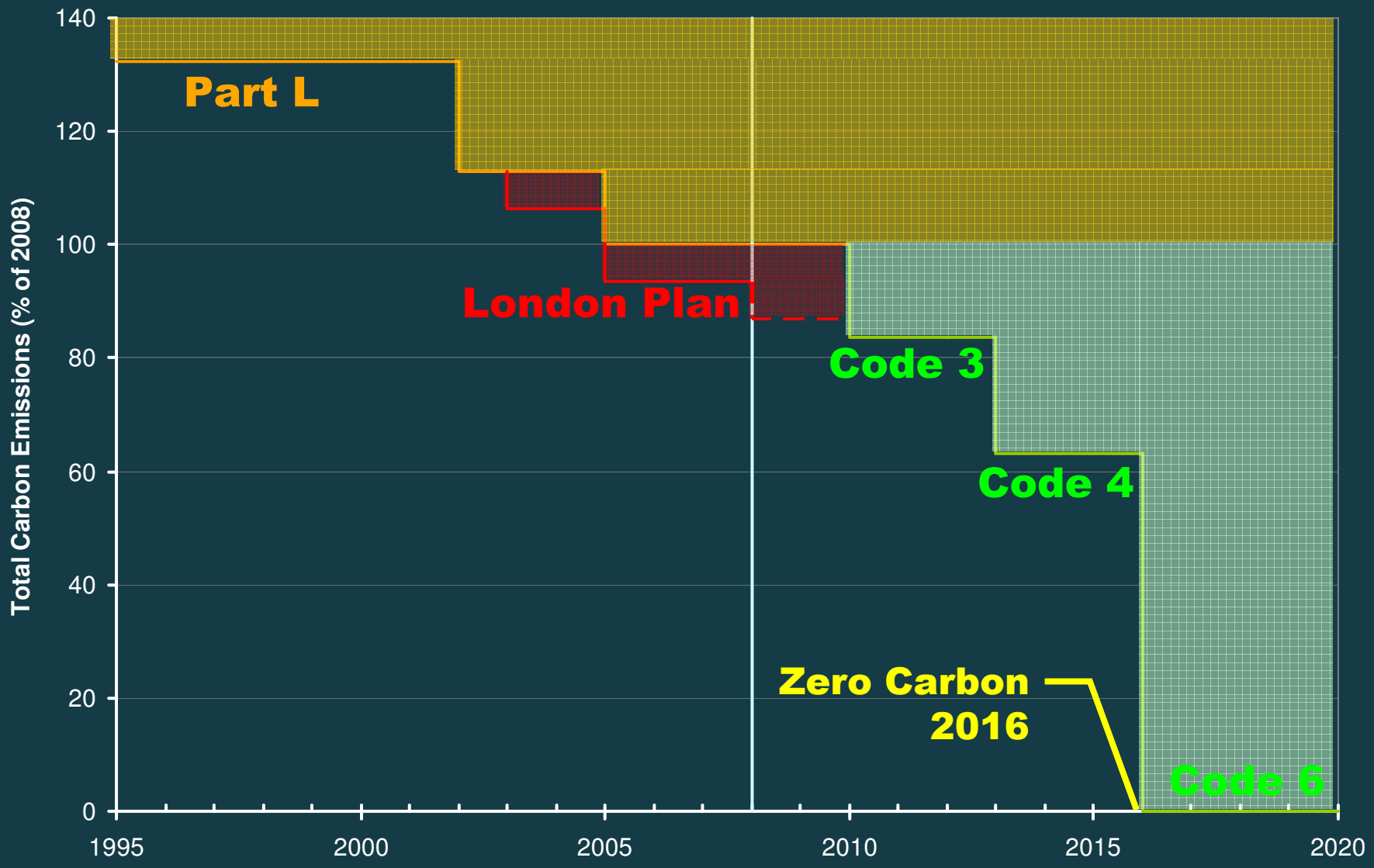
Domestic Carbon Emission Targets



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Standard Terrace House - Insulation

- Heat and hot water demands
- Code3/4 Code 6

	House 1	House 2
Ventilation type	Naturally ventilated	Naturally ventilated
Window U value (W/m^2K)	1.2	0.7
Wall U value (W/m^2K)	0.2	0.11
Roof U value (W/m^2K)	0.2	0.11
Floor U value (W/m^2K)	0.2	0.11
Air tightness (m^3/m^2h at 50Pa)	5	3
Heat loss parameter (W/m^2K)	1.05	0.7

- IES software - predicts hourly heat needs over annual cycle.

