DICEP

20th Annual

Design and Installation of Cost-Efficient Piles Conference

The Westin Cleveland Downtown

CLEVELAND, OHIO

Nov. 5–6, 2019

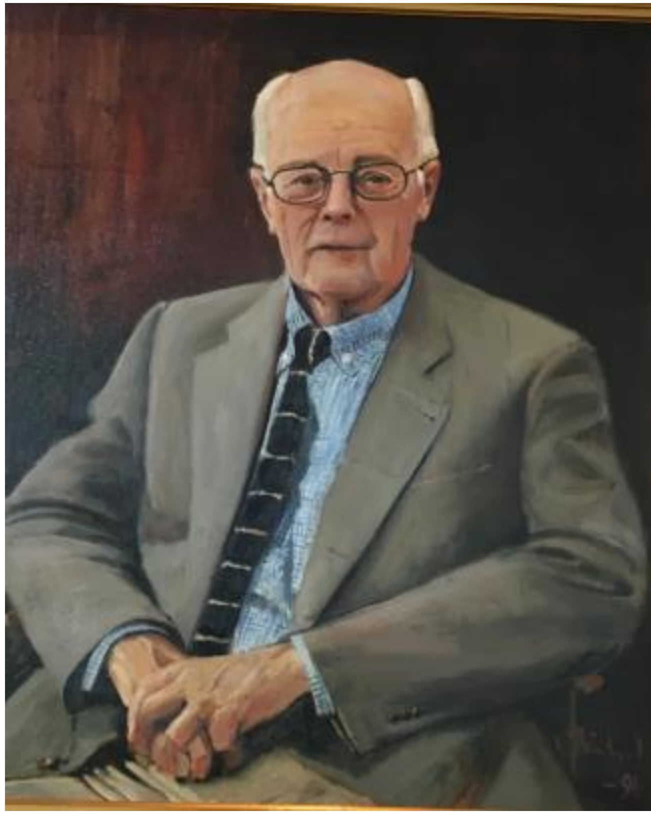
Challenging the Perception of Precast Piles

By Kevin Hague

Managing Director at Aarsleff Ground Engineering Ltd, UK

Heritage

- In 1947, 29-year-old Per Aarsleff left a secure position with the Danish state, borrowed 10,000 Danish Kroner from his father's life insurance, bought an excavator and opened a lignite field in Central Jutland
- His ethos: **"We have always specialised in something that was sufficiently difficult so that others could not be bothered."**
- His principles turned out to be sustainable, and over the years, they have been the source of sound growth. Today, the original 14 men have turned into several thousand employees in the parent company, subsidiaries and associates with sectors: Construction, Pipe Technologies & **Ground Engineering**



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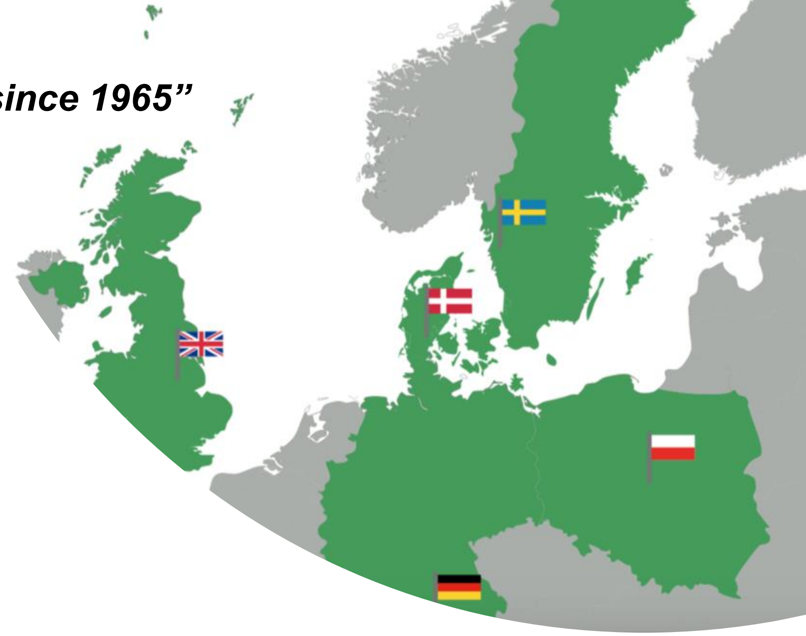
"High quality concrete pile production since 1965"



KEY FACTS

- 5 Manufacturing Factories across Europe
- Together, we supply most of Northern Europe's demand for precast piles
- Producing > 4 mio. meters (~ 13.123.000 ft.) of precast concrete piles per year
- Utilises highly automated production processes

KEY VALUES

Innovation

High Quality

On-time Delivery

Customer Satisfaction

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Manufacture – Production Line Quality

Centrum Piles are manufactured to BS EN 12794 under controlled conditions. All piles are delivered to site with full CE Marking and Batch Identification offering full traceability on every pile supplied

Integrating the **Centrum** Pile System into a foundation design means that the client is utilising a product with many benefits including:

Responsibly sourced, quality raw materials ✓
Full traceability of products manufactured in ISO 9001 factories. ✓
Fast, efficient and environmentally sustainable on-site installation. ✓
Load bearing capacity test data available for design criteria. ✓
Ease of programming for delivery timetables. ✓

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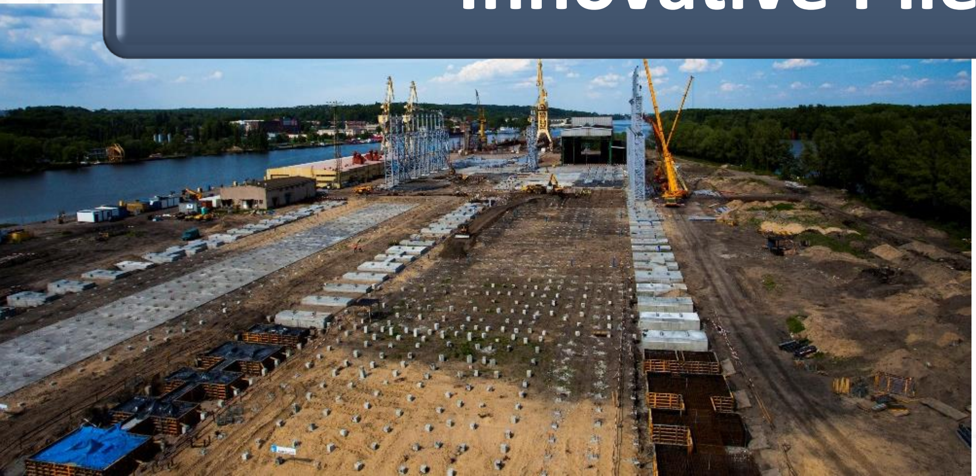
Innovative Piled Solutions



”Supplier of precast piles for the Danish railways since the year 2000”

Electrification Piles

Product lifetime: 120 Years

"Splies are compatible with all pile dimensions from 20x20 to 45x45"

Pile Splices (or Joints)

- Tested and approved according to European regulations
- Can support dynamic loads – i.e. onshore windfarms
- Enables quick assembly of piles on-site
- Produced automatically using robotics

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Mersey Gateway

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Background

- Our study identifies the benefits, challenges and ongoing research into the use of precast, driven piles as part of pile groups in bridge abutment design where complex loading conditions arising from construction on compressible soils are encountered.
- Project example – Mersey Gateway.

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Figure 1 Model picture of Victoria & Widnes Viaduct from the Mersey gateway project (from www.merseygateway.co.uk)

We will not focus too heavily on design, we will focus on the solution.

