Pile Foundations
Applications with Buildings and Bridges

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PART ONE:

❖ Types of deep foundation
❖ Advantages and disadvantages of each type

PART TWO:

❖ Practical design example: CFA and Drilled Pier for a Building
❖ Practical design example: Root Piles for a Bridge
❖ Practical design example: Drilled Piers for a Bridge
Shallow x Deep Foundation

Pile = Deep Foundation = Foundation with length > 2 x diameter or lowest dimension

WORLD MARKET ON FOUNDATIONS

Caputo (2010)

- 36% Shallow
- 48% Deep
- 10% Soil Imprvt.
- 6% Piled Raft
Deep Foundation

DISPLACEMENT

No removal of soil or rock during installation

Screwed cast-in-place

Preformed

Driven cast-in-place

Concrete

Steel

Timber

Composite

Permanent liner

Temporary liner

H Section

Screw Tube Other sections

Concrete liner Steel liner

Reinforced Prestressed

Non-displacement

Complete removal of soil or rock during installation (includes rotary drilled, percussion excavated and hand excavated piles). The sides of the excavated void are as follows:

Supported

Unsupported sockets

Rock

By liner or shoring

By stabilizing fluid

By soil on a continuous flight auger
Wood
# Steel

<table>
<thead>
<tr>
<th>mm</th>
<th>W 150 x 10.0</th>
<th>W 150 x 12.0</th>
<th>W 150 x 15.0</th>
<th>W 150 x 17.0</th>
<th>W 150 x 20.0</th>
<th>W 200 x 14.0</th>
<th>W 200 x 17.0</th>
<th>W 200 x 20.0</th>
<th>W 200 x 24.0</th>
<th>W 300 x 16.0</th>
<th>W 300 x 19.0</th>
<th>W 300 x 22.0</th>
<th>W 350 x 22.0</th>
<th>W 350 x 25.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>W 150 x 10.0</td>
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<td>W 200 x 24.0</td>
<td>W 300 x 16.0</td>
<td>W 300 x 19.0</td>
<td>W 300 x 22.0</td>
<td>W 350 x 22.0</td>
<td>W 350 x 25.3</td>
</tr>
<tr>
<td>mm</td>
<td>H 310 x 110.0</td>
<td>H 310 x 115.0</td>
<td>H 310 x 120.0</td>
<td>H 310 x 125.0</td>
<td>H 310 x 130.0</td>
<td>H 310 x 135.0</td>
<td>H 310 x 140.0</td>
<td>H 310 x 145.0</td>
<td>H 310 x 150.0</td>
<td>H 310 x 155.0</td>
<td>H 310 x 160.0</td>
<td>H 310 x 165.0</td>
<td>H 310 x 170.0</td>
<td>H 310 x 175.0</td>
</tr>
</tbody>
</table>

**weld**
Precast Driven
Continuous Flight Auger
Omega Pile
Franki Pile
Bored and “Barrette” Type Piles

Major procedures for constructing large diameter bored piles

1. Pre-drilling
2. Drill pile shaft and install temporary casing
3. Construct bell-out
4. Clean pile shaft
5. Install permanent liner and reinforcement cage
6. Clean pile shaft again before concreting
SLH Jet Mud Mixer Photo

SLH Jet mud mixer Technical Parameters
(Customized Jet mixing systems are available)