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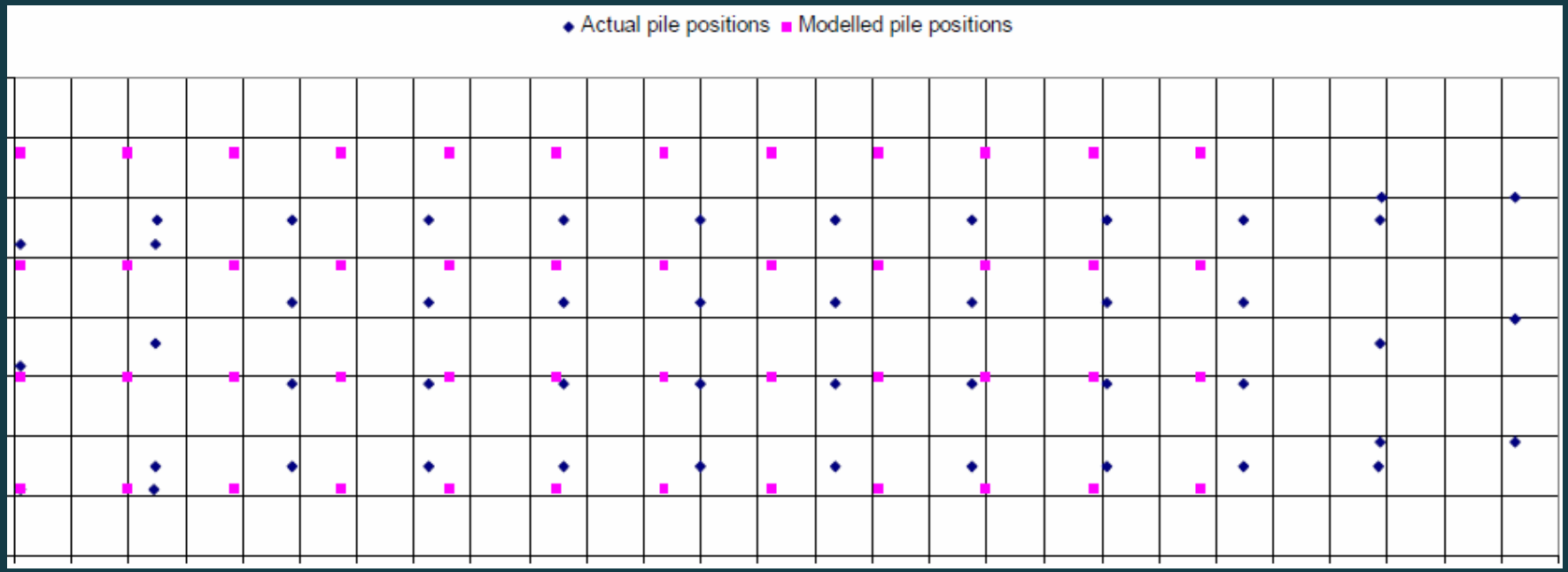
Ground Modelling

- Geotechnical design based on mini piles – long and thin
- London Clay profile
- Geothermal modelling of ground temperature using GLHEPro (3D)

Parameter	Value
Pile length	13.0m
Pile radius	0.1m
Initial temperature of the ground	12°C
Thermal resistance of the pile	0.145 K m W^{-1}
Thermal conductivity of the ground	1.6 W m^{-1} K^{-1}
Volumetric heat capacity of the ground	2400 kJ m^{-3} K^{-1}
Specific heat capacity of water	4200 J kg^{-1} K^{-1}

Geothermal Model GLHE Pro 3D – Pile Layout

- Pile Layout for 11 terraced houses – not exact



Building Code	Mid Terrace No. of 13m long energy piles	Max. hourly building heat requirement	Watts/m pile length (max. hourly)	Max. daily building heat requirement	Watts/m pile length (max daily)
3 or 4	4	4.1kW	80	1.6kW	30kW
6	3	2.4kW	60	0.8kW	20kW

