Additional reinforced embankment with vertical bearing piles

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ABSTRACT: This paper presents a construction of additional embankment with an interesting reinforced soil filling by geogrid, which uses landslide prevention piles as vertical bearing pile, to the existing road embankment for widening road. The reinforced soil filling was adopted from specific conditions that were confirmed during the construction based on initial design of the widening road. Details of the construction and stability of the additional embankment as well as the background of the adoption of the reinforced soil filling are introduced in this paper.

1 INTRODUCTION

Reinforced soil filling by geogrid has been widely applied to additional embankment for road widening from the viewpoint of economical efficiency, workability and reasonability. In the construction of the filling, however, there are cases that different conditions of the foundation ground or existing embankment from the initial design are become clear during the construction despite of execution of previous investigation, conducting of appropriate alternative plan is important in the cases.

Therefore, this paper presents a case example of design alternatives based on new conditions found during construction. In this example, an interesting reinforced soil filling, which uses landslide prevention piles as vertical bearing pile, was constructed as the alternation of the initial design that plans normal reinforced soil filling on the improved foundation ground. Because the experience of the filling is few, in order to confirm the stability of the filling, three-dimensional FEM based design and observational construction were carried out. Details of the construction and stability of the embankment as well as the initial design and the background of the alternation are introduced.

2 INITIAL DESIGN

Figure 1 shows the summary of the initial design on the road widening construction. According to the previous investigation, the existing embankment is built on Dc/Dg layers, and soil material of the embankment is silty clay including gravels of 20-30 mm. In the initial design, based on the investigation, 1) improvement of the foundation ground for the additional embankment, which is a part of the existing embankment, in order to secure the bearing capacity for the additional embankment and entire slope stability caused by cutting of the existing embankment, 2) cutting of the existing embankment with soil nailing, and 3) normal reinforced filling by geogrid, were planed.

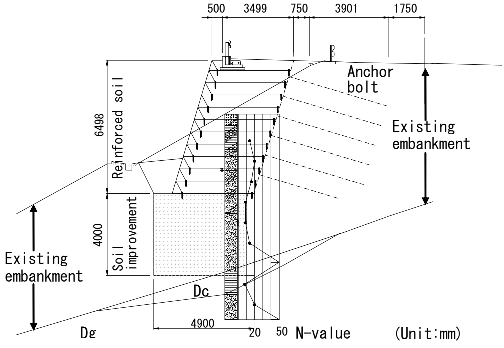

Figure 1. Cross section of original plan

3 ACTUAL SITE CONDITION AND ALTERNATIVE CONSTRUCTION

3.1 *Actual site condition*

The fact, a lot of boulders (diameter is 0.3-1.0m) as shown in Photograph 1 and many parts of soft silty clay (unconfined compressive strength, s_u, is 15kPa) are included in the existing embankment, was become clear during cutting the embankment. From the fact, execution of improvement of the foundation ground including many boulders, which is planed in the initial design, is difficult. Furthermore, because several cracks appeared on the road surface of the embankment, which may be caused by percussion of soil nailing and voids of the embankment accompanied by being boulders, cutting of the embankment with soil nailing was suspended. Consequently, alternative construction was required.

Photograph 1. Boulders in the existing fill

3.2 *Alternative construction*

After the execution of counterweight embankment as the emergency measure, as shown in Figure 2, following alternative construction assumed to use reinforced filling was planned with considering both of safety and economical efficiency.

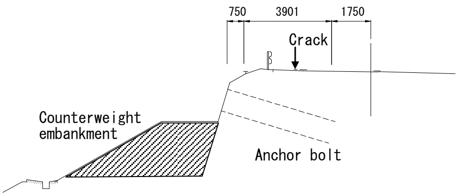

Figure 2. Emergency measure

1) Landslide prevention piles are adopted to secure entire slope stability, if the piles can be applied to the reinforced embankment as vertical bearing piles.
2) Narrow width reinforced filling method is applied to lower part of the additional embankment in order to avoid eliminating of counterweight embankment.

Figure 3 shows the summary of the alternative construction. Adoption of concrete retaining wall or light-weight embankment as an alternative construction was studied deservedly though, from the view point of economical efficiency, the alternatives were rejected.

