The fundamental principles and differences between Drilled Displacement Columns (DDCs) and piles

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1. INTRODUCTION

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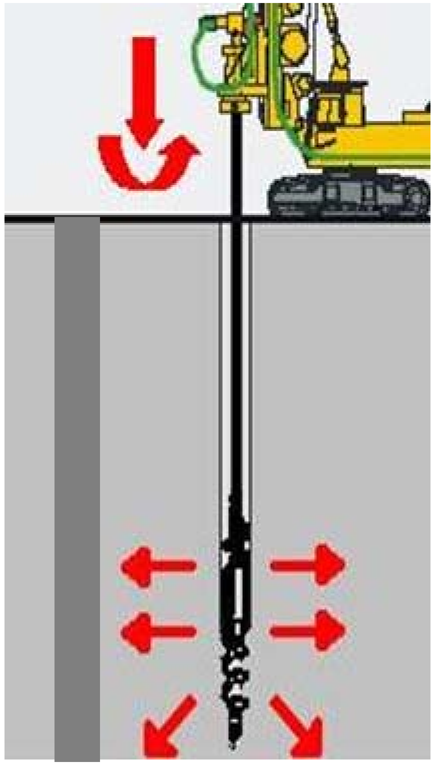


<u>Drilled displacement piles & columns became very popular in the last decades due to:</u>

- High production rates (standardized piling equipment)
- Usually higher pile capacities than CFA / bored piles of similar diameter due to displacement effect (increased shaft capacity)
- Minimal spoil creation
- Typical diameters 360mm, 450mm (and 540mm)

<u>Drilled displacement piles can be used as:</u>

- Load bearing piles
- Settlement reduction elements (rigid inclusions)

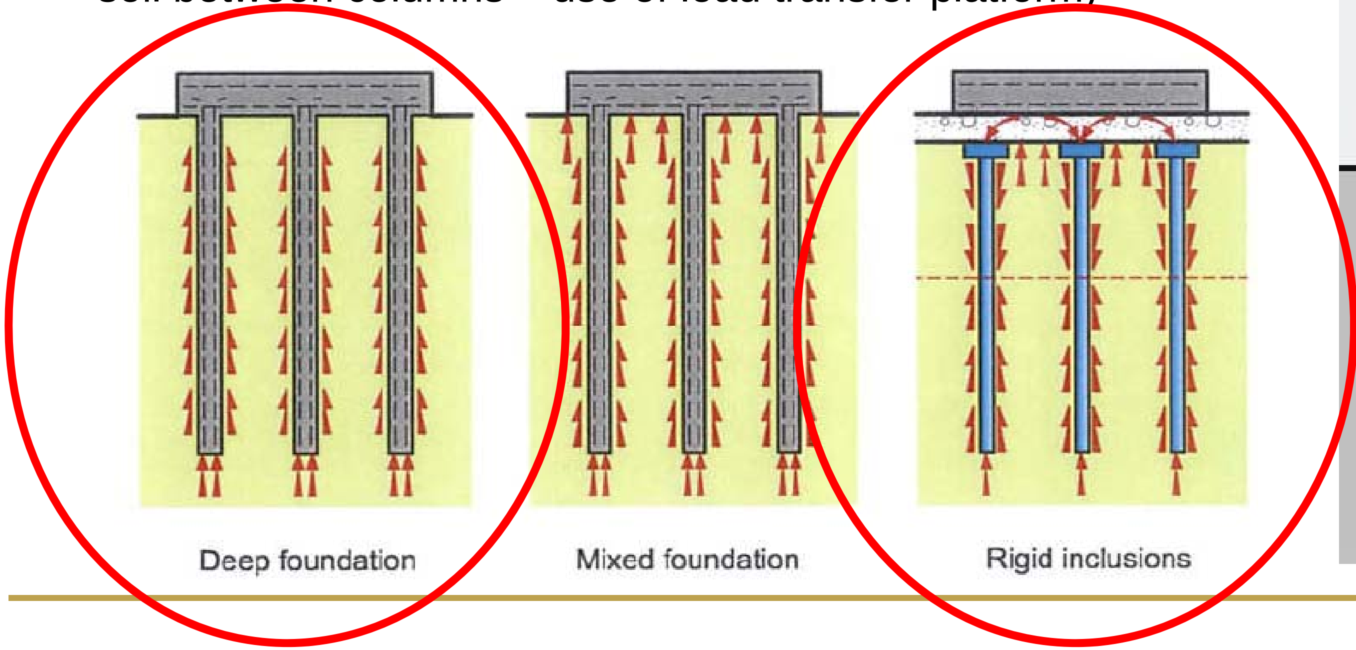
<u>Following major risks can be associated with auger displacement piles:</u>