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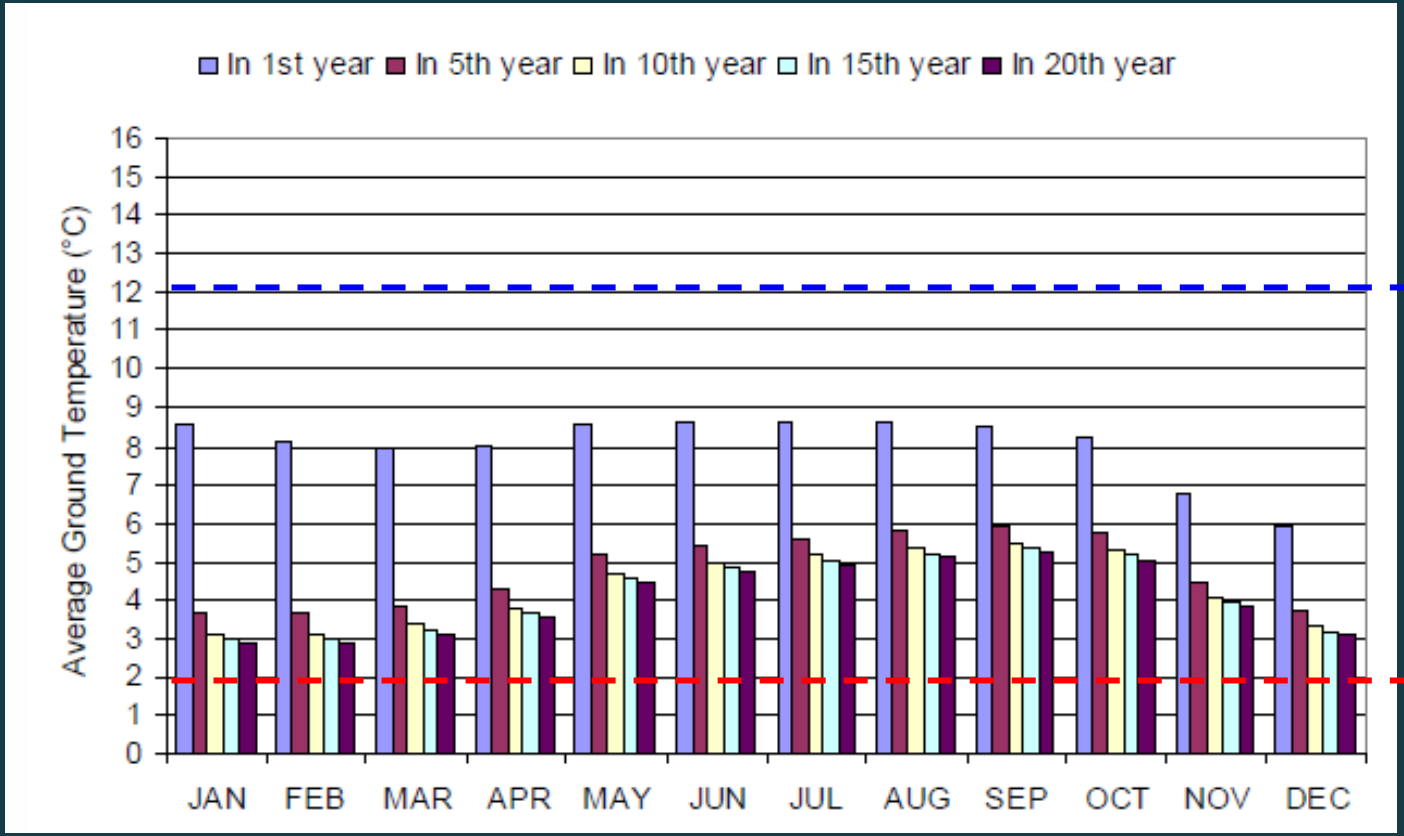
Ground Temp. Modelling – Code 3/4 Terrace



Initial ground temperature

Minimum acceptable ground temperature

- Monthly ground temperatures
- Internal Ground temp stabilise after 10yr - above 2°C