- Perception of Pre-cast:
    - Noise
    - Vibration
    - Disruptive
    - Not as capable
- **Often the pile type chosen is entirely based on local traditions & standards**
- In Northern Europe, the prevailing pile type is DPC, while in contrast Bored Cast-in-place piles are very common in the UK
- This presentation demonstrates that DPC is a robust alternative for a bridge abutment in the UK
- We discuss two pile solutions with a high level comparison in regards to the project economy, construction process

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Avonmouth, Bristol

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York Stadium

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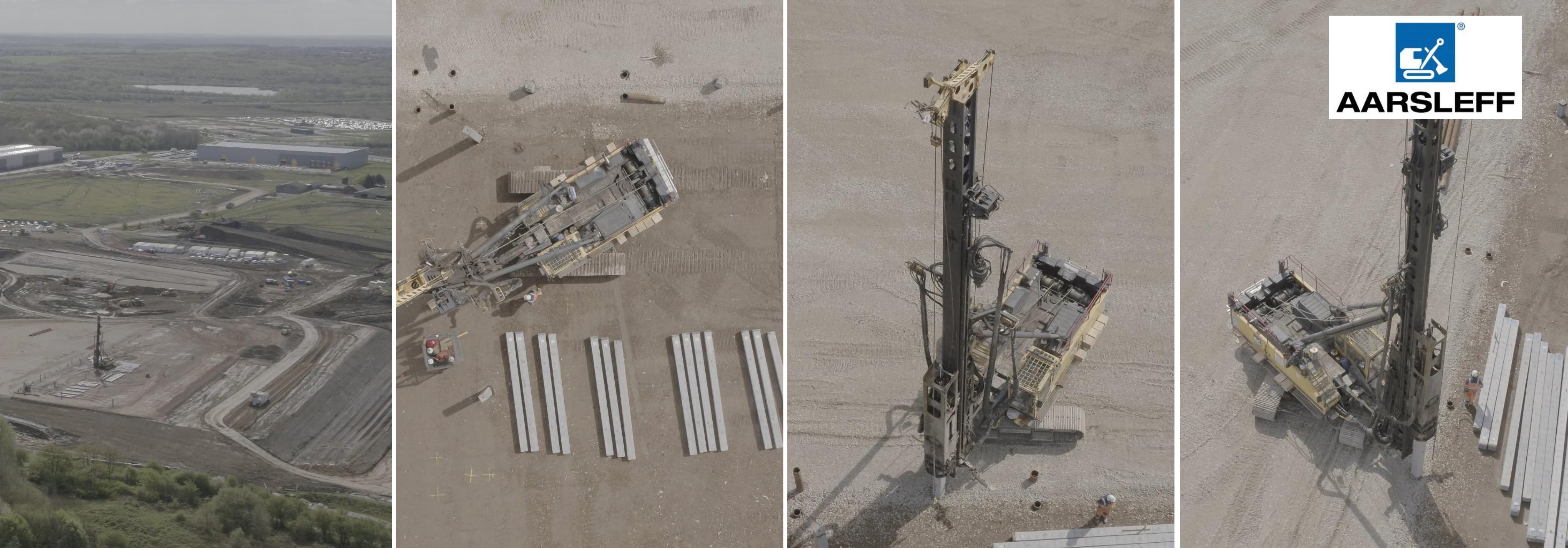

Logic Park, Leeds

Mersey Gateway Viaduct

- Increased pressure on the road infrastructure results in the need for upgrading existing and building new roads and bridges. Major congestion hot spot.
- Victoria & Widnes Viaduct is a typical medium sized multi-span bridge from the Mersey Gateway project
- The abutments are founded on piles, often subject to lateral loading due the volumes of backfill & lateral soil displacement
- Precast driven piles utilise a combination of both vertical and raked piles (to sustain the majority of horizontal loads)

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Geometry & Load from Bridge Set

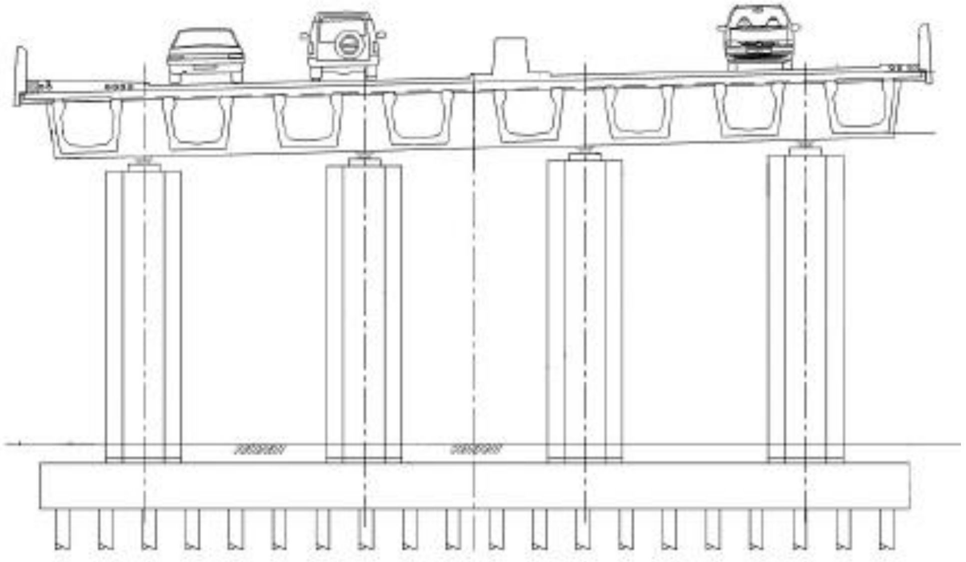

Figure 2 Cross section of Victoria & Widnes Viaduct.

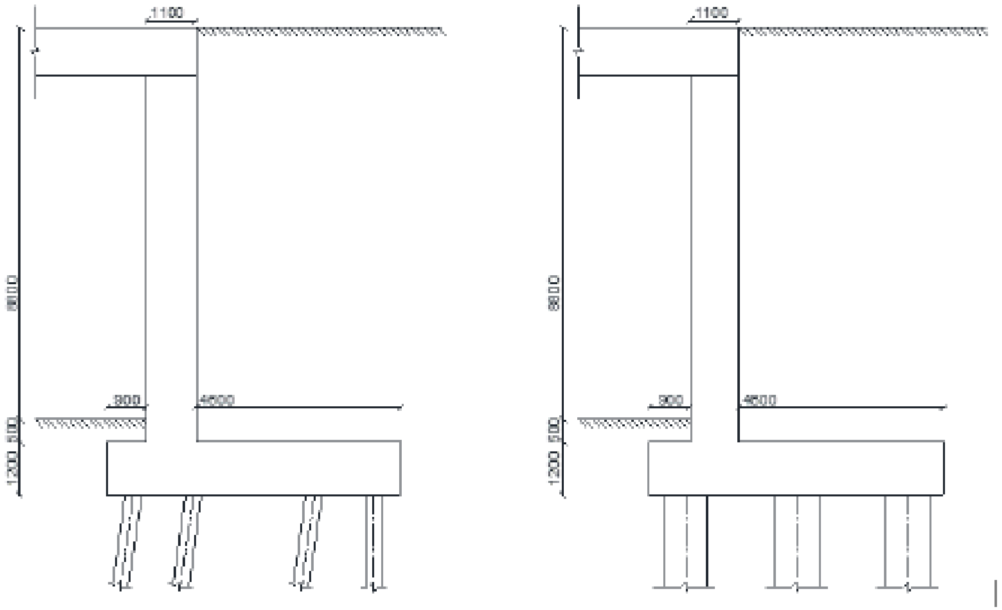

Figure 3 Sketch of abutment (left: driven piles, right: bored

Soil Conditions

Soil Layer	Thickness	Contamination
Embankment fill	8.8m	
Made ground (MG)	3m	
Cohesise Glacial Deposit (GD-C)	15m	
Granular Glacial Deposit (GD-G)	5m	

- Contamination noted in the ground at the pile locations.
- European designer.
- Pre-cast chosen.

