General Aspects and Examples of Soil Nailing in Brazil

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LAYOUT

- History and Aspects of Soil Nailing
- Execution Details of Soil Nailing
- Design Example and Videos
Concept

Excavation

Nail Execution

Surface Protection
Sprayed Concrete

Overall Stability

DHD

Nails

Face Resistance to Water Percolation

DHD
Basics of Design

• Reinforcement of soil with thin elements: *nails*
• Pre-bored sub horizontal hole, with grout
• Originated from shotcrete flexible support in tunnels
• Active zone is formed around excavation
• Started in Brazil in 1970 and France 1972 (*sol cloué*)
• PASSIVE anchors = “nails”
- **DAVIS METHOD**  
  (Shen et al. 1981)

- **GERMAN METHOD**  
  (Stocker et al. 1979)

- **FRENCH METHOD**  
  (Clouterre, 1991)

Several Modes of Failure

- Overall Stability (Slice) method and others.
History

1972: France

Railway Slope in Versailles done by Bouygues & Soletanche company.

1972: Brazil

“Pali Radice” foundation technology of soil reinforcement done by Brasfond, Rodio, Soletanche companies in the Imigrantes Highway
1975, 1981-1986: Germany

Sock, Gudehus and Gassler (1975) launched a 4 years research program to study 8 large scale models of Soil Nailing. In 1981 the study is published with the performance till failure. Deformation values at top of around 0.3% of height.

In 1986 Bauer Company announces the Soil Nailing Technique in its folder.
1976: USA

In 1976 the subsoil retaining structure of the Samaritan Hospital, in Portland, USA was designed by the company Kulchin and Associateds. Vertical slope height of 10/13 m with deformations at crest of around 0.3%h.

In 1981 this design performance is published by Shen et al.

In 1979, at the Davis Campus of the University of California, a large scale research wall of h=9m is executed and monitored (def. of around 0.14/0.17%h)
1984: Brazil (Niterói-RJ)

In 1984 a 17m height soil nailing structure is constructed on the top of a 35m vertical extension cut (lower part designed with a conventional tie back anchored wall)

Soter/Soumayer/Placon/
Tamoio Companies – Icaraí Beach
1987: France ("Clouterre" National Project)

France was the first country to heavily invest in the development of the soil nailing technology, with the creation in 1987 of the "Clouterre National Project".

It had the participation of private companies, governmental institutions, universities and laboratories.
Classic Publications

1991: France

1996: Brazil
1998: Brazil

**Manual de Especificações de Produtos e Procedimentos ABEF**

**Engenharia de Fundações e Geotecnia**

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**Concreto Projetado**

1. Objetivo
2. Redação
   - Normas
   - Documentos complementares
3. Definições
4. Equipamentos, armazenagem e ferramentas
5. Equipamento, materiais e condutibilidade
6. Equipamentos de segurança do trabalho, EPI e instruções
7. Equipamento de controle e verificação de serviços
8. Equipamento de segurança do trabalho, EPI e instruções
9. Materiais necessários à execução, atendimentos e responsabilidade
   - Material primário e especificação
   - Armazenamento e conservação

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**Chumbadores**

1. Objetivo
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**3. Definições**

Para os fins deste documento, aplicam-se as seguintes definições:

3.1 **Chumbadores**

3.1.1 **Chumbadores cravados**

3.1.2 **Chumbadores moldados “in loco”**

3.2 **Armadura**

3.3 **Bomba de perfuração**

3.4 **Bomba injetora**

3.5 **Fluido estabilizante**

3.6 **Fluido de perfuração**

3.7 **Injeção**

3.8 **Misturador e agitador**

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**Figura 1: Partes constitutivas de um chumbador**

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*Notas e condições:* O documento está disponível em: [www.geotecnia.unb.br/gpfees](http://www.geotecnia.unb.br/gpfees)
Advantages

Economy:
• Cost effective technique, as low as 50% of a tieback wall

Rate of Construction:
• Fast rate specially with SFRS shotcrete (sprayed concrete)

Deformation:
• 0.1 – 0.3% of height at top of wall for well designed structures

Flexibility:
• Deformation can be controlled with combined use of anchors

Reliability:
• Already proved in residual and saprolitic soils in Brazil
• Increases stability in unsupported slopes with weak surfaces
Expansion in Brazil

(Example of Solotrat Ltd. - São Paulo Headquarter)
Nail Installation

- After driving or drilling
- Short nails (3 m) by hand hammers
- Corrosion protection aspects
- Driving is not adequate with boulders
- Common drilling with 50-100mm Φ’s
- 20-32 mm steel bars
- > 100 kPa lateral friction
- Pneumatic drill rigs are used
- Light drill rigs are desired
Passive Anchor or Nail

(Injection Tubes & Centralizers)
Injection Phases

1st Phase
- Hole Excavation
- Water/Cement
- Steel Bar

2nd Phase
- Soil Hyd. Rupture and Injection
- Pressure Graph

3rd Phase
- Manchette Valve Opens

1st FASE
2nd FASE
3rd FASE

Graph:
30
20
10

1st 2nd 3rd Fases
Water-Cement Preparation
1. Injection of 1st to 3rd Phases after fulfillment of excavation hole;
2. Water-Cement ratio of 0.5 to 0.7;
3. 1 to 2 cement bags, or 40 to 100 liters of water cement mixture is prepared in a high speed mixer of around 1750 rpm;
4. 1st injection phase commences - 10 liters of mixture per meter;
5. Pressure for injection is measured;
6. If pressures are within 5 to 15 kg/cm² this phase is finished. After 8 hs 2nd injection phases starts. Likewise, 3rd Phase;
7. Around 1.5 to 2.5 cement bags per meter @ final.
Details for Injection