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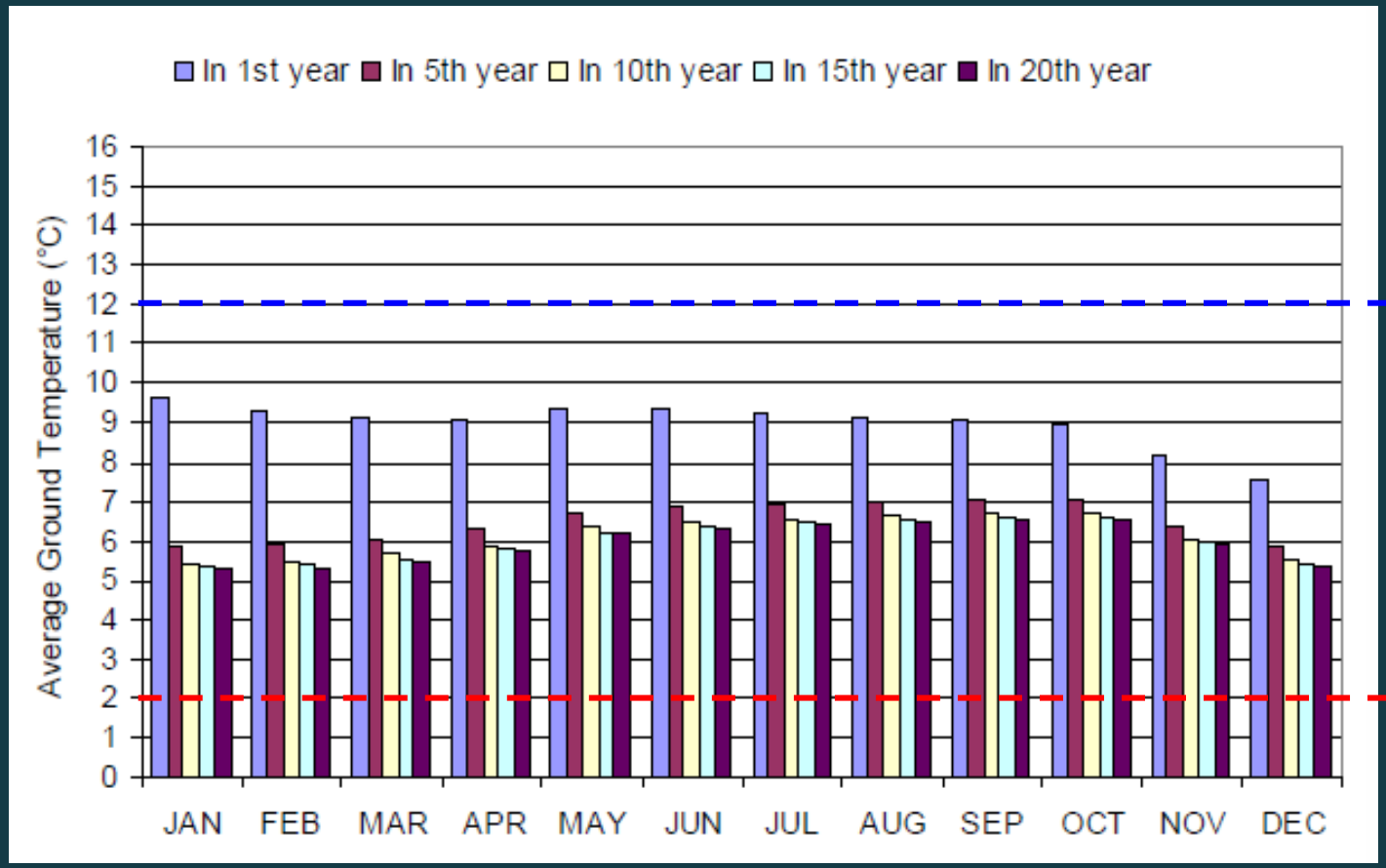
Ground Temp. Modelling –Code 6 Terrace



Initial ground temperature

Minimum acceptable ground temperature

- Monthly ground temperatures for Code 6 terraced housing
- Ground temperatures stabilise after 10 years - above 5°C

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Code Levels Using Energy Piles (CO_2)

- Energy piles with immersion top-up = Code 3
- Energy piles without immersion top-up = Code 4
- Unlikely that energy piles achieve code 5 and 6 unless site renewable electricity is available for heat pump

