Case histories of ground improvement methods for road or airport construction

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Outline

- To illustrate BRIEFLY three ground improvement methods and their applications using three case histories

- The three methods are
  - Vacuum preloading (+ surcharge) method for soft clay treatment for a road
  - Explosive replacement method for a highway construction
  - Drainage enhanced dynamic compaction method for a runway construction
Vacuum Preloading (+ Fill Surcharge) Method
Principle

80 kPa = 11.6 psi
Vacuum Preloading Procedure

Install a layer of sand blanket and vertical drains
Place horizontal pipes
Install field monitoring instruments
Seal with membranes
Apply vacuum (or/ and surcharge)
Case Study: a road on very soft clay

SECTION I

- Borehole
- Water stand pipe
- Multi-level settlement gauge

SECTION II

- Field Vane
- Inclinometer
- Pore-water pressure transducer

364.5 m

51 m
20 kPa = 2.9 psi
Vacuum load and settlement versus duration
Settlement measured at Section I
Pore water pressure reductions in Section 1
Section I

Pore water pressure variation versus depth profiles

Elevation (m)

Pore water pressure (kPa)

$u_o(h)$

$u_s$
Remarks on Vacuum Preloading Method

- Vacuum preloading is applicable to the improvement of soft clay. It is cheaper and faster compared to fill surcharge.
- It is essential to measure both the settlements and pore water pressures in order to calculate the degree of consolidation and evaluate the performance of soil improvement.
- The effective depth of vacuum preloading is much more than 10 m.
Explosive Replacement Method
Basic Idea

- **Explosive Compaction** has been a method used to compact loose granular soil for many years.
- **Explosive Replacement** is to use explosive to remove a soft clay layer and replace it with crushed stones. It is applicable when the soft soil layer to be improved is relatively shallow and stones are readily available.
Charge

Treated section of the foundation

Crushed stone for filling

Profile before improved

5~6

Soft clay

1:0.8

1

6.8~8.5

4~6

20

Section that has been replaced by crushed stones

Pile of crushed stones

Profile before improvement
Profile before explosion

Profile after explosion

1

3 ~ 5

Soft clay
Installation of charges
Backfill and leveling off
Case Study: A Highway Project

Soil profile along a valley:

- 1.8 meters of gravel
- 0.5 meters of soft clay
- 1.8 meters of weathered sandstone bedrock

Vegetation
Conceptual Design for the Highway
Crushed stones, densely packed

5~6 m

Crushed stone embedded in clay

8~9 m

Silty gravel

9~10.5 m

Sandstone with top 1~2 m heavily weathered
$k_s = 180 \text{ MPa}$
Remarks on Explosive Replacement

- The method is faster than preloading and cheaper than deep cement mixing. It is effective when the soft soil layer to be replaced is less than 10 m.

- It is particularly suitable to road construction in mountainous areas where rocks are available (e.g., as part of tunneling for the same road project).
Drainage Enhanced Dynamic Compaction (DC) Method
Basic Idea

- The dynamic compaction method has often been used for the densification of sand. It normally does not work for clay because excess pore pressures cannot be dissipated quickly.

- The problem may be solved by installing vertical + horizontal drains in soil.
Method

- Vertical drains (~ 1.5 m spacing) with a sand blanket (~ 1.5 m thick) on top can be used to accelerate pore pressure dissipation.
- Compaction energy needs to be applied from low to high: 1st round 900 kNm and subsequent 1600 kNm after 80% pore pressure dissipation.
The soil profile along the runway
$d_t = 2.0 \text{ m}$

$W = 12 \text{ t} = 120 \text{ kN}$

$H = 7.5 \sim 13 \text{ m}$
Excess pore pressure change measured at a section with PVDs.

\[ \Delta u \text{ (kPa)} \]

\[ h=6.3 \text{m} \]
\[ h=3.0 \text{m} \]

~ 1 day for 80% PWP to dissipate
Avoid high-energy compaction

Excess pore pressure change measured during high-energy compaction in a section with PVDs.
Comparison of CPT before and after compaction
Remarks on DC

- The method works for cohesive soil **ONLY** when drains + sand blanket are used.
- The compaction energy applied has to be within a certain limit.
- The method works better for soil with low plasticity (PI <15%).
- The depth of improvement < 6 m.
Thank you!