![Image of injection details](image1)

![Diagram of injection process](image2)

![Image of injection setup](image3)
Details:
• Injection

Steel CA50 dia. 20mm bar Coated with Epoxy resin

Drill hole dia. 100 mm

Spacers each 1.5 m

Polythilen plastic tube dia. 14 mm
Effect of Injection Phases

**Fig. 24.** Pullout tests results

**Fig. 25.** Effect of pressure grouting

**Fig. 26.** Relative effect of one-phase pressure grouting
Grout Filling + 1st Phase

GF + 1st 2nd Phases

Modified after Souza et al. (2005)

<table>
<thead>
<tr>
<th>Nail</th>
<th>Injection Type</th>
<th>Pull Out Tests</th>
<th>Average (kN/m)</th>
<th>Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n.º 7</td>
<td>Grout Filling</td>
<td>50,1 / 8,4</td>
<td>7,3</td>
<td>100</td>
</tr>
<tr>
<td>n.º 8</td>
<td>Grout Filling</td>
<td>37,6 / 6,3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n.º 12</td>
<td>GF + 1st Phase</td>
<td>100,0 / 16,7</td>
<td>13,0</td>
<td>178</td>
</tr>
<tr>
<td>n.º 10</td>
<td>GF + 1st Phase</td>
<td>56,4 / 9,4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n.º 9</td>
<td>GF + 1st/2nd Phases</td>
<td>62,7 / 10,5</td>
<td>11,5</td>
<td>157</td>
</tr>
<tr>
<td>n.º 11</td>
<td>GF + 1st/2nd Phases</td>
<td>75,2 / 12,5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Increase in pullout resistance
Analysis of the Injection Values and Characteristics
Analysis of the Injection Values and Characteristics

Iso-volume curves
Iso-volume curves
Analysis of the Injection Values and Characteristics

Iso-Pressure Curves
1st. Injection Phase
Analysis of the Injection Values and Characteristics

Iso-Pressure Curves
2\textsuperscript{nd}. or 3\textsuperscript{rd}. Injection Phases
Exhumed Nail

Initial Injection
(6 to 8 l/m³)

1st. to 3rd. Injection Phases (10 to 20 l/m³)

Air Bubble

Injection Tubes

Steel Bar
Construction Details

Nail Head:
• With or without steel plate and wrenches
• Small torque of 5 kN is incorporated as residual load
• Inclinations of 10-20 degrees
• Embeddement in a cast-in-place concrete niche
• Grounting with or without (gravity head) pressures
Fig. 8. Nail head details for inclined slopes (a) bending; (b) embedded in concrete plate

Fig. 9. Nail heads in niches, Hong Kong
Details:

- **Nail**

Steel reinforcement dia. 6.3mm each 10cm
60cm wide band

2x welded mesh Q138 4.3mm thread each 10cm

100 mm drill hole

Soil

Manchette valves spaced each 1 m

Water-cement grout

Spacers each 1.5 m

Steel plate, screw and accessories

100x100x10mm

Vertical wall 150 mm thickness or inclined 100 mm minimum cover of 30 mm

Poliethilen plastic tube dia. 14 mm

Manchette valve at 0.5m of hole base

Steel 20mm dia. bar coated with epoxy resin
Sprayed Concrete and Concrete Wall

Wall Thickness
Around 7 to 15 cm
Slope Facing:

- Shotcrete is applied through dry or wet mix
- Thickness of 50-150 mm
- One or two steel meshes
- Steel reinforced shotcrete (SFRS) is also used:
  - fibers 30-50 mm length, 0.5 mm dia.
  - dosage 35-60 kg/m$^3$
  - good for slope irregularities
- Vegetation combined with nails
Steel Mesh

Plastic Fiber
Excavation and Execution Process
Internal Drainage

Tubes

Geotextile
Even without water the drainage must be executed.
Deep Horizontal Drainage: DHD

- PVC Rigid Tube \( \phi = 2\frac{1}{4}'' \)
- Wrapped with Geotextile
- Rigid PVC Tube \( \phi = 4'' \)
- Sealing
- \( i = 5^\circ \)
Vertical Joints

- Thickness 1 to 2 cm
- Depth 3 to 6 cm
- Distance 2 to 10 distance between nails
Soil Reinforcement: Vertical Nails
Instrumentation of Wall

Displacement Measurements at each Depth

Steel Plate

Concrete Face

Individual rods at distinct levels covered with plastic tube and grease

\[ \delta = \frac{d}{H} \% \]

Graph showing displacement and level over time.
Executive Design Project
Cindacta Project - Friburgo-RJ

Tie Back Wall

Soil Nailing
VIDEOS
REFERENCES


• Personal pictures.

• Internet pages.

• Executive Design projects from ACRosa Engenharia de Consultoria Ltda., Rio de Janeiro, Brazil

• SOLOTRAT Ltd. Brazil - Flyer, Manual and Presentations