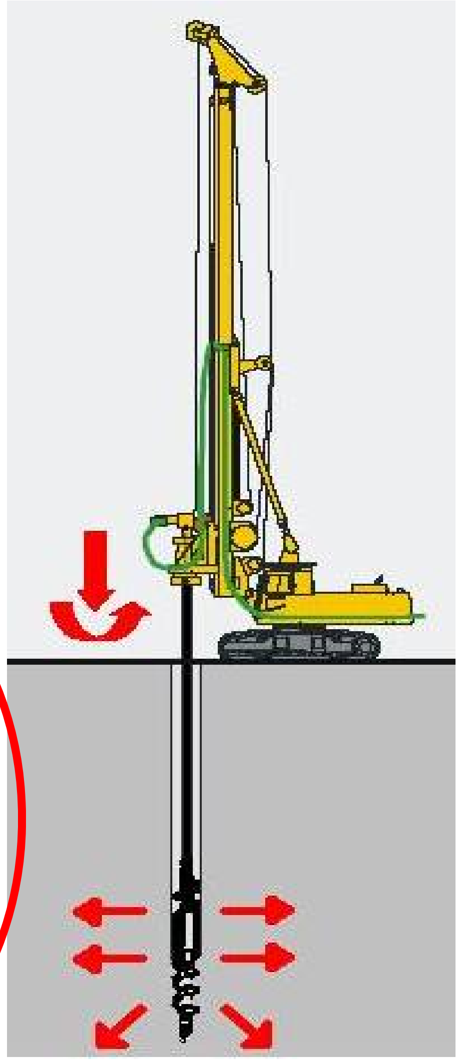
- Potential damage of adjacent piles / structures due to displacement effect
- Inability to drill through hard layers / obstructions

1. INTRODUCTION

Applications:

- Piled foundations (reinforcement, embedment in stiff layer, etc)
- Mixed foundations (pile raft – combined load transfer by piles and slab)
- Rigid inclusions (combined load transfer through columns and soil between columns – use of load transfer platform)

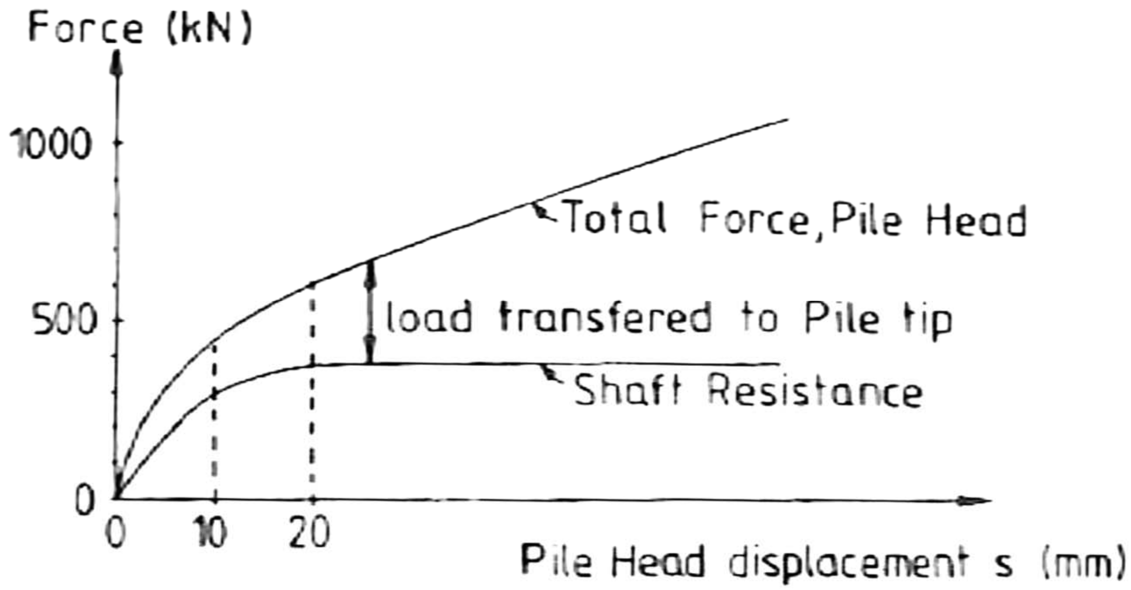




2. PILED FOUNDATIONS

Load transfer:

