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
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

"High quality concrete pile production since 1965"

KEY VALUES

Innovation 📍
High Quality 🎉
On-time Delivery 🕒
Customer Satisfaction 😊
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.
Innovative Piled Solutions
Electrification Piles

Product lifetime: 120 Years
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
Mersey Gateway
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.
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
Avonmouth, Bristol
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)
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

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

<table>
<thead>
<tr>
<th>Soil Layer</th>
<th>Thickness</th>
<th>Contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankment fill</td>
<td>8.8m</td>
<td></td>
</tr>
<tr>
<td>Made ground (MG)</td>
<td>3m</td>
<td></td>
</tr>
<tr>
<td>Cohesive Glacial Deposit (GD-C)</td>
<td>15m</td>
<td></td>
</tr>
<tr>
<td>Granular Glacial Deposit (GD-G)</td>
<td>5m</td>
<td></td>
</tr>
</tbody>
</table>
Figure 4 Pile layout. Left: driven piles and right: bored piles
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.
Results

Figure 6  Displacement field (displacement isochrones) due to immediate settlements from placing the embankment fill and consolidation thereof. 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.
Results

Figure 7  Behaviour of piles at loading from bridge deck. 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
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
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
## The Case Study

<table>
<thead>
<tr>
<th>Row</th>
<th>No.</th>
<th>Rake</th>
<th>Dimensions</th>
<th>Length (m)</th>
<th>No.</th>
<th>Rake</th>
<th>Dimensions</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>1:8</td>
<td>350x250mm</td>
<td>18</td>
<td>11</td>
<td>Vertical</td>
<td>1000mm</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>1:8</td>
<td>350x350mm</td>
<td>18</td>
<td>10</td>
<td>Vertical</td>
<td>1000mm</td>
<td>36</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>1:8</td>
<td>350x350mm</td>
<td>18</td>
<td>5</td>
<td>Vertical</td>
<td>1000mm</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>Vertical</td>
<td>350x350mm</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>26</td>
<td>-</td>
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<td>-</td>
</tr>
</tbody>
</table>

Table 1. Summary of abutment pile details

<table>
<thead>
<tr>
<th>Row</th>
<th>Main Bar</th>
<th>Length</th>
<th>Shear Links</th>
<th>Main Bar</th>
<th>Length</th>
<th>Shear Links</th>
<th>Main Bar</th>
<th>Length</th>
<th>Shear Links</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 B20</td>
<td>18m</td>
<td>B12@200</td>
<td>14 B32</td>
<td>5m</td>
<td>B12@125</td>
<td>7 B25</td>
<td>36m</td>
<td>B12@240</td>
</tr>
<tr>
<td>2</td>
<td>20 B20</td>
<td>18m</td>
<td>B12@200</td>
<td>8 B32</td>
<td>5m</td>
<td>B12@240</td>
<td>8 B25</td>
<td>36m</td>
<td>B12@240</td>
</tr>
<tr>
<td>3</td>
<td>20 B20</td>
<td>18m</td>
<td>B12@200</td>
<td>6 B32</td>
<td>5m</td>
<td>B12@240</td>
<td>6 B25</td>
<td>36m</td>
<td>B12@240</td>
</tr>
<tr>
<td>4</td>
<td>20 B20</td>
<td>18m</td>
<td>B12@200</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>

Table 2. Summary of reinforcement details
## Benefits & Advantages

<table>
<thead>
<tr>
<th></th>
<th>Driven Piles</th>
<th>Precast Concrete</th>
<th>Bored Piles</th>
<th>Saving (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Volume (m³)</td>
<td>135</td>
<td>846</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Reinforcement (t)</td>
<td>68</td>
<td>56</td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td>Spoil (m³)</td>
<td>0</td>
<td>1,142</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Programme Duration (inc. set up)</td>
<td>9 shifts</td>
<td>20 shifts</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Vehicle Movements (Nr.)</td>
<td>26</td>
<td>514</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>Carbon Footprint (tCO₂e)</td>
<td>160</td>
<td>440</td>
<td>63</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Technique comparison
Benefits & Advantages Cont.

Figure 4. Carbon footprint comparison
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.
Reykjavik, Iceland
Energy Piles

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

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

How does the ground source heat exchange work?

- Winter – using energy & providing heating
- Summer – storing energy & providing natural cooling

- 8-17 meters (26-56 ft.) depth
- Constant temperature
  - ~ 8-10°C / 46-50°F
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.
R&D

Energy Piles

Energy situation

Energy policy

New business Areas

New research Areas

Private Companies
- **Centrum Pæle A/S**

Research institutions
- **VIA UC & AAU**

Cooperation

Innovative products
- **Energy piles**

Applied research
Scientific Proof

Lars Christensen
CEO, Centrum

Centrum Pæle A/S

Innovationsfonden

VIA University College

INSERO HORSENS
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."

**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 m² building area
- Located in Vejle, Denmark
  (Thermal conductivity 2.2 W/m/K)
Energy Piles

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

The **Dimensioning** tool output

**Conclusion:**
Average ground temperature remains constant at around 9°C after 15 years

Temperature **does not** reach the freezing point (0°C).
Energy Piles

The **Dimensioning** tool output

Recommended positioning of energy piles for case building

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

Energy piles installation

Inlet/outlet tubes
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.
Energy Piles

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

Financial considerations

<table>
<thead>
<tr>
<th>Materials</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy pile parts – 160 pcs.</td>
<td>47.000 USD.</td>
</tr>
<tr>
<td>Heat pumps incl. installation</td>
<td>80.000 USD.</td>
</tr>
<tr>
<td>Installation – piles to heatpump</td>
<td>41.500 USD.</td>
</tr>
<tr>
<td>Planning and consultancy</td>
<td>7.700 USD.</td>
</tr>
<tr>
<td>Total</td>
<td>176.200 USD.</td>
</tr>
</tbody>
</table>

Assumptions for energy piles based on the case building:
- Location Vejle, Denmark
- 4.000 m²
- COP heat pump: 3
- EER cooling: 20
- Electricity price: 0.096 USD / kWh
- Heating demand: 140 MWh
- Cooling demand: 40 MWh
## Energy Piles

### Financial considerations

<table>
<thead>
<tr>
<th>Running costs</th>
<th>Energy piles</th>
<th>District heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>4.200 USD.</td>
<td>17.800 USD.</td>
</tr>
<tr>
<td>Cooling</td>
<td>193 USD.</td>
<td>1.500 USD.</td>
</tr>
<tr>
<td><strong>Total per year</strong></td>
<td>4.400 USD.</td>
<td>19.300 USD.</td>
</tr>
<tr>
<td><strong>Savings w/ energy piles per year</strong></td>
<td>14.900 USD.</td>
<td></td>
</tr>
</tbody>
</table>

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

- **Pay-back period of energy pile system vs. District heating**: 6 years

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Questions?
Thank you!