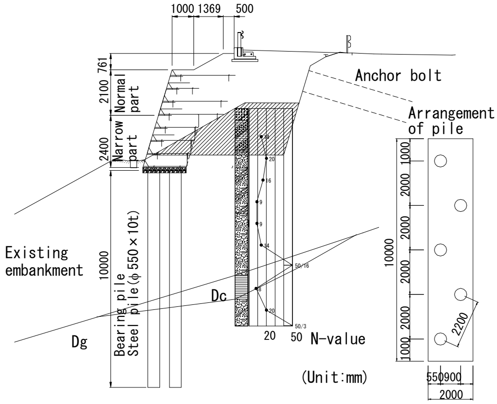

Figure 3. Alternative construction

4 DESIGN OF THE ALTERNATIVE CONSTRUCTION

4.1 *Narrow width reinforced filling method*

Narrow width reinforced embankment can be achieved from piling up of wrapped soil by geogrid as shown in Figure 4. More specifically, apparent shear strength of the wrapped soil can be improved from the confining effect caused by that the geogrid wrapping soil confines the deformation of the internal soil accompanied by the piling pressure of upper filled reinforced soil. Required tensile strength of the geogrid wrapping soil can be given as following equation (Matsuoka *et al*. 2000).

$$T = \frac{\sigma_1 - \sigma_3 K_p}{2\left(K_p/h - 1/B\right)} \tag{1}$$

where, T : tensile force, σ_1, σ_3 : major and minor principle stresses, K_p : coefficient of passive earth pressure and h,B: height and width of wrapped soil.

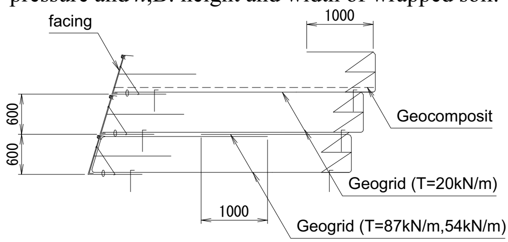

Figure 4. Narrow width reinforced embankment

4.2 *Application of landslide pile to the reinforced embankment as bearing pile*

The tensile forces that act in the geogrid wrapping soil of the lowest reinforced filling layer, which is occurred by using the landslide prevention piles as vertical bearing piles, were predicted by using three-dimensional FEM analysis as shown in Figure 5. Where, wrapped interior soil by geogrid and ground are modeled by solid element, geogrid wrapping soil and piles are modeled by shell element. Table 1 presents the geotechnical and the structural parameters adopted in this analysis. The load on the lowest reinforced filling layer (uniformly-distributed load: 140kPa) is estimated from the subgrade reaction acting on the surface of the layer against the upper additional reinforced embankment.

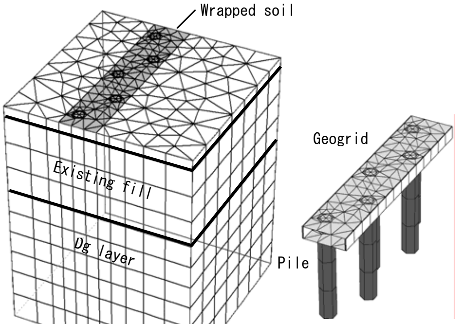

Figure 5. Analysis model

Table 1. Geotechnical and structural parameters

Parameters*	γ (kN/m³)	E (kN/m²)	ν	c (kN/m²)	ϕ (deg.)
Soil	19.0	4.0×10^4	0.3	0.0	30.0
Existing fill	19.0	3.0×10^4	0.3	15.0	10.0
Dg layer	19.0	1.0×10^5	0.3	(elastic body)	
Parameters*		E (kN/m²)	ν	thickness (m)	dia. (m)
Geogrid		transverse 4.8×10^6 longitudinal 1.3×10^6	0.3	5.0×10^{-3}	-
Pile		2.0×10^8	0.3	1.0×10^{-2}	0.55

* γ : unit weight, *E* : Young's modulus, ν : Poisson's ratio, *c* : cohesion, ϕ : internal friction angle

Figure 6 shows the deformation of the lowest reinforced filling layer. According to the result, the maximum relative displacement of the layer between the parts of pile and interspace of piles is 40mm. Figure 7 shows the gradation of the tensile force acting in the wrapping geogrid. According to the result, the maximum tensile forces acting in the geogrid is about 60kN/m and 40kN/m in the transverse and longitudinal directions, respectively. Consequently, the geogrid, which allowable tensile force with considering reduction of the strength due to creep is 87kN/m and 54kN/m in the transverse and longitudinal directions, was designed for the lowest layer.

