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Technical report – Embankments

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ABSTRACT: This report summarizes and discusses 23 papers including 5 oral presentations in the session of Embankments at IS Kyushu 2002. Reinforcement embankments have been the author's concern for a long time, and many successful contributions were carried out. However there remain the problems for the understanding on the mechanism of reinforced structures under the various conditions and the constitution of the design methods. Field and laboratory experiments, numerical analyses were conducted to get the solutions for the problems on the reinforced embankments. Some topics were challenged for new applications to embankments. New steps and contributions in the Embankments session were forwarded but still remained problems for the further understanding

1 INTRODUCTION

1.1 *The embankments stabilization as "Earth Reinforcement"*

In design and construction of embankments, it is necessary to confirm surrounding conditions of embankments such as fill material, foundation, external forces and/or inertia forces, seepage, flood force as shown in Figure 1. The lack of the engineering knowledge makes embankments to be damaged by slope failure or excess deformation.

For the safety of embankments, the most suitable countermeasure such as the earth reinforcement should be chosen through engineered judgment in the evaluation of reinforcing mechanism under given requirements and conditions.

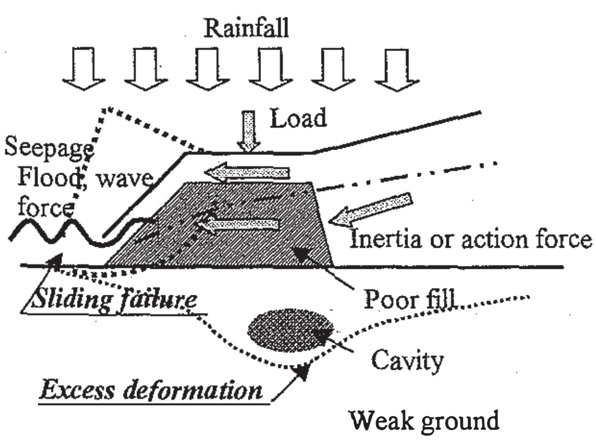

Figure 1. Image of conditions against embankments.

The proposals in the session were the new steps for the purpose of understanding the suitable stabilizing embankments by earth reinforcement.

1.2 *Categorization of submitted papers*

23 papers were submitted for the Embankment Session. The topics were focused as following.

a) Cohesive soil embankment by geosynthetic reinforcements and/or drainage fabrics: 7 papers.
b) Embankments on soft ground or cavities by laying reinforcements and/or pile foundations: 4 papers.
c) Reinforced embankments under seepage and/or flood forced conditions: 2 papers.
d) Lining or soil-cover system interaction combined with reinforcements and geomembranes: 4 papers.
e) Design or modeling for the stabilized embankments by geosynthetic reinforcements: 2 papers.
f) New applications or new understandings as the reinforced embankment by field 1G-prototype models/ practical structure or nG-centrifugal model tests: 4 papers.

Practical applications in the session were highways, railways, waste containments, bridge pier, river dyke and reinforced foundation. Fill materials treated in the papers were granular materials, cohesive soils, residual soils and waste fills. Geosynthetics were used as geogrids, geononwovens, geocomposites, soil bags and fibers in the submitted papers.

Brief introductions according to the above mentioned category are shown in the following chapter.

2 SUMMARY OF SUBMITTED PAPERS

2.1 *Cohesive soil embankment by geosynthetic reinforcements and/or drainage fabrics*

To cope with poor fill materials, countermeasures to increase the shear strength of soils, are applied by chemical mixing, consolidation through drainage, reinforcement and electrokinetics etc. 7 papers were categorized to this topic.

Nagashima, H. et al. conducted comparative study on the sandwich layer effect by series laboratory model tests (1G).

Yasuhara, K. et al. also conducted laboratory model loading tests with comparing laying geocomposites with or without sand-mat.

Kamon, M. et al. have been developed of GHD, Geosynthetic Horizontal Drain method through field tests (H=3m, 6m, 10m). They focused frictional coefficient and durability of geosynthetics from a long time testing.

Chew, S.H. et al. introduced case study on road widening steep slope embankment project by reusing residual soil (H=16m). During monitoring of the construction, high-stability of the embankment was confirmed during heavy rainfall.

Ito et al. confirmed deformation and strength increase of the cohesive soil embankment (H=20m, w=50—70%) through consolidation by use of belt shape geononwovens with hollow pipes.