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Pile Layout – Aarsleff Research

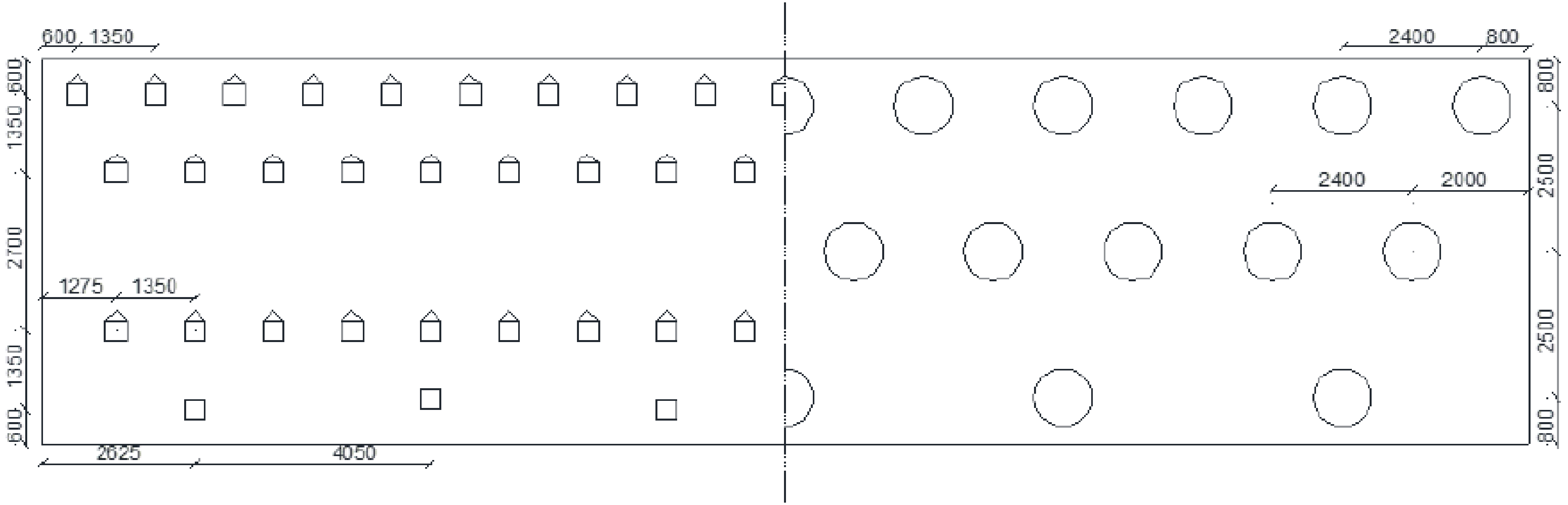

Figure 4 Pile layout. Left : driven piles and right : bored piles

Model

Traditional analytical calculations for a single pile and numerical modelling have been used to determine the general pile layouts

A sketch of the 3D FEM is shown in Figure 5

What are the main elements of FE modelling?

What are the stages representing construction phases in the FE analyses?

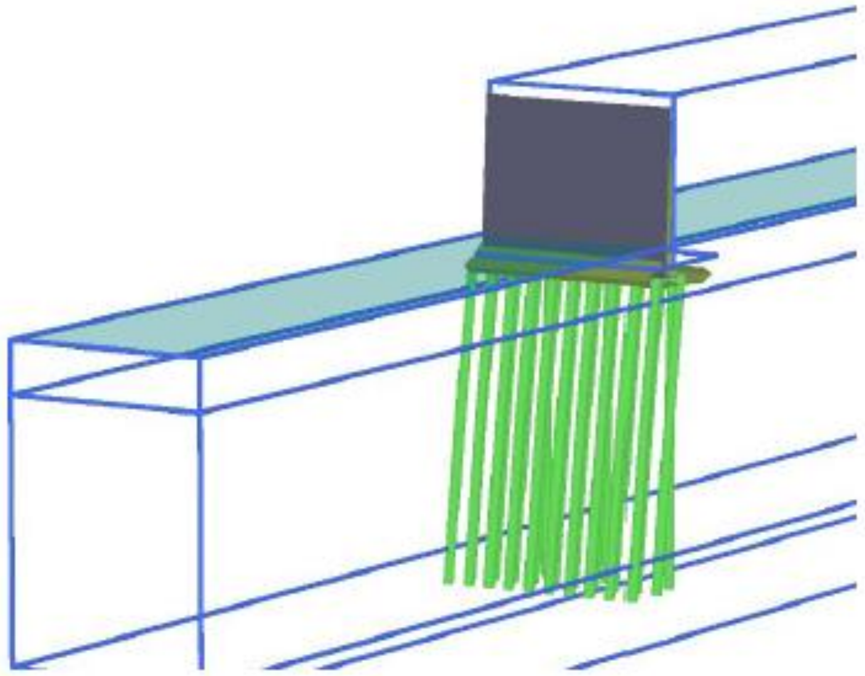

Figure 5 FE model of abutment with precast driven piles.

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Results

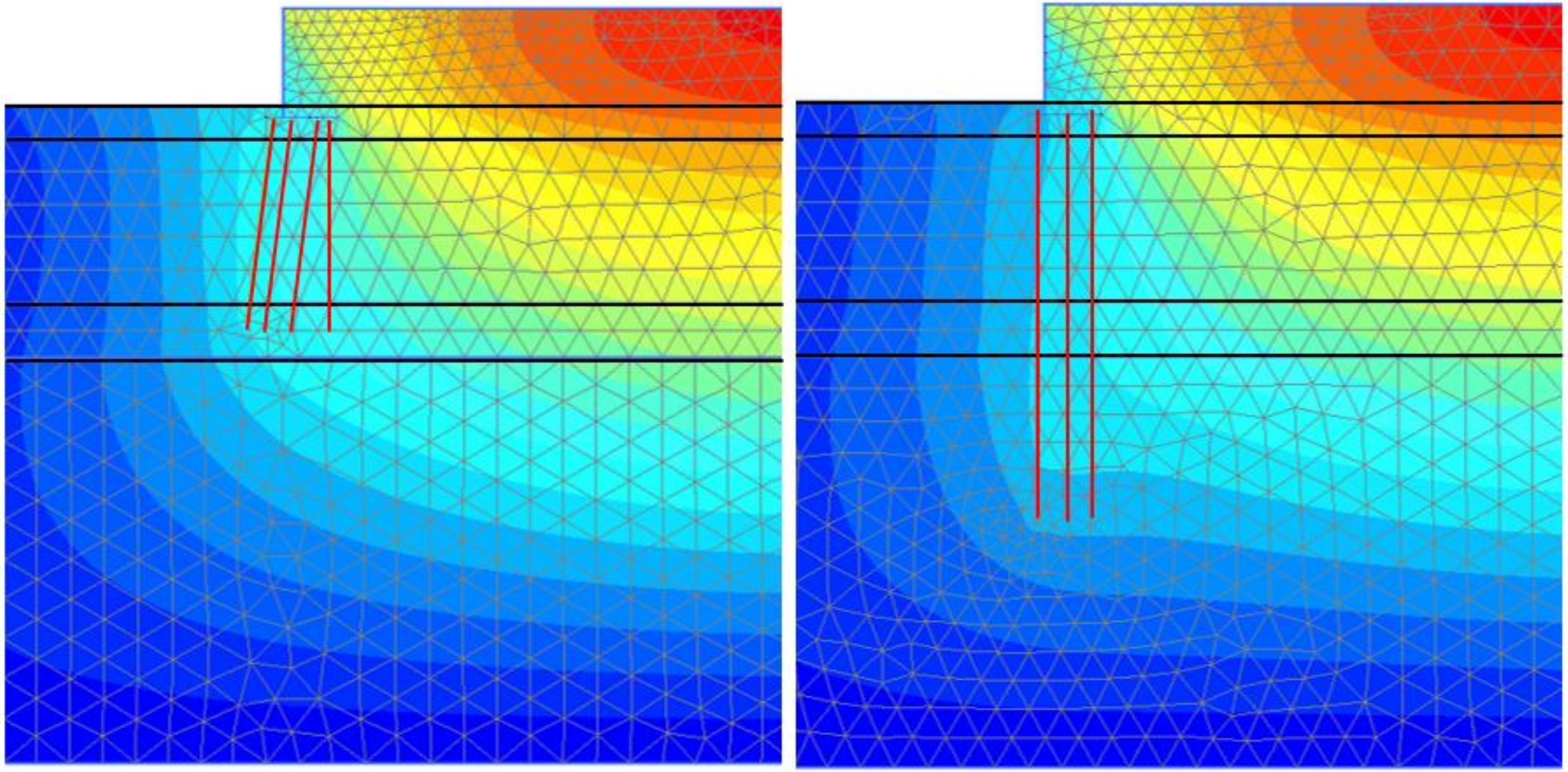

Figure 6 Displacement field (displacement isochrones) due to immediate settlements from placing the embankment fill and consolidation hereof. Left driven piles and right bored piles. Colours ranging from blue to red represents displacements from 0 to 770 mm. Layer boundaries are marked with black lines and piles are marked with red lines.