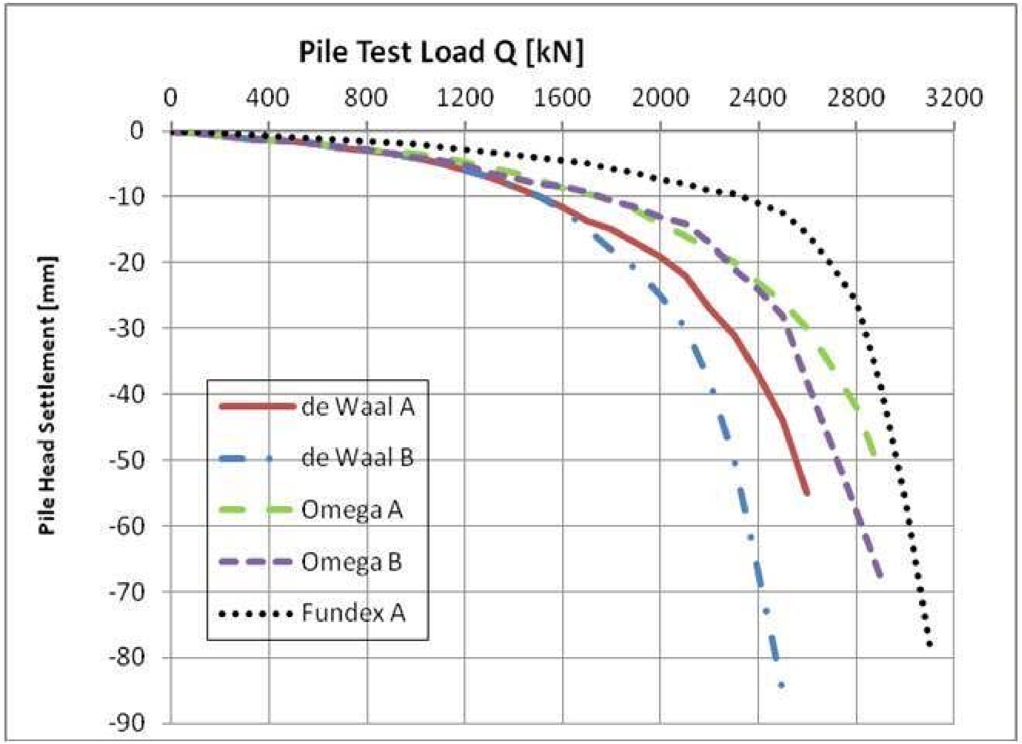
- From the structure to the pile via a rigid connection (pile cap)
- The soft layer is <u>bridged</u> by the pile and the load is transferred in the ground by:
  - Shaft resistance
  - Base resistance

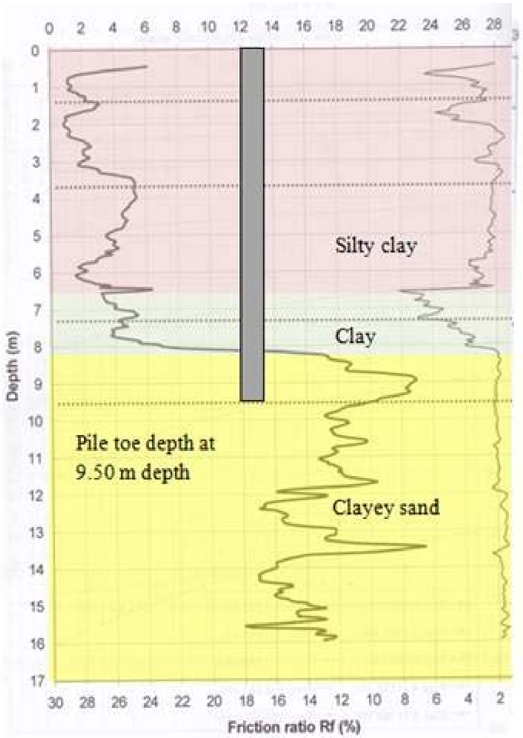


2. PILED FOUNDATIONS

Pile capacity:

- Verified by pile load tests (static, dynamic or other testing methods)
- Settlement of the pile determines the settlement of the structure





2. PILED FOUNDATIONS

Summary piled foundations:

- Fixed connection between pile and structure (pile cap);
- Transfer of tension, lateral loads and/or bending might be required (reinforcement cage);
- Substantial penetration into competent layers is required (load transfer);
- 'High strength' (> 32 Mpa) reinforced concrete;
- Sensitive to installation tolerances (additional bending moments);
- Verification of shaft integrity is important as load transfer occurs through the pile;