It is important to constitute design method for the engineering practices. Naughton, P. J. presented design method and design examples for the cohesive soil embankments with high water content with considering dissipation time, settlement and checking transmissivity of combined reinforcement drainage geogrids.

Jones, C. J. F. P. et al. have been developed EKG, electrokinetic geosynthetics as a new application for dewatering cohesive soil by lying horizontally placed. Full-scale field trial (H=4.8m) were carried out with use of poor fill material as c_{u0}=7–10kPa. The mechanism is based on electro-osmotic theory by laying electrodes in 30V.

2.2 *Embankments on soft ground or cavities by laying reinforcements and/or pile foundations*

Countermeasure for embankments on soft ground or cavities are chosen by laying reinforcements on surface of base ground with or without pile foundations as supporting embankment loads. 4 papers were categorized to this topic. This kind of topics can be categorized as "Foundations".

Stolarski, G. et al. introduced road embankment over old waste dump, chemical contaminated and heterogeneous layer of 4-6m thickness by laying geogrids. From field measurement it is confirmed the effect of decreasing the settlement and differential settlement of the embankment and protecting environmental contamination.

Ast, A. et al. introduced overbridging system, geogrids 2 layers sandwiched by cement stabilized base layer, for embankments over cavity by field experiments. Water filled cushions was used for cavity model. Results of monitoring and some aspects of design were presented as a safe and economic engineering structure.

Sa, C. T. et al. assessed the behavior of reinforced piled embankments and reinforced retaining walls on soft soils by numerical parametric simulations (FLAC). Parameters as pile spacing, foundation stiffness, wall height and number and stiffness of reinforcements were varied. The behavior of case histories was supported the analyses.

Alexiew, D. et al. introduced case history of piled railway embankment. Interesting case of projects were concerned on renewal the existing embankment to high speed train embankment by removing top part of embankment, installation cemented stone columns, horizontal geosynthetic reinforcement and new track embankment. It is reasonable for eliminate additional embankment load against soft soils.

2.3 *Reinforced embankments under seepage and/or flood conditions*

To keep the stability of reinforced embankments, it is necessary to consider the effect of seepage and/or flood conditions in case of river dikes, coastal soil structures and so on. 2 papers were categorized to this topic.

Hiro-oka, A. et al. assess the stability of reinforced embankments subjected to seepage flow by a series of 50G centrifugal model tests. Smaller deformation of the model embankment occurred in case of smaller laying space of reinforcements. Stability of the reinforced embankments was confirmed by limit equilibrium method as slip circler considered measured seepage flow in embankments.

Sawada, K. et al. conducted three case of trial construction of reinforced river dike to investigate the real behavior and establish a design and construction method. Height and width of the test dike were 3.0m and 6.0m. Failure modes are estimated as overflowing, piping, sliding or erosion of slopes, soil draw-out from slopes, squeezing and seepage. During the monitoring, trial dikes were immersed with flood by heavy rainfall. Although the soil were draw out from the dikes and deformed, they did not failed in whole. It was confirmed the efficiency of reinforcing effect of river dike.

2.4 *Liner or soil-cover system interaction combined with reinforcements and geomembranes*

4 papers were categorized lining of soil-cover system interaction combined with reinforcements and geomembranes. The distribution of forces within each component of liner system is complex.

Gourc et al. introduced inclined test and the assess stress mobilization of composite liner system on slope. Numerical simulation on the test was carried out to evaluate friction interfaces in liner system.

Krishna P. K. V. S. et al. presented a numerical analysis by the finite difference for the estimation of tension in a geomembrane liner considering lower interface response of the liner with the underlying soil to be hyperbolic. Parametric study and design charts were presented quantifying the effects of stiffness of the interface, height of fill above and the length of liner, lateral stress coefficient, interface strength parameters, etc.

Zornberg, J. G. et al. presented a framework for the design of steep reinforced veneer slopes such as soil covers in landfill facilities. Instead of using geosynthetic reinforcements along the veneer slope, the proposed framework analyzes the use of horizontally placed inclusions within the slopes. Analytical expressions provides as a function of the soil shear strength and veneer configuration.

Nakamura, S. et al. conducted trapped door tests of liner system for evaluation of damage in case of subsidence occurrence in the base of landfill. In the series of test, liner systems were compared and evaluated. Liner systems for tests were composed of geomembrane made from HDPE (High Density Polyethylene) or FPA (Flexible Polypropylene Alloy) under- and overlying the geotextles, and geogrids.