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Results

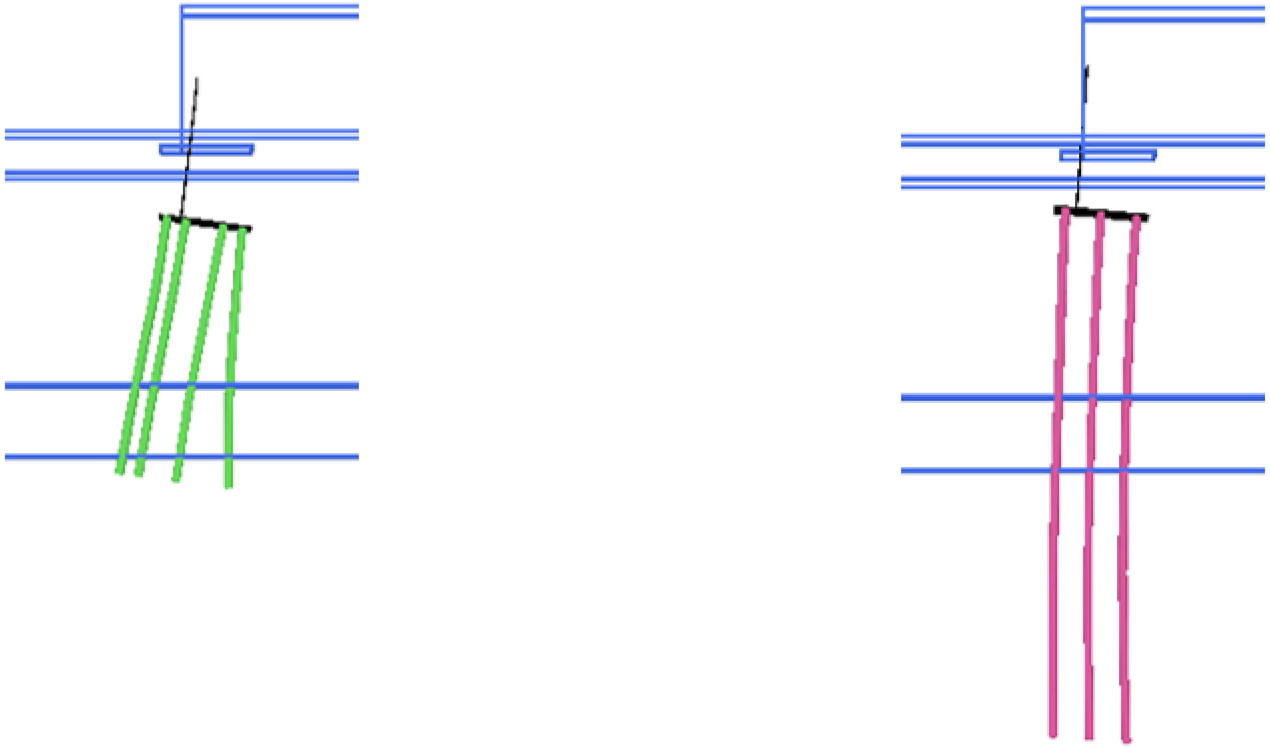

Figure 7 *Behaviour of piles at loading from bridge beck. Left driven piles and right bored piles. Note the deformations are scaled by a factor of 15.*

Reinforcement

Applied concrete and reinforcement necessary to sustain the structural effects in the piles are:

- **Precast driven piles**

Concrete: Characteristic strength of 50 MPa

Reinforcement: Longitudinal bars: 24 NR. H20

Ties: H8/200

- **Bored piles**

Concrete: Characteristic strength of 40 MPa

Reinforcement:

Front row: Longitudinal bars: 22 NR. H25

Ties: Upper 3 m H12/125,

Lower 33 m H12/250.

Middle row: Longitudinal bars: 24 NR. H20

Ties: H12/250

Rear row: Longitudinal bars: 20 NR. H20

Ties: H12/400

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Greener Construction

33% reduction in the initial cost of construction and the whole life cost of built assets

50% reduction in the overall time, from inception to completion, for newbuild and refurbished assets

50% reduction in greenhouse gas emissions in the built environment

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The Driven Pile Process

Figure 3. Raking precast concrete piles being installed with a hydraulic impact hammer

Driven Precast Concrete Piles Vs Bored Piles

- Quality
- Cost Effective
- Flexible
- Reliable and Available
- Environmentally Sound

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The Case Study

Driven Precast Piles					Bored Piles			
Row	No.	Rake	Dimensions	Length (m)	No.	Rake	Dimensions	Length (m)
1	19	1:8	350x250mm	18	11	Vertical	1000mm	36
2	18	1:8	350x350mm	18	10	Vertical	1000mm	36
3	18	1:8	350x350mm	18	5	Vertical	1000mm	36
4	6	Vertical	350x350mm	18		-	-	-
Total	**61**				**26**			

Table 1. Summary of abutment pile details

Driven Precast Piles				Bored Piles					
Row	Main Bar	Length	Shear Links	Main Bar	Length	Shear Links	Main Bar	Length	Shear Links
1	20 B20	18m	B12@200	14 B32	5m	B12@125	7 B25	36m	B12@240
2	20 B20	18m	B12@200	8 B32	5m	B12@240	8 B25	36m	B12@240
3	20 B20	18m	B12@200	6 B32	5m	B12@240	6 B25	36m	B12@240
4	20 B20	18m	B12@200	18	-	-	-	-	-

Table 2. Summary of reinforcement details

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Benefits & Advantages

	Driven Precast Concrete Piles	Bored Piles	Saving (%)
Concrete Volume (m^3)	135	846	84
Reinforcement (t)	68	56	-20
Spoil (m^3)	0	1,142	100
Programme Duration (inc. set up)	9 shifts	20 shifts	55
Vehicle Movements (Nr.)	26	514	95
Carbon Footprint (tCO_2e)	**160**	**440**	**63**

Table 3. Technique comparison

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Benefits & Advantages Cont.