<table>
<thead>
<tr>
<th>Model</th>
<th>SLH150-50</th>
<th>SLH150-40</th>
<th>SLH150-35</th>
<th>SLH100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matching Pump</td>
<td>SB8=6.13(55kw)</td>
<td>SB8=5.13(45kw)</td>
<td>SB5=4.13(30kw)</td>
<td>SB4=3.11(15KW)</td>
</tr>
<tr>
<td>Capacity</td>
<td>240m³/h(1056GPM)</td>
<td>180m³/h(732GPM)</td>
<td>120m³/h(528GPM)</td>
<td>60m³/h(284GPM)</td>
</tr>
<tr>
<td>Pressure</td>
<td>0.25-0.40Mpa</td>
<td>0.25-0.40Mpa</td>
<td>0.25-0.40Mpa</td>
<td>0.25-0.40Mpa</td>
</tr>
<tr>
<td>Inlet</td>
<td>150mm</td>
<td>150mm</td>
<td>150mm</td>
<td>100mm</td>
</tr>
<tr>
<td>Nozzle caliber</td>
<td>50mm</td>
<td>45mm</td>
<td>35mm</td>
<td>30mm</td>
</tr>
<tr>
<td>Hopper dimension</td>
<td>750×750mm</td>
<td>750×750mm</td>
<td>600×600mm</td>
<td>500×500mm</td>
</tr>
<tr>
<td>Burden speed</td>
<td>≤100kg/min</td>
<td>≤80kg/min</td>
<td>≤60kg/min</td>
<td>≤40kg/min</td>
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<tr>
<td>Density</td>
<td>≤2.8g/cm³</td>
<td>≤2.4g/cm³</td>
<td>≤2.0g/cm³</td>
<td>≤1.5g/cm³</td>
</tr>
<tr>
<td>Viscosity</td>
<td>≤120s</td>
<td>≤120s</td>
<td>≤80s</td>
<td>≤50s</td>
</tr>
</tbody>
</table>

Jet mud mixing system

- Bentonite Mud or Polimer Fluid
Injected Pile ("pali radice" Type)
Injected Pile (micropile Type)
Drilled Caissons

- Replace multiple pile clusters with caissons and eliminate caps
- Bells spread the load at higher elevations minimizing time and materials
- Drilled and belled piers in lieu of spread footers for greater economy

PIER FOUNDATION DETAILS
FOR REPAIR ONLY TO DAMAGED FOUNDATION WHERE SPECIFICALLY DAMAGED

Porous Cap & Footing at the Same Time

BELLED BOTTOM FOR SUPPORT, WHERE REQUIRED, PREVENTS UPHEAVAL

Internet Pictures
Special Large Scale Types

Soil Excavated with recovered casing (dia ≤ 3)
Weathered Rock

Ultimate resistance ($q_u < 30 \text{ MPa}$) excavated with special bit
Fresh rock
(dia ≤ 2.5 m)
excavated with
special bit
General Requirements for Foundation Projects

1. Knowledge of the general topography of the site as it affects foundation design and construction, e.g., surface configuration, adjacent property, the presence of watercourses, ponds, hedges, trees, rock outcrops, and the available access for construction vehicles and materials

2. The location of buried utilities such as electric power and telephone cables, water mains, and sewers

3. The general geology of the area with particular reference to the main geologic formations underlying the site and the possibility of subsidence from mineral extraction or other causes

4. The previous history and use of the site including information on any defects or failures of existing or former buildings attributable to foundation conditions

5. Any special features such as the possibility of earthquakes or climate factors such as flooding, seasonal swelling and shrinkage, permafrost, or soil erosion

6. The availability and quality of local construction materials such as concrete aggregates, building and road stone, and water for construction purposes

7. For maritime or river structures, information on tidal ranges and river levels, velocity of tidal and river currents, and other hydrographic and meteorological data

8. A detailed record of the soil and rock strata and groundwater conditions within the zones affected by foundation bearing pressures and construction operations, or of any deeper strata affecting the site conditions in any way

9. Results of laboratory tests on soil and rock samples appropriate to the particular foundation design or construction problems

10. Results of chemical analyses on soil or groundwater to determine possible deleterious effects of foundation structures

(Tomlinson, 1986)
Typical CFA Pile Design
Typical Drilled Pier Design for a Building
Details
Design Project: Root Piles for a Bridge

Rio das Rãs Project
Typical Sounding: Soil and Rock

Classificação das Camadas

<table>
<thead>
<tr>
<th>No de Golpes</th>
<th>Percentagem de R.D.O. (%)</th>
<th>Resistência à penetração</th>
<th>N.A (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sítio arenoso compacto a muito compacto com vermelho</td>
<td>30</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Sítio arenoso muito compacto com círculos com fragmentos de rocha alterada (granito)</td>
<td>30</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Granito médium alterado, extremamente frustrado, muito consistente. Rdp - 0%</td>
<td>30</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Granito são, pouco frustrado, muito consistente. Rdp - 93,76% - Ângulo das fracturas - 60° e 90°.</td>
<td>30</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Granito pouco alterado, extremamente frustrado, muito consistente. Rdp - 0%</td>
<td>30</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Granito são, pouco frustrado, muito consistente. Rdp - 88.66% - Ângulo das fracturas - 0°.</td>
<td>30</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>
**Design Approach**