CO_2 savings compared with the Part L 2006 target emission rates (determined using the SAP methodology)

	House 1 (HLP = 1.05 W/m² K)	House 2 (HLP = 0.8 W/m² K)
Condensing gas boiler	12% (Code 2)	28% (Code 3)
Energy piles and heat pump with immersion top up	35% (Code 3)	42% (Code 3)
Energy piles and heat pump without immersion top up	48% (Code 4)	55% (Code 4)
Biomass boiler	70% (Code 4)	72% (Code 4)

Cost Comparison - Installation

- Both housing types high efficiency gas boilers prove cheaper than energy piles
- Energy piles cheaper than biomass boiler system
- Operational costs lower – recovery time.

Average heating system installation costs determined for a typical mid-terrace house

	Gas boiler + radiators (£)	Gas boiler + underfloor heating (£)	Ground source heat pump + energy piles + underfloor heating (£)	Biomass boiler + radiators (£)
House 1 (HLP = 1.05)	3 500	3 400	12 100	14 900
House 2 (HLP = 0.8)	3 400	3 200	11 400	14 900

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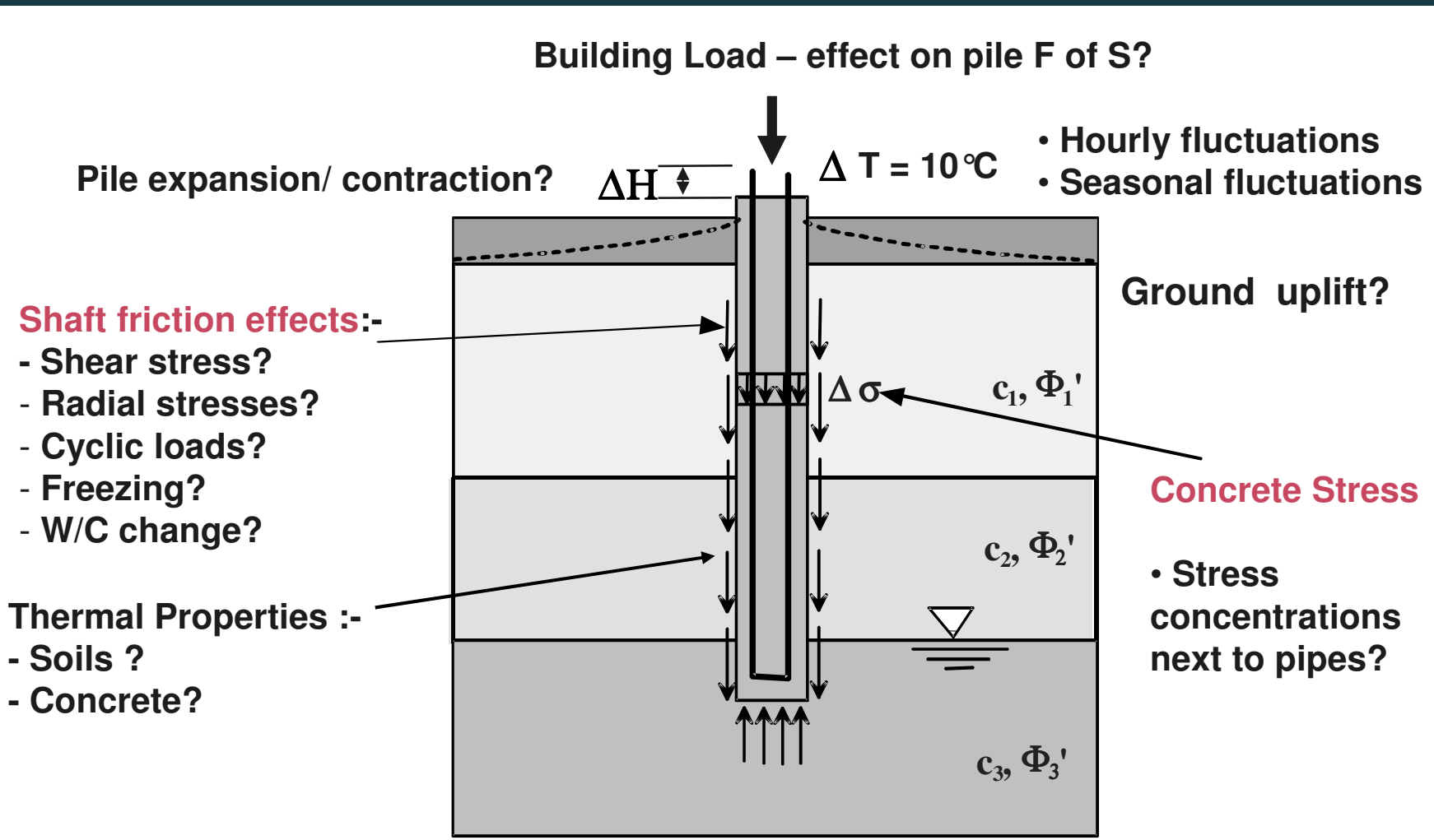
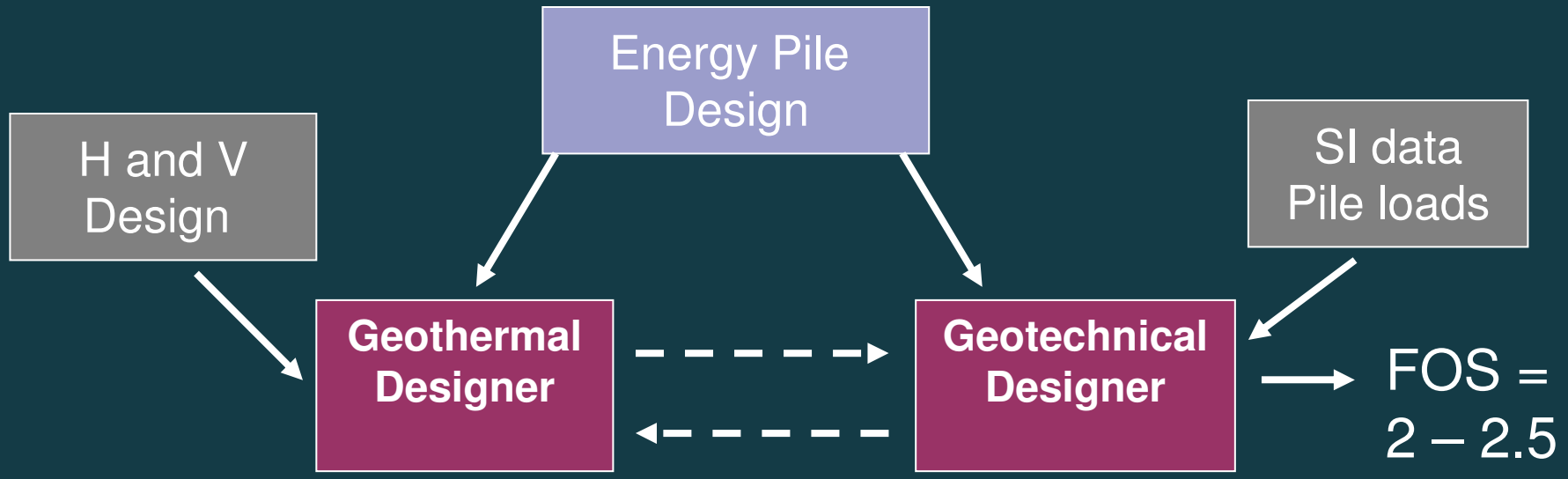
Pile design issues – Effect of heating pile?

Heat pump sets:

- Hourly temp fluctuations? (DT = 10℃)?
- Seasonal temp fluctuations? (T = 30℃ to -5℃)?