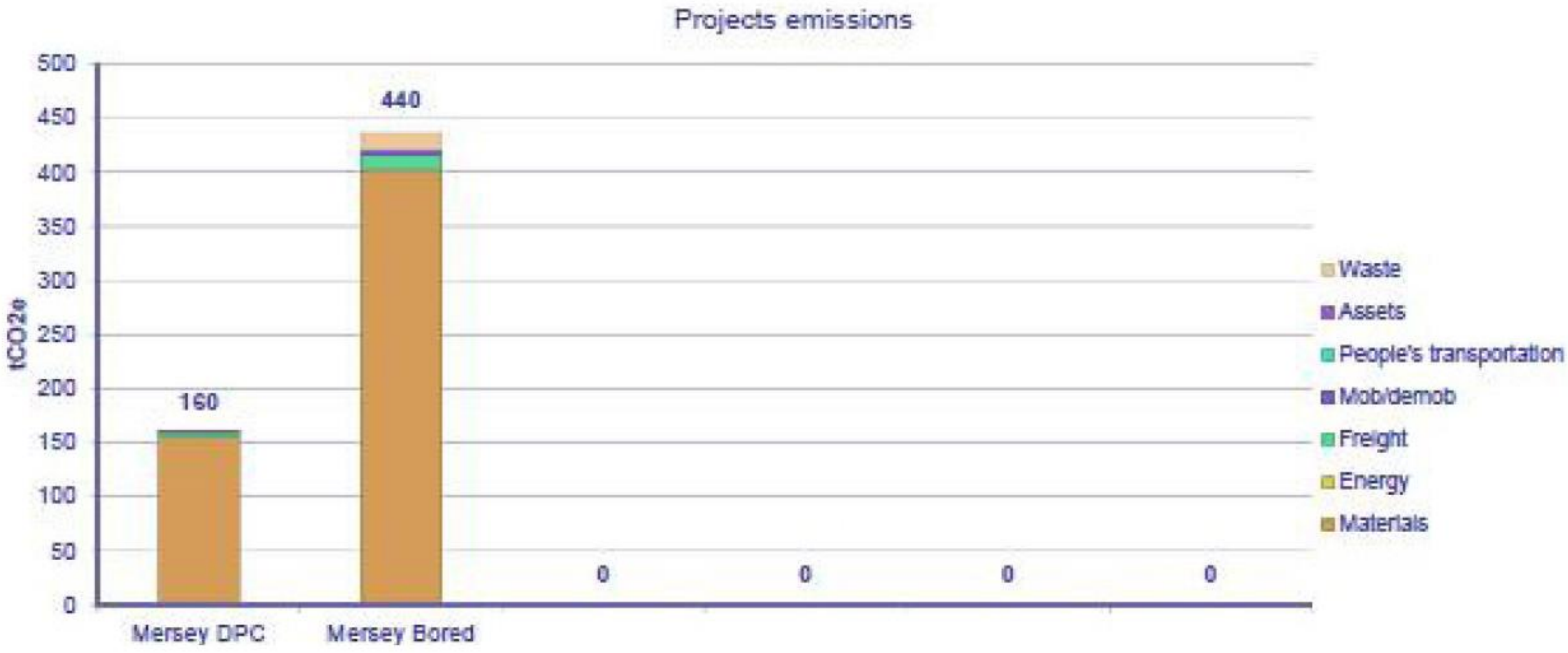

Figure 4. Carbon footprint comparison

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Conclusions

- Quality control is improved
- Overall programme duration is reduced
- Cost savings are recognised
- Waste is significantly reduced, saving costs through zero waste to landfill
- Industry is committed to reducing carbon emissions
- Potential reduction in carbon associated with infrastructure foundations can be significant
- Early engagement across the consultant and contractor community
- A driven pile solution incorporating raking piles is a viable solution for bridge structures

Summary

- Driven piles provide the opportunity to apply raked piles, which sustain the horizontal loads as axial pile forces
- The Mersey construction site was known to be contaminated. The use of driven piles results limited handling of polluted soils during pile installation
- This reduces the necessary precautionary measures to fulfil environmental requirements for earth moving
- Controlled manufacturing environment for the precast piles ensures a high degree of control over material and the casting process
- Testing of driven piles requires a smaller setup compared to bored piles and the driven piles do not need to wait for curing of the concrete prior to testing
- It is thus possible for a swifter response in case of unexpected incidents during construction and subsequent rearrangement of piles.

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Reykjavik, Iceland

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Energy Piles

Energy piles provide the foundations for effective climate solutions in sustainable construction through the utilisation of the Earth's renewable resources

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… in other words – combining a precast concrete pile with ground source heat exchanger.

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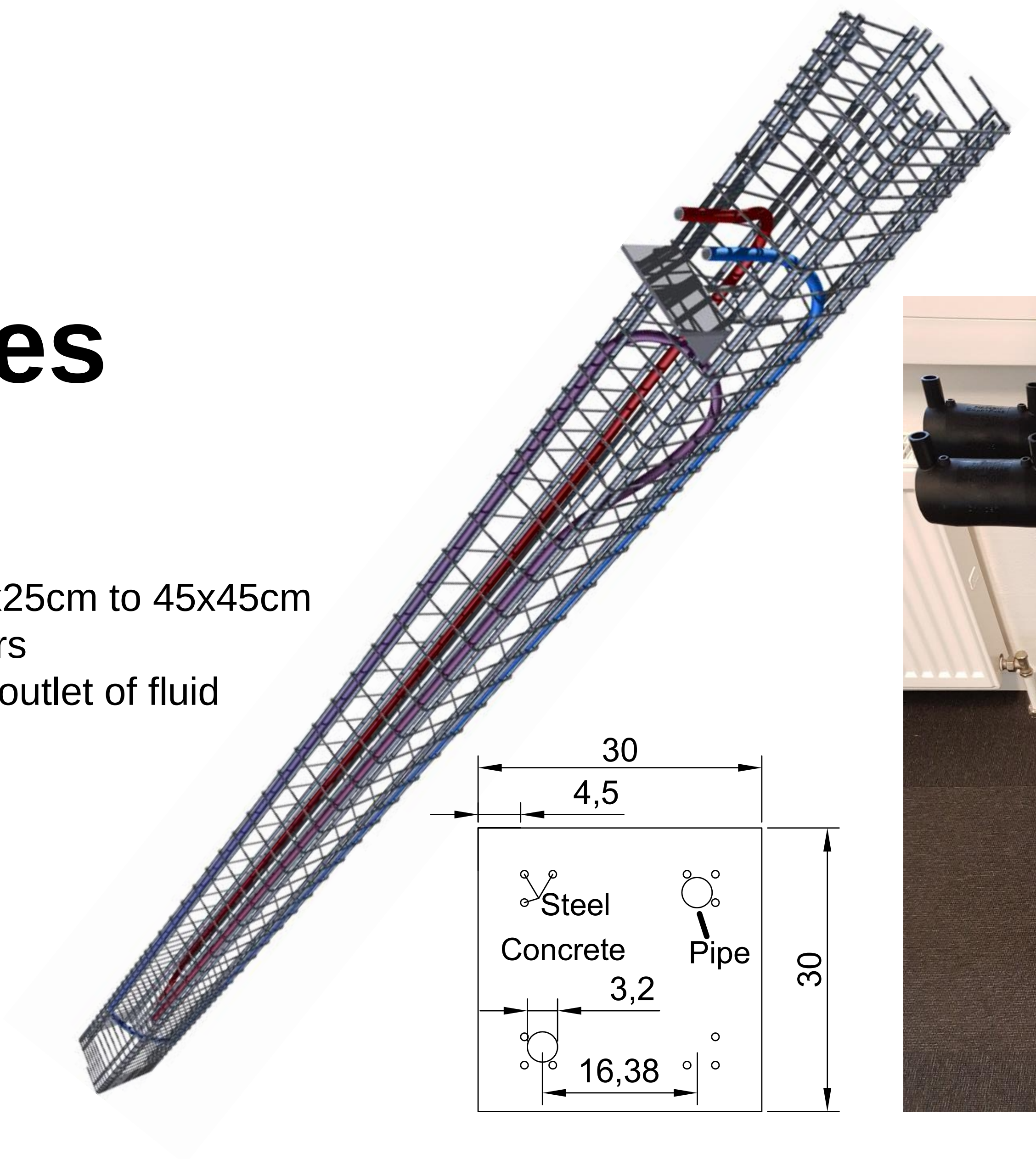
Energy Piles

The set-up:

- Available in all dimensions from 25x25cm to 45x45cm
- Available in lengths from 7-18 meters
- Produced with PE tubes for in- and outlet of fluid
- Cast in concrete



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How does the ground source heat exchange work?