**LEGENDAS E REGRAS**

MÉTODO - SCHIETEL

\[ F_{x}, y, z : \text{Forças Externas Axiais segundo os eixos X, Y e Z,} \]

\[ M_{x}, y, z : \text{Momentos Externos segundo os eixos X, Y e Z,} \]

\[ \alpha : \text{Ângulo que a estaca faz com o eixo Z,} \]

\[ \gamma : \text{Ângulo que o semi-eixo positivo do eixo X faz com o eixo da projeção de estaca.} \]

Adotar a regra da mão direita (polegar rolando) para os momentos externos.

A origem do sistema de referência deve coincidir com a projeção no plano XY, do centro de cacha do estaque.

**NOTA:** Para este caso, ao todo, utilizar ESTAQV de autor.

**ESFORÇOS AXIAIS NAS ESTACAS**

<table>
<thead>
<tr>
<th>EST.</th>
<th>Nf (kaf)</th>
<th>Nf (KN)</th>
<th>ESFORÇO</th>
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<tbody>
<tr>
<td>1</td>
<td>47.698.11</td>
<td>476.98</td>
<td>Compressão</td>
</tr>
<tr>
<td>2</td>
<td>115.450.05</td>
<td>1.154.50</td>
<td>Compressão</td>
</tr>
<tr>
<td>3</td>
<td>48.161.92</td>
<td>481.02</td>
<td>Compressão</td>
</tr>
<tr>
<td>4</td>
<td>50.561.29</td>
<td>505.61</td>
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<tr>
<td>5</td>
<td>52.143.14</td>
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</tr>
<tr>
<td>6</td>
<td>50.896.16</td>
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</tr>
<tr>
<td>7</td>
<td>-427.37</td>
<td>-427</td>
<td>Tração</td>
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<tr>
<td>8</td>
<td>103.862.62</td>
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<td>Compressão</td>
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<tr>
<td>9</td>
<td>2.441.69</td>
<td>2.441</td>
<td>Compressão</td>
</tr>
<tr>
<td>10</td>
<td>106.761.68</td>
<td>1.067.62</td>
<td>Compressão</td>
</tr>
<tr>
<td>11</td>
<td>59.189.21</td>
<td>591.89</td>
<td>Compressão</td>
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<tr>
<td>12</td>
<td>57.942.23</td>
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<td>13</td>
<td>59.524.90</td>
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<td>14</td>
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<tr>
<td>15</td>
<td>-9.115.75</td>
<td>-91.16</td>
<td>Tração</td>
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<tr>
<td>16</td>
<td>62.387.26</td>
<td>623.87</td>
<td>Compressão</td>
</tr>
</tbody>
</table>

Soma Nf Cos\(\alpha\)

\[ 858.560.00 \quad 8585.60 \]
Transversal Details
Steel Reinforcement of Top Cap of the Foundation Group
Design Project: Drilled Pier for a Bridge

Km 803/968 Figueiropólis–Ilhéus Project
## Typical Sounding: Soil and Rock

### Soil and Rock Sounds Description

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Soil Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 2</td>
<td>Silty sand</td>
<td>Water-saturated, loose, with occasional gravel.</td>
</tr>
<tr>
<td>2 - 3</td>
<td>Sand</td>
<td>Medium dense, slightly cemented.</td>
</tr>
<tr>
<td>3 - 4</td>
<td>Gravel</td>
<td>Well-graded, moderate to well-cemented.</td>
</tr>
<tr>
<td>4 - 5</td>
<td>Sandstone</td>
<td>Medium dense, containing some silt and clay.</td>
</tr>
</tbody>
</table>

### Laboratory Analysis

- **Porosity:** 20%
- **Density:** 2200 kg/m³
- **Permeability:** 0.01 cm/s

### Corresponding Image

![Sounding Core Samples](image-url)
Longitudinal Section
Design Approach
Executive Design Blueprint
Details of Shaft and Base
Steel Reinforcement of Top Cap of the Foundation Group
REFERENCES

- Executive Foundation Projects: Dinamiza Ltd., Brasília-DF