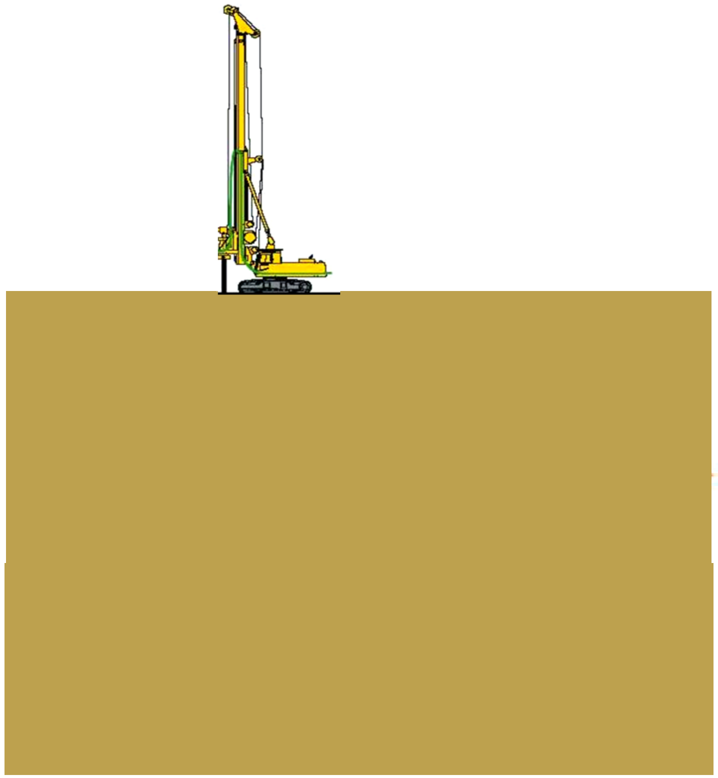
- Ground heave will occur due to displacement effect (typically minor);
- Lateral movements will occur due to displacement effect (typically minor); and

- Soil displacement effects can be taken into consideration in some design methods (e.g. Bustamante & Gianeselli, 2003)

- **Typically required for high/medium structural loads with low settlements**

3. RIGID INCLUSIONS / DDCs

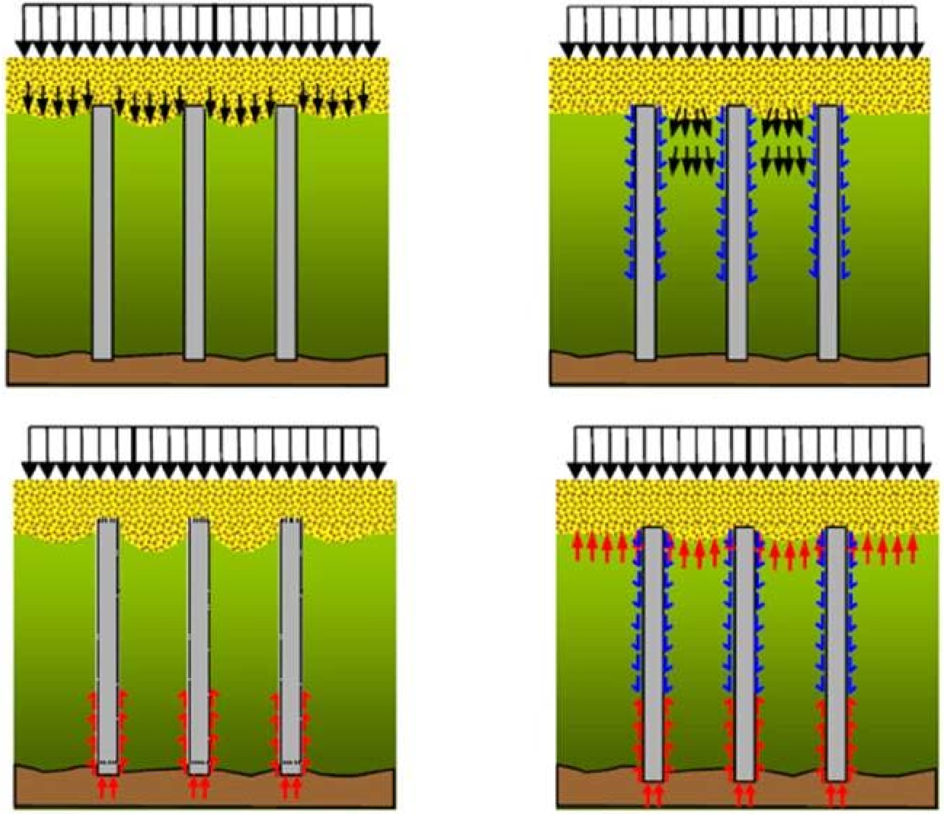
Working principles of DDCs:



3. RIGID INCLUSIONS / DDCs

Working principles of DDCs:

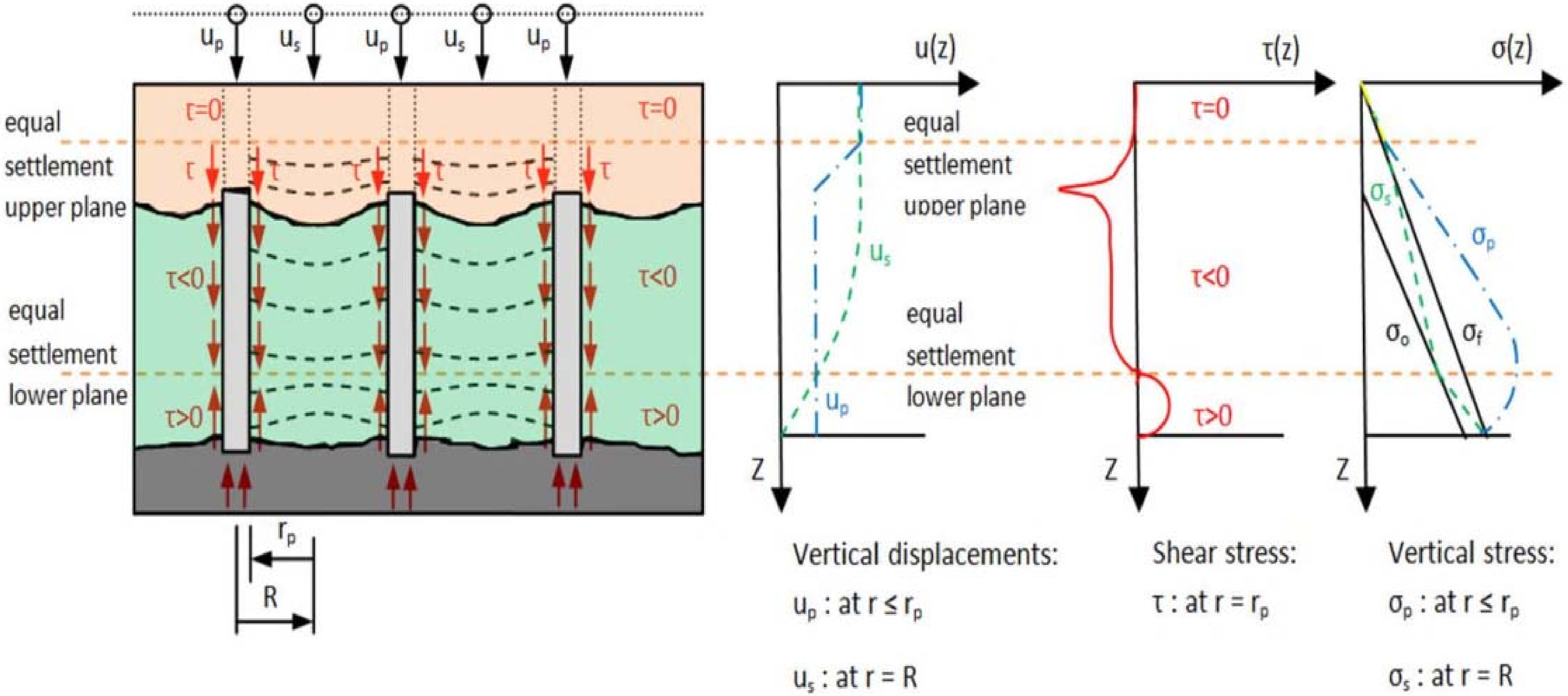
- Settlement of soft soil between DDC heads
- Transfer of load to DDCs by negative skin friction
- Settlement of DDCs and load transfer by positive skin friction at DDC toe / base section
- Equilibrium between negative and positive forces at neutral point (inside soft soil)



(courtesy of Bachy Menard)

3. RIGID INCLUSIONS / DDCs

Shear mechanism, stresses and displacements of an embankment founded on rigid inclusions after Simon und Schlosser, 2006.



3. RIGID INCLUSIONS / DDCs

Plomteux und Lacazidieu (2007) define the condition of equilibrium as followed:

$$Q + F_n = F_p + Q_p$$

<u>where:</u>

Q = vertical load at the head of the rigid inclusion;

F_n = negative skin friction, applied above the equal-settlement lower plane;

F_p = positive skin friction, mobilised below the equal-settlement lower plane; and

Q_p = tip resistance in the anchorage layer.