Energy Piles

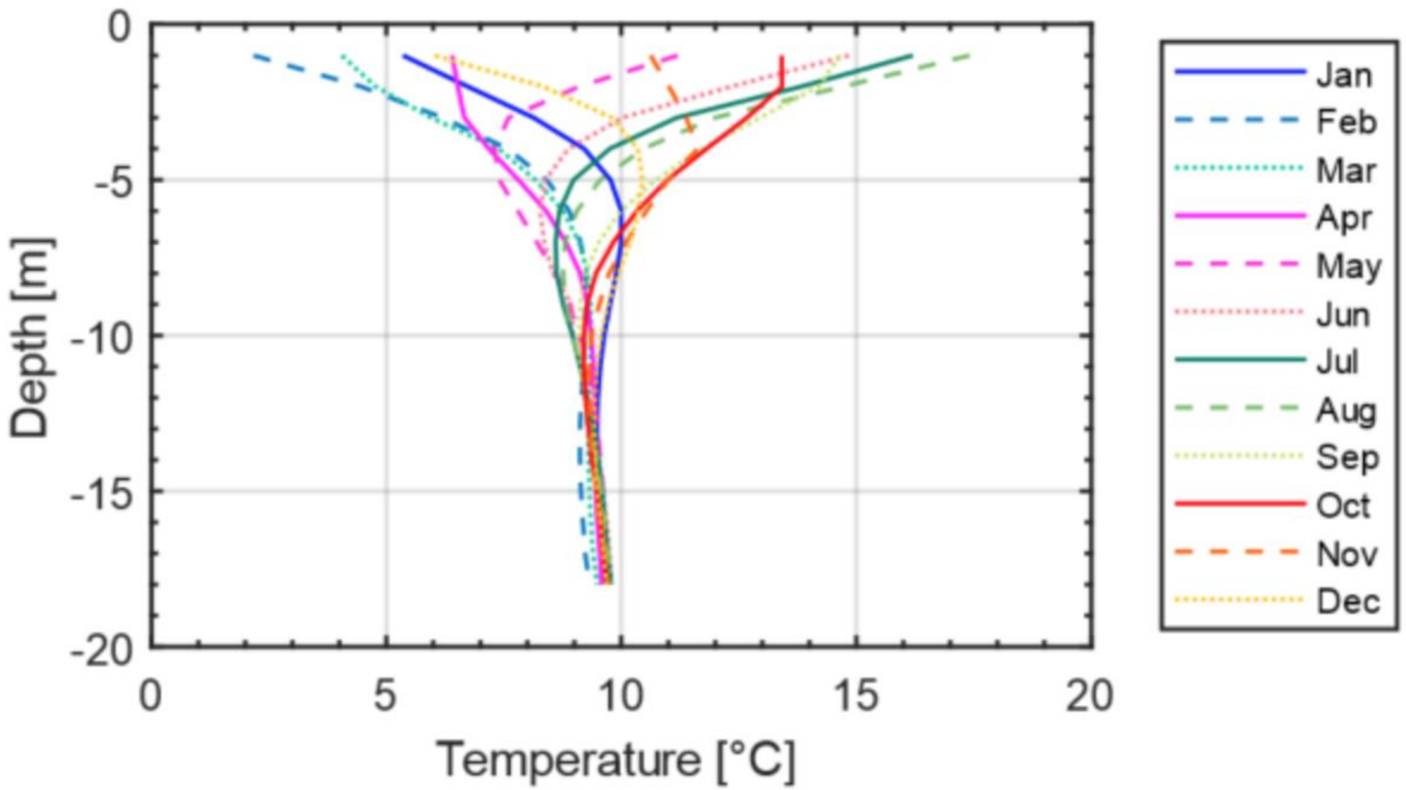
- 8-17 meters (26-56 ft.) depth
- Constant temperature
  ~ 8-10ºC / 46-50ºF

Winter – using energy & providing heating

Summer – storing energy & providing natural cooling

Soil temperature over a year in Denmark - Compared with depth in the ground.

The temperature in the ground varies with the changing seasons in the upper layers, while the temperature remains constant in the layers energy piles operate in.



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R&D

Energy Piles

Energy situation

Energy policy

New business Areas

New research Areas

Private Companies
- *Centrum Pæle A/S*

Cooperation

Research institutions
VIA UC & AAU

Innovative products
- *Energy piles*

Applied research
Scientific Proof

Lars Christensen
CEO, Centrum

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VIA University College
Innovationsfonden
INSERO HORSENS

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Energy Piles

The **Dimensioning** tool

”Providing the possibility to forecast the feasibility of energy piles as the primary energy source in any building based on factors already known.”

Maria Alberdi-Pagola, Ph.D. author and developer of the energy piles dimensioning tool

Input factors:

- Heating demands of building
- Cooling demands of building
- Total area of the building
- Geographical location of building

Case example for the following slides:

- 140 MWh heating / year
- 40 MWh cooling / year
- 4.000 m^2 building area
- Located in Vejle, Denmark (Thermal conductivity 2.2 W/m/K)

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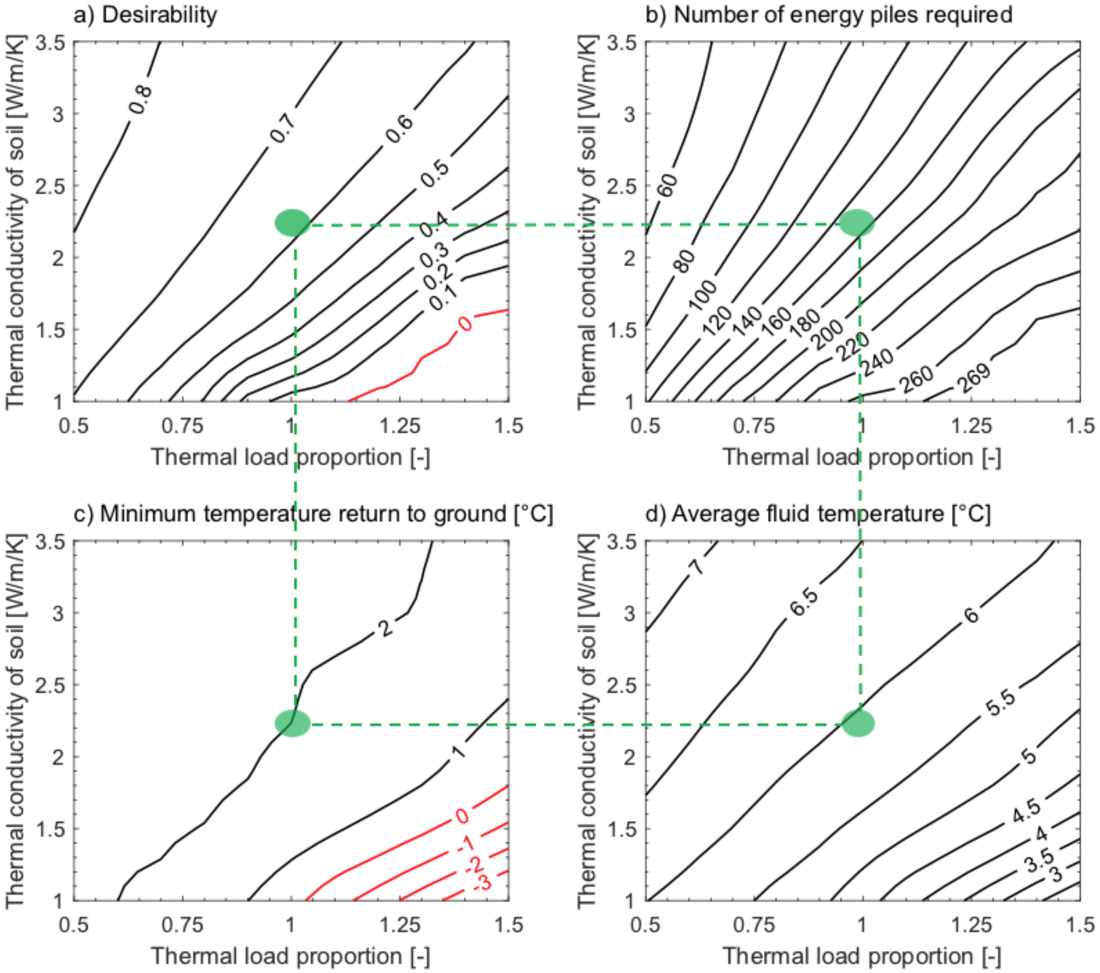
Energy Piles

Maria Alberdi-Pagola, Ph.D. Author and developer of the energy piles dimensioning tool

The **Dimensioning** tool output

Case building is feasible, since:

- Amount of energy piles required to meet energy demands is acceptable ~160
- Min. Temperature remains close to 2°C
- Avg. Temperature is acceptable ~6°C



Energy Piles

Maria Alberdi-Pagola, Ph.D author and developer of the energy piles dimensioning tool