Designers Responsibilities



Constraints

- Heat demand
- Heat transfer - piles
- Heat storage – ground
- Heat pump spec
  - -5℃ to 30℃

- Large Δt
  - Expansion
  - Consolidation
  - Freezing
- Shaft friction
- Concrete stress

Combined Pile load test Response test

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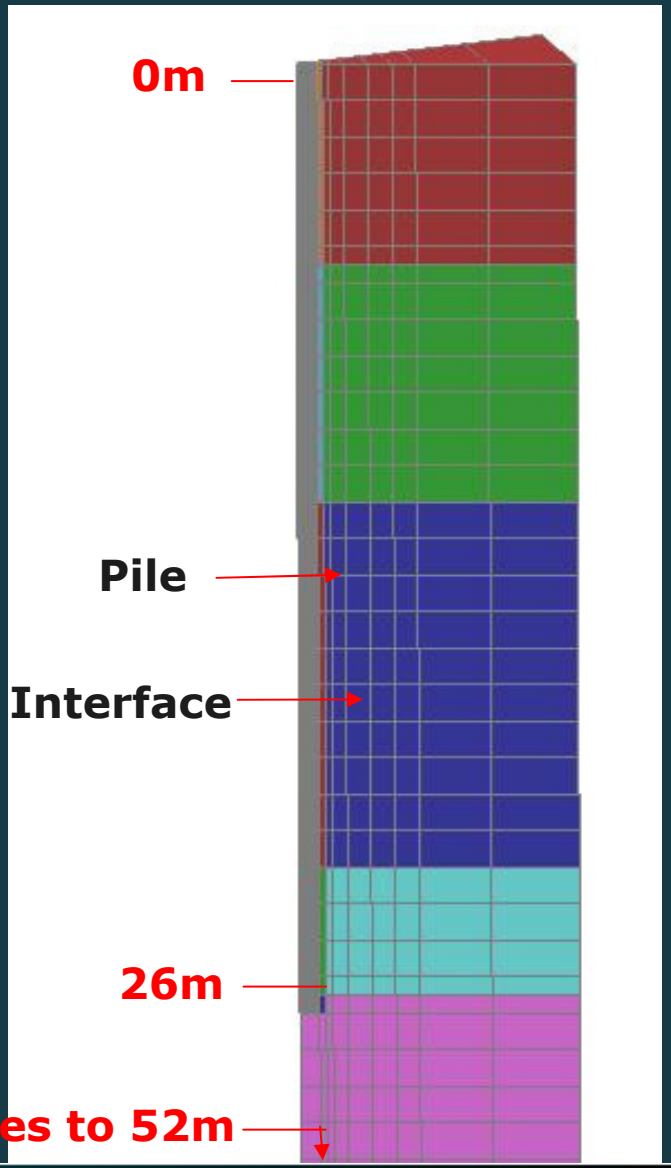
Back analysis of energy pile reponse / load test

- Pile load and thermal test data. – (Laloui Paper)
- Temperature-time history (24 days).
- Axi-symmetric model of single pile / soil. – Dyna 3D
- Coupled thermal – mechanical - consolidation analysis, including:-
  - Thermal conduction and expansion,
  - Pore pressure generation,
  - Non linear soil material behaviour.



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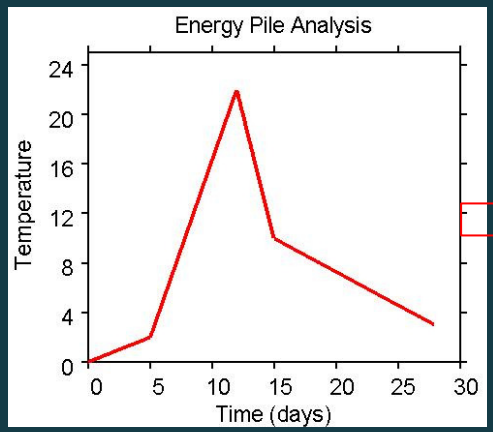
Sample results