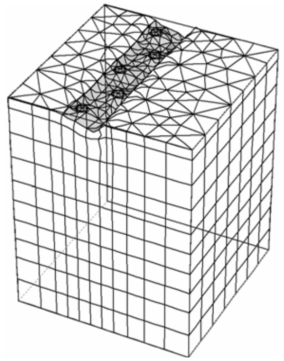

Figure 6. Deformation of the bottom layer

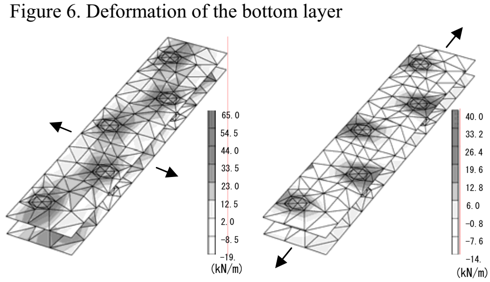

Figure 7. Gradation of tensile force acting in the geogrid

5 OBSERVATIONAL CONSTRUCTION

Observational construction have been carried out in order to confirm both of safety and validity of the design based on the numerical analysis, because there is no experience of the construction adopted in this site so far in Japan.

5.1 *State of the construction*

The construction of the widening road has already completed. The construction states of the completion of the landslide prevention pile installing, setting geogrid, and wrapping soil by geogrid of the lowest layer are shown in Photographs 2 to 4, respectively.

Photograph 2. Install the pile

Photograph 3. Install the geogrid

Photograph 4. Wrap the geogrid

5.2 *Field observation*

In this observational construction, the strain occurring in the wrapping geogrid of closed area to the piles in the lowest layer has been measured, as shown in Figure 8. Figure 9 shows the comparison with analyzed strain occurring in the geogrid and measured ones accompanied with the progress of the construction. According to the results, smaller strain than the analyzed one has been measured and the validation of the design on alternative construction could be confirmed. In addition, the strain occurring in the wrapping geogrid of the middle part of narrow width reinforced embankment has been also measured as shown in Figure 8. Safety of the construction could be also confirmed from the smaller strain occurring in the geogrid than the limit one as shown in Figures 10 and 11.

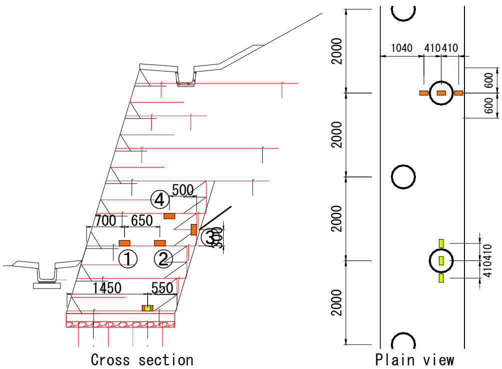

Figure 8. Arrangement of strain gauge

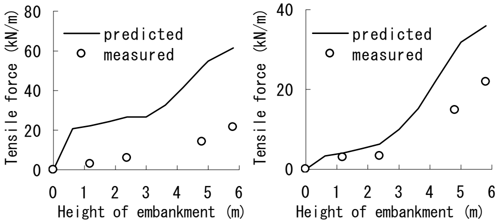

Figure 9. Comparison of predicted and measured tensile forces

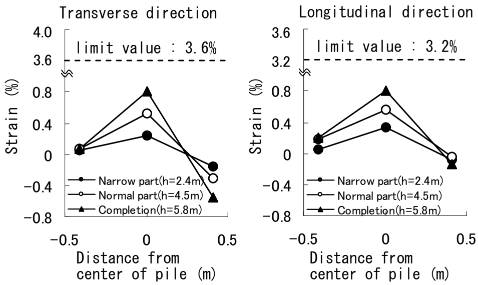

Figure 10. Measured strain of bottom geogrid

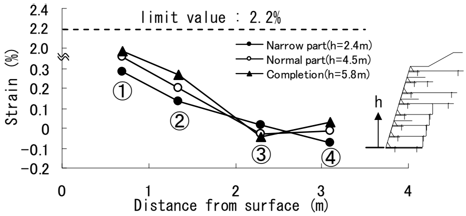

Figure 11. Measured strain of third layer

6 CONCLUSIONS

This paper can be concluded as follows; 1) the background of the application of the reinforced filling by geogrid, which use landslide prevention piles as vertical bearing piles, to additional embankment for road widening was introduced, 2) the specific reinforced embankment was designed by using three-dimensional FEM analysis, and 3) the validity of the design could be confirmed by observational construction.

REFERENCES

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