Earthwork and Ground Technology

Site Improvement
Methods of site improvement

• Removal and replacement
• Preloading
• Vertical drains
• In-situ densification
• Grouting
• Stabilization using admixtures
• Reinforcement
Removal and replacement

• One of oldest and simplest methods is simply to remove and replace the soil
• Soils that will have to be replaced include contaminated soils or organic soils
• Method is usually practical only above the groundwater table
Preloading

- Simply place a surcharge fill on top of the soil that requires consolidation
- Once sufficient consolidation has taken place, the fill can be removed and construction takes place
- Surcharge fills are typically 10-25 feet thick and generally produces settlement of 1 to 3 feet.
- Most effective in clay soil
Advantages of preloading

• Requires only conventional earthmoving equipment
• Any grading contractor can perform the work
• Long track record of success
Disadvantages of preloading

- Surcharge fill must extend horizontally at least 10 m beyond the perimeter of the planned construction, which may not be possible at confined sites.
- Transport of large quantities of soil required.
- Surcharge must remain in place for months or years, thus delaying construction.
Vertical Drains

• Vertical drains are installed under a surcharge load to accelerate the drainage of impervious soils and thus speed up consolidation
• These drains provide a shorter path for the water to flow through to get away from the soil
• Time to drain clay layers can be reduced from years to a couple of months
Vertical Drains
PVD (Prefabricated Vertical Drain)

- Geosynthetics used as a substitute to sand columns
- Installed by being pushed or vibrated into the ground
- Most are about 100 mm wide and 5 mm thick
Vertical Drain Installation

Photo from: http://www.joostdevree.nl/bouwkunde/vertical_drain_2.www_imtek_com_tr.jpg
VERTICAL DRAINS

Photo adapted from vertical drain supplier
Without inserting PVD, dissipation of excess pore pressure is a slow process.

With PVD the excess pore pressure dissipates quickly through shorter drainage paths.
Typical installation of PVD

- Typically spaced 3 m on centers

Prefabricated Drains Available in Malaysia

- Nylex
- Emaskiara
- etc
In-situ densification

- Most effective in sands
- Methods used in conventional earthwork are only effective to about 2 m below the surface
- In-situ methods like dynamic deep compaction are for soils deeper than can be compacted from the surface
Dynamic vs. Vibratory

Dynamic (Impact)

Vibratory
Compaction

sand

clay

Photo adapted from Monash Univ. CIV4249
Vibratory probe compaction

- Long probe mounted onto a vibratory pile driver compacts the soil around the probe; penetrations spaced in a grid pattern similar to vertical drains
Vibratory probe compaction
Beware of transmission of ground vibrations
Vibroflotation

- Probe includes the vibrator mechanism and water jets
- Probe is lowered into the ground using a crane
- Vibratory eccentric force induces densification and water jets assist in insertion and extraction
- Vibratory probe compaction is effective if silt content is less than 12-15% and clay is less than 3%
- Probes inserted in grid pattern at a spacing of 1.5 to 3 m
Reclamation works - Singapore

Photo by: Keller Holding
<table>
<thead>
<tr>
<th>Ground Type</th>
<th>Relative Effectiveness</th>
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</thead>
<tbody>
<tr>
<td>Sands</td>
<td>Excellent</td>
</tr>
<tr>
<td>Silty Sands</td>
<td>Marginal to Good</td>
</tr>
<tr>
<td>Silts</td>
<td>Poor</td>
</tr>
<tr>
<td>Clays</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Mine Spoils</td>
<td>Good (if granular)</td>
</tr>
<tr>
<td>Dumped Fill</td>
<td>Depends upon nature of fill</td>
</tr>
<tr>
<td>Garbage</td>
<td>Not Applicable</td>
</tr>
</tbody>
</table>
Vibro-replacement stone columns

• Vibro-Replacement extends the range of soils that can be improved by vibratory techniques to include cohesive soils. Reinforcement of the soil with compacted granular columns or "stone columns" is accomplished by the top-feed method.
Stone Column

Soil treatment for CH 2085 to CH 2200

vertical drains
P.V.D. at 1.2m centres

stone columns
1.0m diameter at 2.5m centres

vertical drains
P.V.D. at 1.2m centres

Photo by: Keller Malaysia
Vibro-replacement stone columns

Top-feed vibroflot rig

Adding stone in top-feed installation

Bottom-feed vibroflot rig
Dynamic compaction

- Uses a special crane to lift 5-30 tons to heights of 40 to 100 feet then drop these weights onto the ground.
- Cost effective method of densifying loose sands and silty soils up to 15 to 30 feet deep.
Grouting

• Defined as the injection of a special liquid or slurry material called grout into the ground for the purpose of improving the soil or rock

• Types of grouts
  – Cementitious grouts
  – Chemical grouts
Grouting methods

Intrusion grouting
- Consists of filling joints or fractures with grout
- Primary benefit is reduction in hydraulic conductivity
- Used to prepare foundation and abutments for dams
- Usually done using cementitious grouts

Permeation grouting
- Injection of thin grouts into the soil
- Once the soil cures, becomes a solid mass
- Done using chemical grouts
- Used for creating groundwater barriers or preparing ground before tunneling
**Construction site installation**

1. Sleeve pipe installation
2. Soil fracturing
3. Multiple grouting

*Graphic source: Keller*
Grouting methods

• Compaction grouting
  – When low-slump compaction grout is injected into granular soils, grout bulbs are formed that displace and densify the surrounding loose soils.
  – Used to repair structures that have excessive settlement
Grouting methods

Jet grouting

- Developed in Japan
- Uses a special pipe with horizontal jets that inject grout into the ground at high pressures
- Jet grouting is an erosion/replacement system that creates an engineered, in situ soil/cement product known as Soilcrete\textsuperscript{sm}. Effective across the widest range of soil types, and capable of being performed around subsurface obstructions and in confined spaces, jet grouting is a versatile and valuable tool for soft soil stabilization, underpinning, excavation support and groundwater control.
Stabilization using admixtures

- Most common admixture is Portland Cement
- When mixed with soil, forms soil-cement which is comparable to a weak concrete
- Other admixtures include lime and asphalt
- Objective is to provide artificial cementation, thus increasing strength and reducing both compressibility and hydraulic conductivity
- Used to reduce expansion potential of clays
- Used in surface mixing applications
A 500 m long embankment had to be constructed on a 4-5 m thick, extremely soft, silty clay layer of the Humber estuary at Hull, Great Britain. To guarantee the stability of the embankment, soil improvement of the silty clay was required. LCM offered a geotechnical solution by means of dry-deep soil mixing.
Reinforcement

• Soil is stronger in compression than in tension
• To improve strength in tension, geosynthetics placed in soil for soil reinforcement
Soil improvement

Photo by A Naser Abdul Ghani
Soil improvement

Photo adapted from Bulletin Ingenieur
Reinforced earthwall construction
The fundamental concept of soil nailing consists of reinforcing the ground by passive inclusions, closely spaced, to create in-situ a coherent gravity structure and thereby to increase the overall shear strength of the in-situ soil and restrain its displacements.