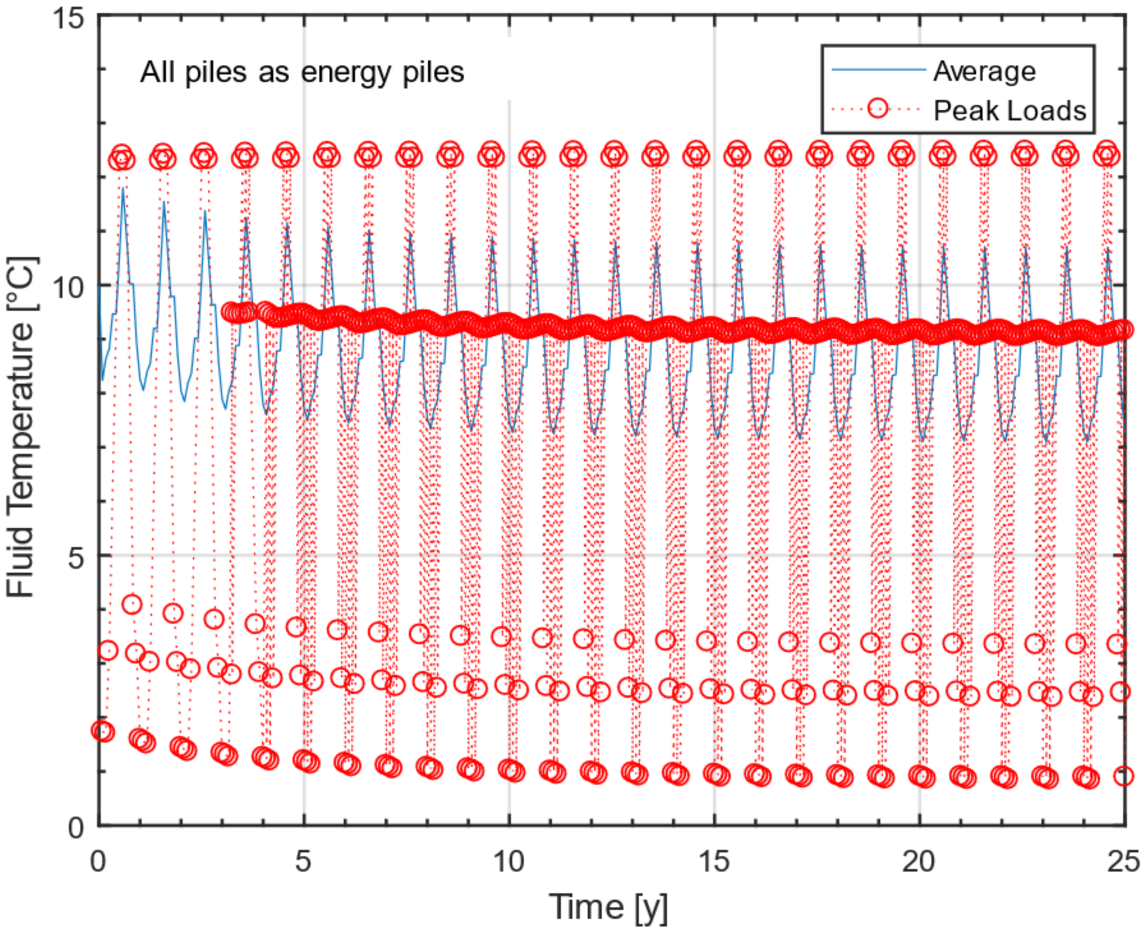
The **Dimensioning** tool output

Conclusion:

Average ground temperature remains constant at around 9ºC after 15 years

Temperature **does not** reach the freezing point (0ºC).

Ground temperature simulations for case building

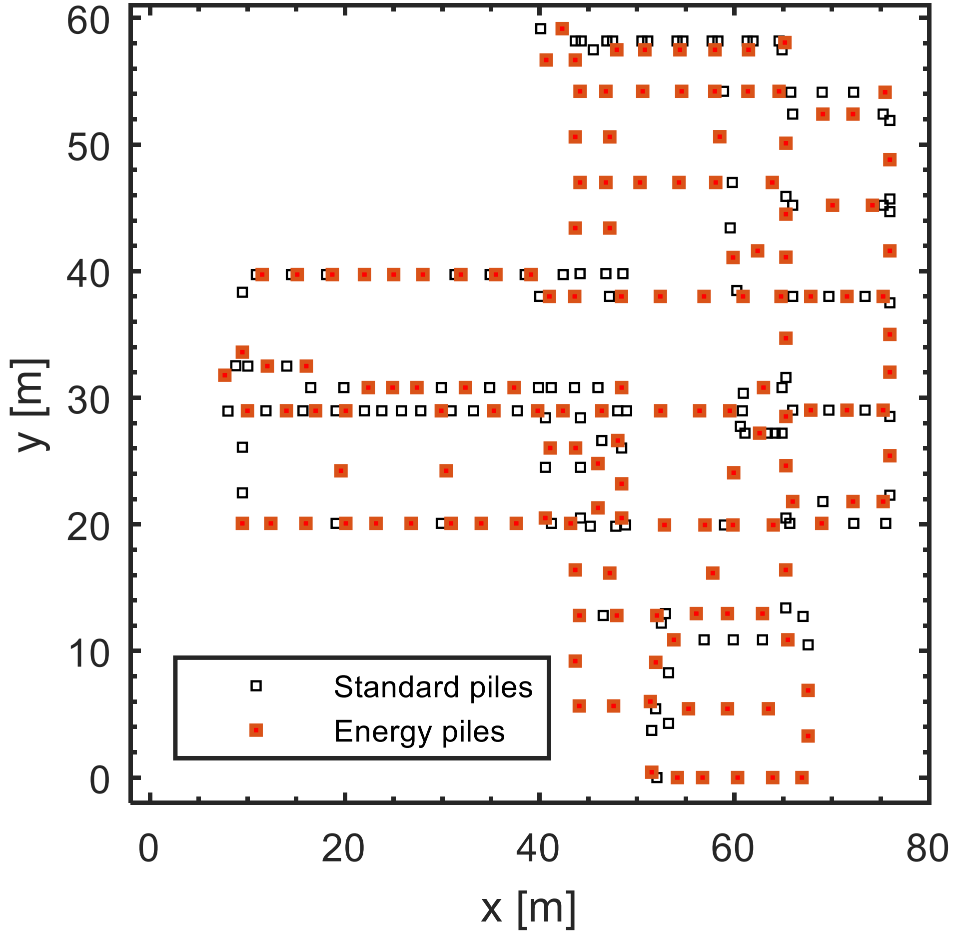


Energy Piles

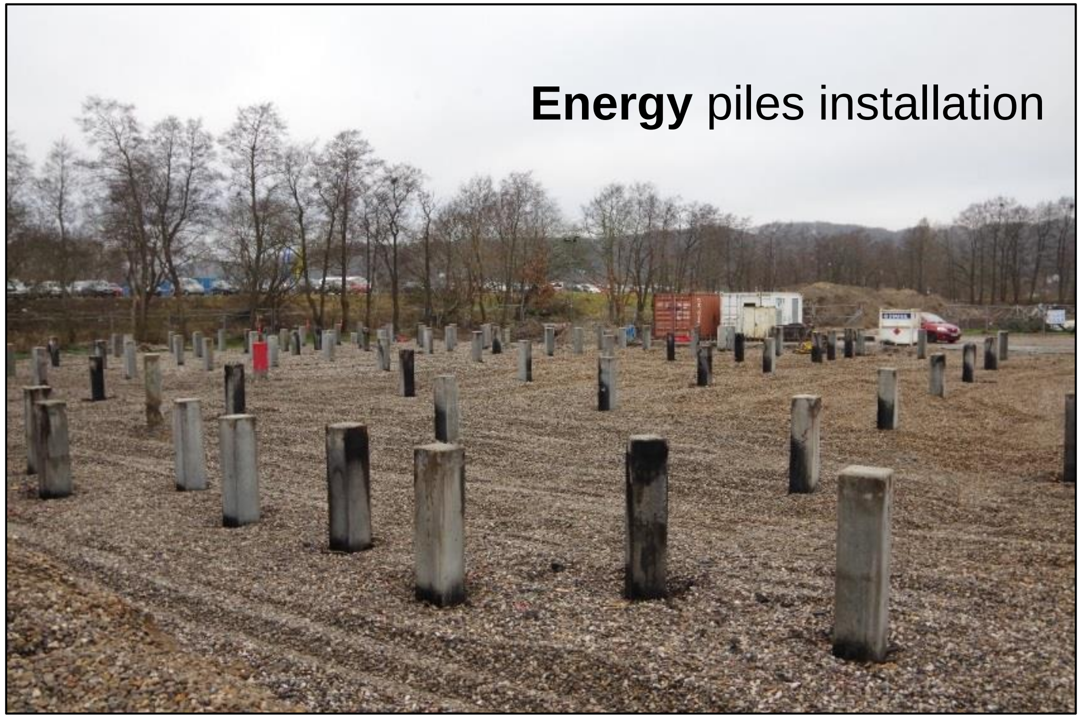
Maria Alberdi-Pagola, Ph.D. Author and developer of the energy piles dimensioning tool

