Geosynthetics in Embankments on Soft Soils

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1. Introduction

The earth reinforcement technique is one of effective solutions in geotechnical engineering.

The applications to retaining walls and slopes have relatively popular on this technique.

This is because only stability or failure is main issue.
However,

Basal reinforcement is rather complicated.

Because,

1) Stability, and the same time,
2) Deformation

Basal Reinforcements (1)

(a) Reinforcement beneath foundation

(b) Reinforcement beneath any kinds of structures
Classification of the method

(1) Improvement of trafficability
   1) Sheet method, 2) Net method, 3) Bamboo method

(2) Basal reinforcement
   1) Plane (geotextiles and geogrids)
   2) 3-D (mattress and geo-cell)

(3) Combined technology with
   1) Piling
   2) Improved soil pile
Embankment on soft soils

The use of geosynthetics or geotextiles to improve deformation and stability of embankment over soft soils is one of the effective solutions in geotechnical engineering. Here, not only stability of embankment but also controlling the ground settlement are expected.

1) To reduce settlement or displacement of soft soils
2) To prevent failure of total embankment and soft soils

3) To prevent sliding failure at the geosynthetics surface
2. Stability analysis

1) For overall stability

\[ F_s = \frac{M_R + \Delta M_R}{M_D} \geq typically 1.2 \sim 1.3 \]

where:
- \( M_D \): driving moment of soil (kN m/m)
- \( M_R \): resisting moment of soil (kN m/m)
- \( \Delta M_R \): reaction moment by geosynthetics (kN m/m)
2) For stability against slip failure

\[
F_s = \frac{P_R}{P_A} \geq \text{typically}1.5
\]

- \(P_A\): active thrust due to embankment on geosynthetics (active earth pressure) (kN/m)
- \(P_R\): friction along the fill-reinforcement interface force (kN/m)

The efficiency of the geosynthetics

Safety factor

by Jewell, 1996
Case history (plane)

Embankment

Silty soil

Geogrids

Case history (3-D)

Embankment

Soft ground
Case history (construction process)

During placing reinforcing materials
During construction at the slope face

Construction of embankment
3. Reinforcement with other methods
Reinforcement with pile

Geotextiles

Pile

Soft soil

Foundation ground

Arching

Membrane effect

Concept of this technique

- Embankment load is shared with geotextiles and pile.
- Reduce of settlement, stability of the ground, and lateral displacement can be expected.
- Not only mechanical stability but also economical advantage are expected.
System of reinforcement with pile

Importance of mechanism of the system

- There are two or more techniques combined.
- Behavior is complicated because of combined nature of the system.
- Stress re-distribution due to combining has to know for the design

We try to evaluate real behavior of the system using X-ray CT!
Behavior of reinforcement with pile using X-ray CT

Test apparatus

Reinforcing materials

Force-stain relationship
Test cases and test method

Test cases
Case 1: without geogrid
Case 2: with Grid-A
Case 3: with Grid-B

CT images

CASE1 (without geogrid)

CASE2 (with Grid-A)

CASE3 (with Grid-B)
Vertical CT images

CASE1

CASE2

CASE3

Arching behavior in 3-D

3-D reconstruction image for the case of without reinforcement from X-ray CT
Summary of the method with piles (one of Japanese practice)

Embankment on soft soils
(reduce of settlement and differential settlement)

Two types of piling (low improved soil pile)

(a) Floating type  (b) End bearing type
Applications of piles

(a) End bearing type

Floating type

Model of load at the ground due to pile

Total volume of this area is the load distribution for the ground in between 4 piles.
Load redistribution

Depth of embankment

Load redistribution for one pile

Calculation of settlement

Settlement of the ground

\[ S_C = S_0 \frac{\Delta P_c}{\Delta P} \]

- \( S_0 \): settlement without reinforcement
- \( \Delta P \): total embankment load
- \( \Delta P_c \): embankment load for the ground

Settlement of pile

\[ S_P = \frac{\Delta P_p}{E} L \]

- \( \Delta P_p \): embankment load for the pile
- \( L \): pile length
- \( E \): Young’s modulus for the pile

Differential settlement: \( \Delta S = S_c - S_p \)
Important notice

1. Spacing of 2 piles
2. Strength of improved soil pile

Check for punching failure in the embankment

Check for the strength in terms of spacing

Case history (with soil cement pile, Japan)
4. Concluding remarks

- Earth reinforcement technique is well established even for basal reinforcement.
- This technique for embankment on soft soils also has been used successfully.
- Arching effect in the soil was clearly investigated in 3-D using X-ray CT.
- The combined technology with reinforcement will become more popular.
- Earth reinforcement will be used to the countermeasure for natural disaster more. (heavily rain, earthquake, tsunami and else)

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Thank you and
Merci beaucoup