Field studies on bearing capacity of vibratory and impact driven piles

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Introduction

Engineering aspects related to the use of the vibratory and impact driving techniques:

- **Driveability**
  - e.g. the penetration speed achieved versus depth

- **Environmental impact**
  - e.g. the level of ground vibrations induced

- **Bearing capacity**
  - e.g. the prediction of bearing capacity from the driving log
  - the bearing capacity of piles
Research Motivation

• A thorough literature study revealed that the bearing capacity of vibratory piles is up to 60% lower than impact driven piles

• The bearing capacity of vibratory driven piles cannot be calculated with sufficient accuracy based on the observed final rate of penetration

• Practice: vibratory piles are redriven with an impact hammer on the last meters for acceptance as a bearing pile
Main objektive

- Comparative investigations of vibratory piles to impact-driven piles concerning bearing capacity
- Determine the influence of vibro-driver parameters on the bearing capacity
- Investigate the soil plugging behaviour of vibratory driven piles
- Elaborate links between the results of the cone penetration tests and the driving log of vibratory driven piles

Approaches

- Theoretical work
- Full-scale field studies
Vibratory technique and the mode of action

**Vibratory technique:**

- **Stationary part**
- **Vibratory part**

**Static surcharge force**

**Sinusoidal excitation force**

**Mode of action:**

- **Shear strength reduction**

The soil resistance during vibratory driving is lower than the bearing capacity

**Pile vibratory resistance** ➞ **Bearing capacity**

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Field studies, pier construction

Foundation:

In-situ-concrete pile

Combined sheet pile wall

Open-ended steel piles
  \( L = 31.3 \text{ m} \) (27.5 m)
  \( \varnothing = 914.7 \text{ mm} \),
  \( t = 12.7 \text{ mm} \),
  \( a = 4.3 \text{ m} \)

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Field studies, concept of test programme

recording of driving data influenced on the bearing capacity of in-situ piles

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Field studies, site investigations and laboratory tests

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**Field studies, used drivers**

- **IHC Hydrohammer S 70**
  - 3,5 t (ram weight)
  - 70 kNm (max. blow energy)
  - 50 bl/ min (blow rate)

- **MS 32 HFvar**
  - $f = 39,6$ Hz (frequency)
  - $M_{st}=32$ kgm (eccentric moment)
  - $F_{dyn} = 1976$ kN (excitation force)

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Scope of field studies

- 3 pile groups, each pile group consists of 2 pairs of piles

Study encompasses the following investigations:

- 4 pairs of piles were tested for direct comparison on vibratory and impact driven driven piles
- 2 pairs of piles were installed with different vibratory parameters (frequency and eccentric moment)

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Driving log, pair of piles A1

- Cone resistance $q_c$ (MN/m²)
- Depth [mNN]
- Vibro pile
- Impact pile
- Relating driving energy [MNm/m]
- Total energy: $E_{tot} = 33$ MNm
- Blow energy: $E_{blow} = 56$ kNm
- Set per blow: ~9 mm
- Velocity [mm/s]
- Driving frequency: $f = 35$ Hz
- Eccentric moment: $M_{st} = 24$ kNm
- Excitation force: $F_{dyn} = 1161$ kN

Bearing capacity after 13 d: [kN]

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<th>Method</th>
<th>$R$</th>
<th>$R_s$</th>
<th>$R_b$</th>
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<td>Impact</td>
<td>2054</td>
<td>1510</td>
<td>544</td>
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<tr>
<td>Vibratory</td>
<td>2286</td>
<td>1675</td>
<td>611</td>
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</tbody>
</table>

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Driving log, pair of piles A2

- Cone resistance $q_c$ [MN/m²]
- Relating driving energy [MNm/m]
- Velocity [mm/s]

### Bearing Capacity after 15 d: [kN]

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<th></th>
<th>R</th>
<th>$R_s$</th>
<th>$R_b$</th>
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</thead>
<tbody>
<tr>
<td>Impact</td>
<td>5251</td>
<td>4299</td>
<td>952</td>
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<tr>
<td>Vibratory</td>
<td>4753</td>
<td>3970</td>
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</tbody>
</table>

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Conclusion and outlook

• The results of two comparative field studies carried out on vibratory and impact driven piles have been presented

• Vibratory pile tested exhibits slightly higher capacity than impact piles in medium dense sand

• Impact pile tested has a higher bearing capacity than vibratory piles in very dense sand

• Both vibratory and impact piles are unplugged in dense and medium sand

• Driving logs regarding the bearing capacity for vibratory piles have to be defined

• Reliable criteria for the design of vibratory piles are required, i.e. links between cone resistance and the driving log of vibratory piles have to be developed