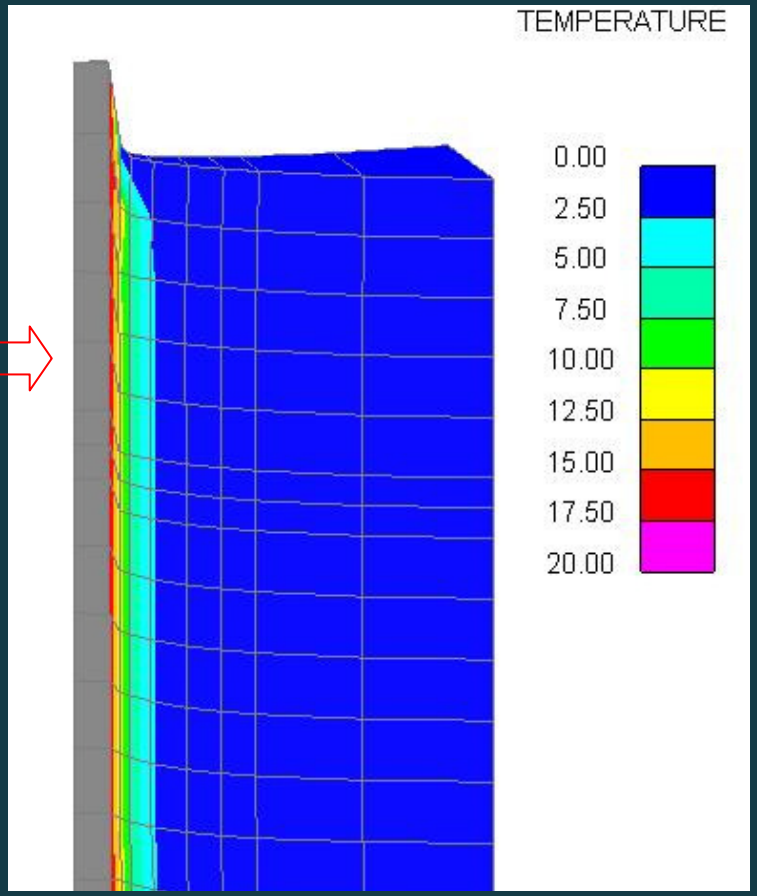
- Thermal expansion – pile top displaces 3mm upwards (movement magnified in image).
- The soil resists the upward movement,
- Pile in axial compression (Max stress - 6MPa)

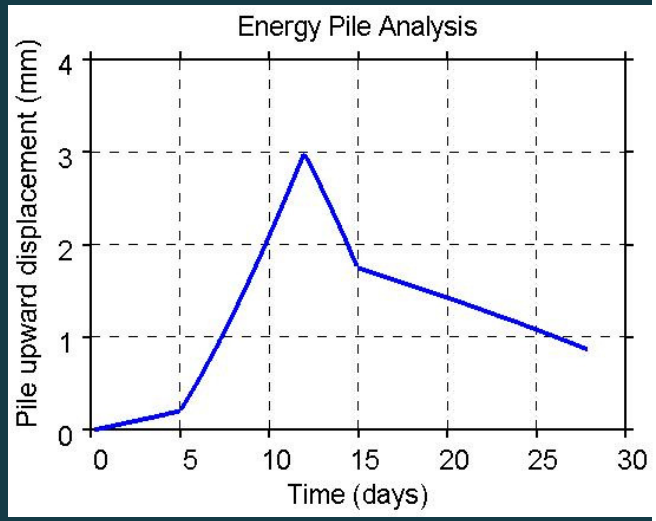


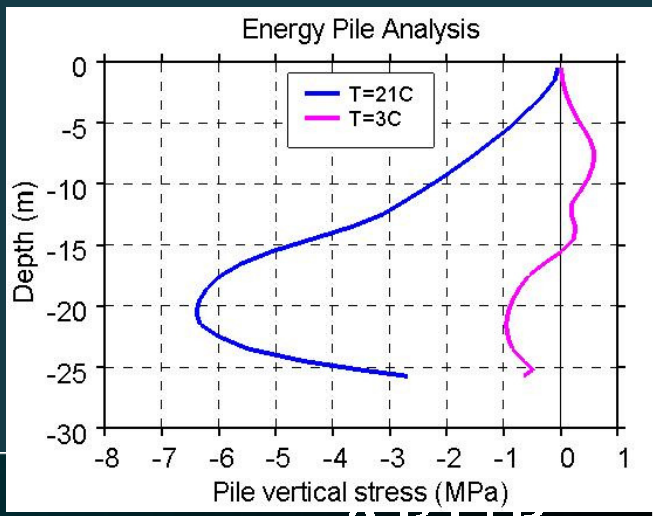
Temperature-time input to pile

Heat for 12 days

(applied uniformly within pile)







Conclusions on NHBC Guide – Energy piles

- **Design - Code for Sustainable Homes**
  - Emission targets and Code requirements
- **House – heating energy requirements**
- **Energy pile design**
  - Geotechnical design - Load capacity and factor of safety
  - Geothermal design
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Thank you for your attention

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