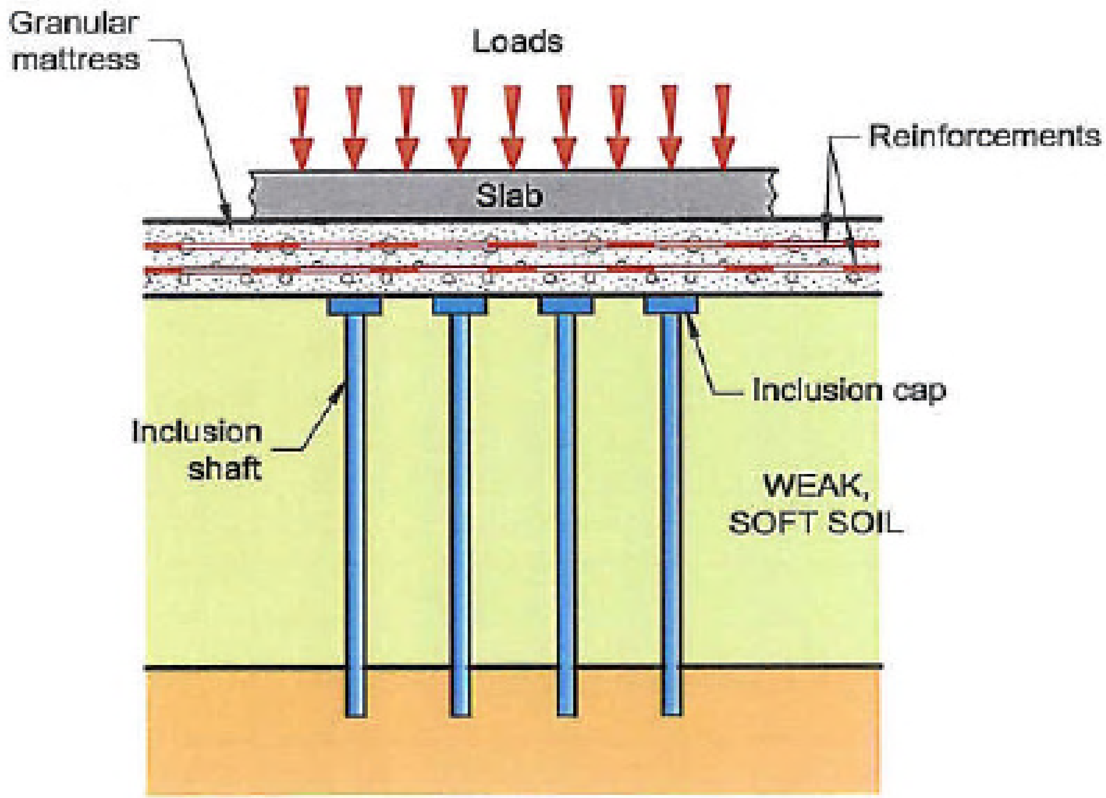
Shaft capacity / skin friction determination is critical!

- → Knowledge of soil parameters; and
- → Knowledge of installation method

3. RIGID INCLUSIONS / DDCs

Typical elements of DDC systems:

- Slab or structure;
- Load transfer layer;
- Rigid inclusion / DDC;
- Soft soil; and
- Bearing layer.



The system requires a grid of columns to behave like rigid inclusions. The system needs to develop the load transfer mechanism, individual columns will behave like piles.

3. RIGID INCLUSIONS / DDCs

Summary soil improvement with rigid inclusions / DDCs:

- Settlement reduction (consider the entire system);
- Typically no bending moments or tension loads (from structure);
- Penetration into competent layers only marginal (load transfer);
- ‘Low strength’ (often 5-15 Mpa) plain concrete members;
- NOT sensitive to installation tolerances (soil improvement system);

- Ground heave will occur due to displacement effect (can be significant);
- Lateral movements will occur due to displacement effect (can be significant);

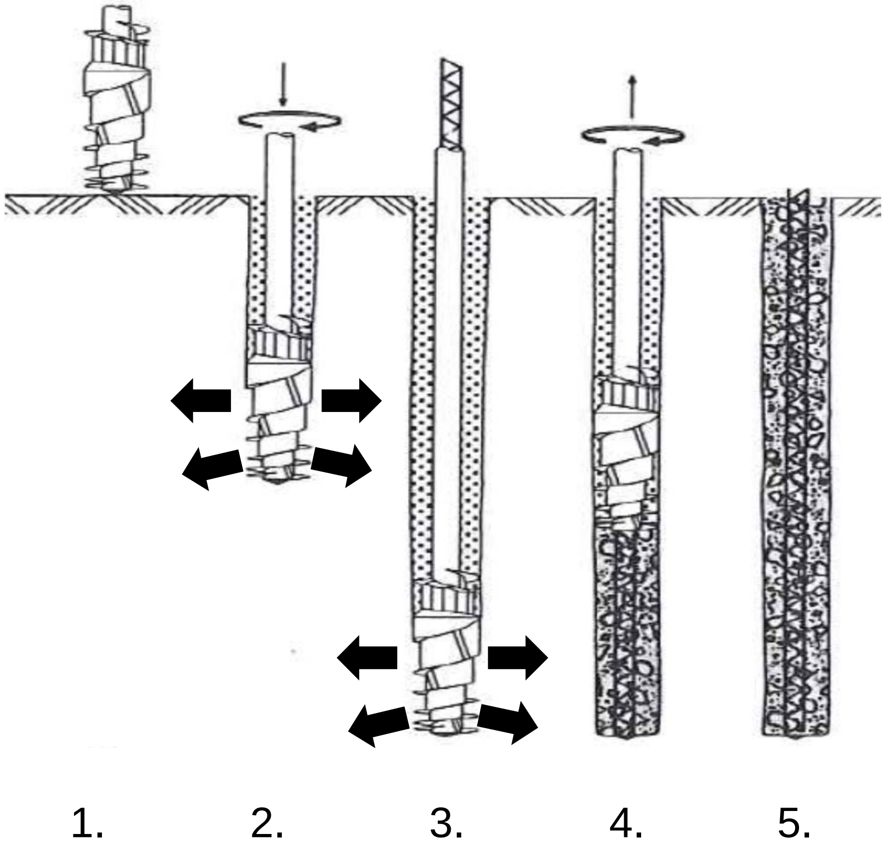
- Verification of shaft integrity is important for construction QA; and