The **Dimensioning** tool output

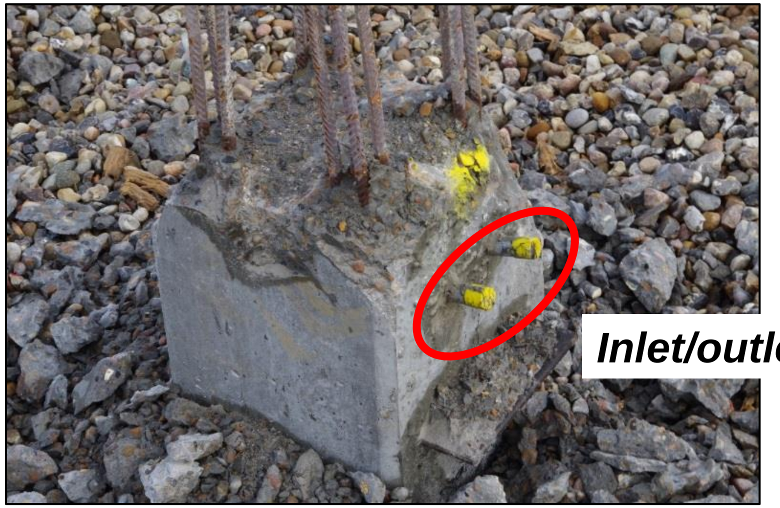
Recommended positioning of energy piles for case building



Energy Piles



Energy piles are typically placed with 3.5 m between them to counteract "cannibalizing" on each others' ground energy resources.



Energy piles coupled in manifolds.

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VIA University College

vejle KOMMUNE

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VØLUND VARMETEKNIK

Energy Piles

Energy piles as an integrated, decentral cooling and heating solution in the sustainable cities of tomorrow.

Søren Erbs Poulsen,
Ph.D., docent at VIA UC and project manager of the EUDP-project in
Ny Rosborg, Vejle, Denmark.

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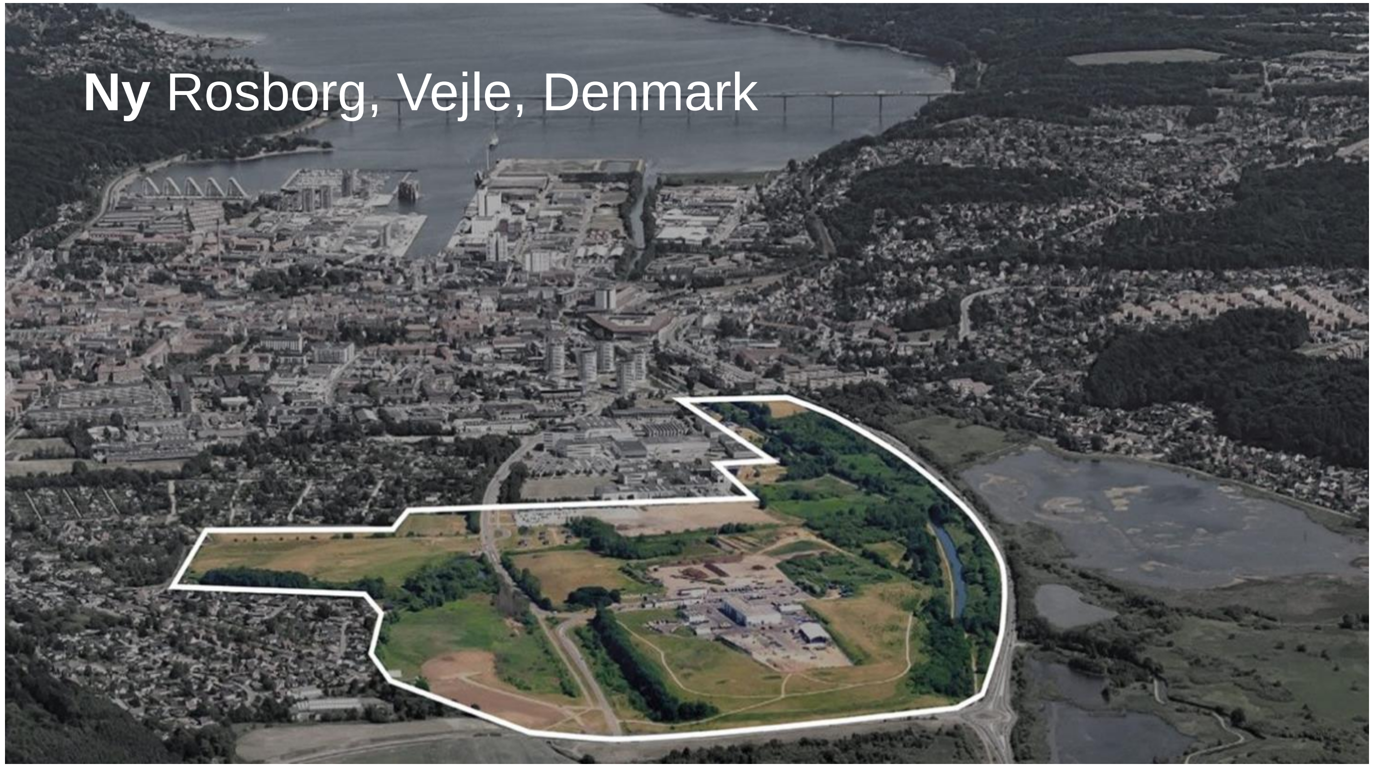
EUDP:
Energy Technology Development and Demonstration Program

Energy Piles

Søren Erbs Poulsen, Ph.D., docent at VIA UC and project manager of the EUDP-project in Ny Rosborg, Vejle, Denmark.



EUDP:
Energy Technology Development and Demonstration Program

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Energy Piles

Assumptions for energy piles based on the case building:

- Location Vejle, Denmark
- 4.000 m^2
- COP heat pump: 3
- EER cooling: 20
- Electricity price: 0,096 USD / kWh
- Heating demand: 140 MWh
- Cooling demand: 40 MWh

Jonas Henriksen,
Sales Engineer – Energy Piles,
Centrum Pæle, Denmark

Financial considerations

Capital costs

Materials	Costs
Energy pile parts – 160 pcs.	47.000 USD.
Heat pumps incl. installation	80.000 USD.
Installation – piles to heatpump	41.500 USD.
Planning and consultancy	7.700 USD.
Total	176.200 USD.

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Energy Piles

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- Cooling demand: 40 MWh

Financial considerations

Running costs & pay-back period vs. Danish district heating.

Jonas Henriksen,
Sales Engineer – Energy Piles,
Centrum Pæle, Denmark

Running costs	Energy piles	District heating
Heating	4.200 USD.	17.800 USD.
Cooling	193 USD.	1.500 USD.
Total per year	4.400 USD.	19.300 USD.
Savings w/ energy piles per year	14.900 USD.	
Pay-back period of energy pile system vs. District heating	6 years	

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Questions?
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Thank you!

Kevin Hague
Managing Director,
Aarsleff Ground Engineering UK
kevinhague@aarsleff.co.uk

Ashley ?
Head of PreConstruction
Company Country
ashleycarter@aarsleff.co.uk

Maria Alberdi-Pagola
Research Engineer,
CP Test Denmark
maria@cptest.dk

Søren Erbs
Docent,
VIA UC Denmark
soeb@via.dk

Jonas Henriksen
Sales Engineer,
Centrum Pæle A/S Denmark
jonas@centrumpaele.dk