- Soil displacement effects are NOT taken into consideration in the design

- **Typically required for low/medium structural loads with medium/high settlements**

4. INSTALLATION PROCESS

Typical installation process of drilled displacement columns / piles after Bottiau (1998):



1. Set up auger at position and install cap to close concrete outlet at auger tip.
2. Install auger by rotating clockwise and applying vertical pull down force.
3. Drill auger to design depth, the displacement body of the auger pushes the soil cut by the auger tip into the surrounding ground.
4. Pump concrete through hollow auger stem and extract auger while rotating clockwise, always maintaining concrete pressure positive and auger embedded in fresh concrete.
5. Install reinforcement into fresh concrete, if required.

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4. INSTALLATION PROCESS

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Pictures courtesy of Bauer Maschinen GmbH (Germany)

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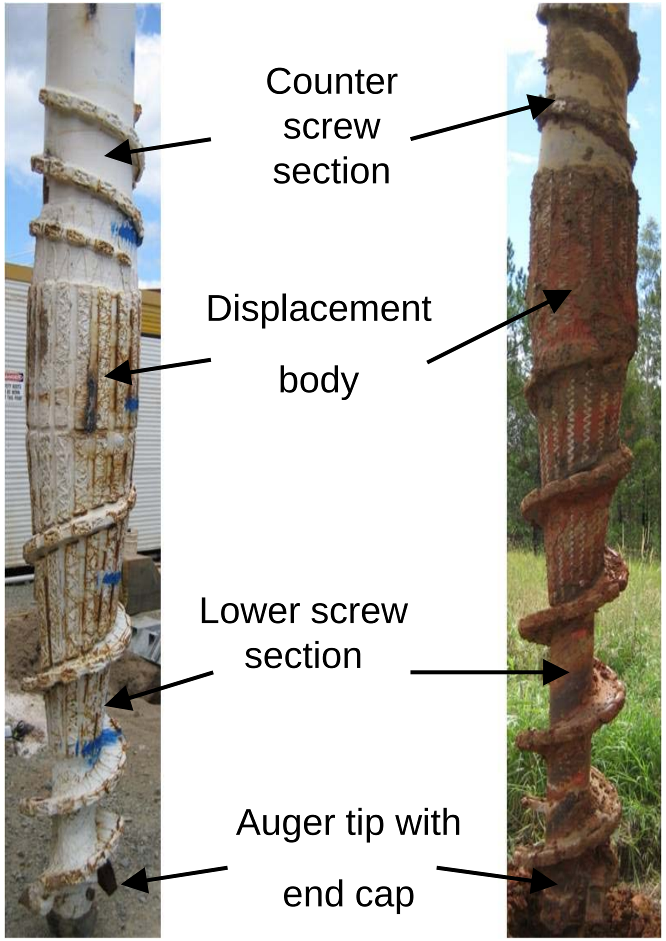
4. INSTALLATION PROCESS

Different full-displacement augers can be used:

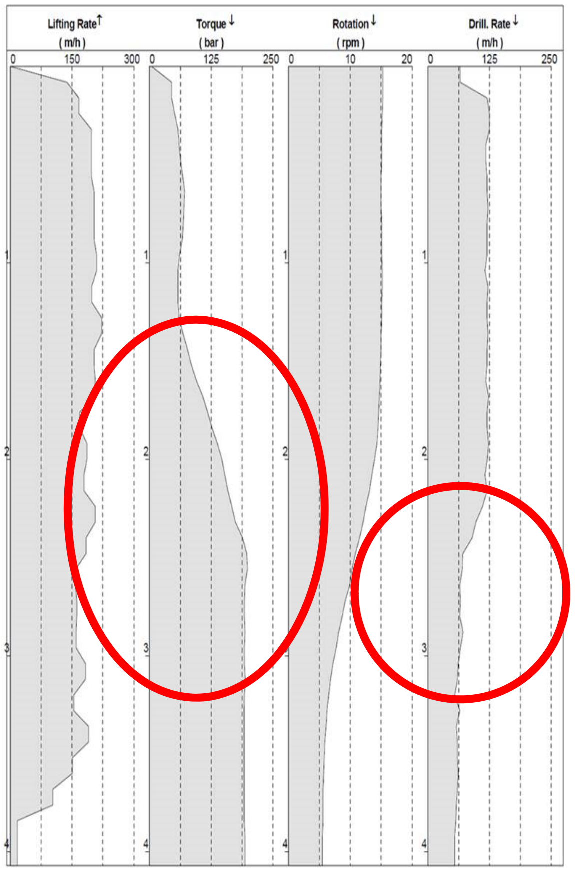
- Progressive Displacement Auger (left)
- Rapid Displacement Auger (right)

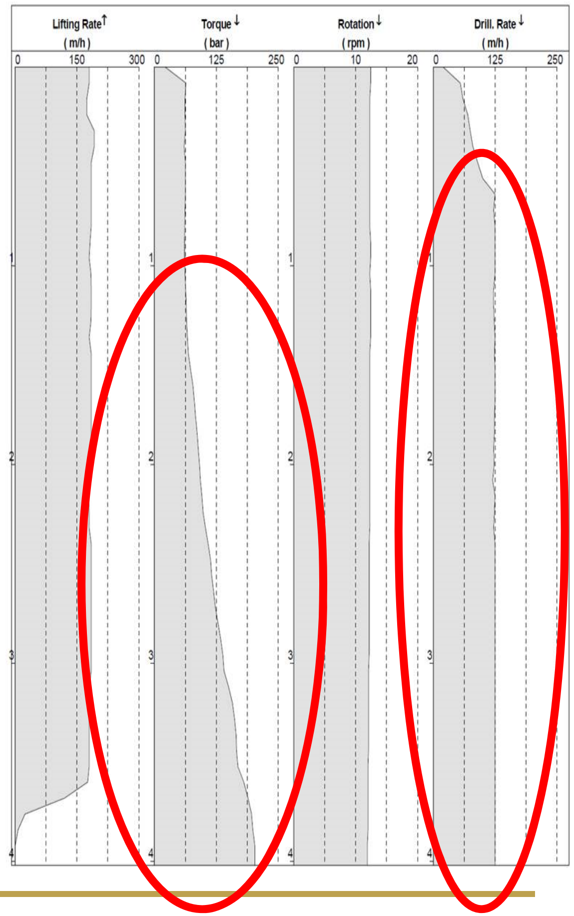


4. INSTALLATION PROCESS - ENERGY INPUT

Installation monitoring records:

- provide information about energy input and potential performance of the DDC or pile
- Insufficient energy input (left)
- Sufficient energy input (right)
- Insufficiently powered rigs can cause underperforming columns or piles





5. WHAT ELSE…

Potential issues:

- Ground heave during installation:
  - Lifting of column heads;
  - Potential cracking of columns; and
  - Lifting of working platform.
- Lateral soil movement during installation:
  - Adopt suitable working sequence.
- Necking:
  - Ensure sufficient concrete over-consumption;
  - Ensure sufficient concrete pressure; and
  - Avoid deep cut-off levels (fresh DDCs/piles).

- Provide adequate working platform;
- Provide suitable load transfer platform; and
- Install monitoring system to verify design.

6. CONCLUSIONS

- The design philosophy between rigid inclusions and piles is different:
  - **Settlement reduction of existing soil, reinforced with rigid elements (DDC);**
  - **Load transfer via stiff elelents to bridge the soft soil layer (PILES).**
- Soil movement will occur during the installation of all soil displacement systems, depending on the soil type, installation sequence, installation parameters, etc.), soil movements can be significant in all directions;
- Soil movement and the resulting effects on structures and adjacent piles/columns are not taken into consideration in current design approaches for both, rigid inclusions (DDC) and displacement piles;
- Soil improvement effects around the pile shaft are taken into consideration for some design methods for displacement piles, which leads to increased load capacities;
- The design of the LTP needs to be carried out carefully;
- Installation monitoring is crucial for both systems to control QA on site; and
- Performance monitoring (load tests and settlement monitoring) is crucial to verify the design parameters.

7. DISCUSSION / Q&A

Thank you

for your attention!