2.5 *Design or modeling for the stabilized embankments by geosynthetic reinforcements*

Experiences and know-how can be obtained from watching performances of reinforced soil structures. However, it is necessary to convert quantitatively as some suitable formulae expressed reinforced mechanism for ease to use. The target of all research activities is to constitute design methods for various reinforced structures evaluated reinforcing mechanism.

2 papers categorized this topic, but above-mentioned papers also included design method as Naughton, P. J. et al, Gourc, J. P. et al. and Krishna, P. K. V. S. et al.

Madhav, M. R. et al. proposed modeling on response of geosynthetic reinforcement to transverse force assuming a simple Winkler type model. Fundamental concept was that the response to the applied force depends not only on the interface shear characteristics of the reinforcement but also on the deformational response of ground. A parametric study quantified the contiributions of length and interface characteristics of the reinforcement, stiffness of the ground, etc. on the over all response.

Shahgholi, M. et al. presented Horizontal Slice Method (HSM) as a new limit equilibrium method. Comparative analyses using HSM and established computer program showed good agreement, and confirmed the advantages of method. By the way, same approach was developed as inclined slice method for nailing (Gutierrez, V. and Tatsuoka, F., 1988).

2.6 *New applications and approach as the embankment reinforcement*

4 papers were submitted on new applications and approach as the embankment reinforcement subjected by various action forces.

Li, G. X. et al. assess performance and stability of fiber reinforced cohesive soil by centrifuge model tests (45—120G) compared with un-reinforced case. By reinforcing fill material, acceleration at failure occurred and critical height and depth of tension zone were increased.

Tatta, N. et al. considered earth flow prevention embankment reinforced with geosynthetics as flexible structure. Horizontal loading were conducted for two types of model (H=1.5m, 6m, vertical facing) assumed as pseudo-static load of earth flow force. Shear resistance of the structure was increased by reinforcements. It was concludes that additional treatment by pre-stressing would improve the structure as an integration body.

Deformation analysis of preload and pre-stressed (PLPS) reinforced soil method for railway bridge pier, constructed in 1996 during construction and in service was introduced by Uchimura, T. et al. To develop a methodology for predicting the time-dependent behavior of such structure, New Isotach Model, three component rheology models, was used to analyze the observed behavior of PLPS pier during preloading procedures.

Kubo, T. et al. successfully constructed an arching structure by using large-sized sandbags that perform restriction effect of geosynthetics as bag material. The purpose was to evaluate its constructability and result of its observation. From the success of construction, the authors concluded the proposed method was able to construct with regarding some deformation of soil bags.

3 FLOOR DISCUSSION

For the leading the floor discussion, following points were presented by discussion leader.

1) Stability during construction and long term durability

2) Estimation of deformation, shear strength of fill, interface response and expected function of geosynthetics
3) Modeling of analysis for stability and deformation
4) Design for ultimate or service state
5) New application
6) Problems for the next steps to fulfill the gap between design assumption and actual performance.

Followings are main discussion points in the floor discussion:

1 To Palmeira, E. M. by Punlop, Kyoto Univ.: What is the permeability *k* value used in the analysis? Because *k* value affect the settlement pattern and lead to the variation of tensile forces in reinforcements. *k* value is very sensitive in my opinion.
2 To Palmeira, E. M. by Huang, C. C. Taiwan: Fig.4 did not show the case when there are no reinforcement layers. How to evaluate the effect of reinforcement in the case?
3 To Palmeira, E. M. by Boussida, Tunis: On negative friction between soft soil and piles in the last example.
4 To Sawada, K. by Yokota, H. Miyazaki Univ.: On the prevention effect of facing treatment by vegetation for trial construction of the reinforced river dike.
5 To Gourc, J. P. by Chai, J. Saga Univ.: On friction angle of soil.
6 To Jones, C. J. F. P. by Loke, Polyfelt Asia: On constitution of trial wall using EKG, (a)What will be the effect to the soil in the event of continuous wetting and drying condition e.g. in high rainfall region? (b)In your construction process, you mentioned that the bottom layer was allowed to dry before the next construction. However construction of the next layer using the wet soil will again saturate the soil layer at the bottom. How do you prevent that?
7 To Li, G. X. China by Gourc, J. P. Univ. Grenoble: Do you carry out application in the field of reinforcement by fibers in China?
8 Comment by Srinivasa Murthy, B. R. India: He introduced failed slope reconstruction, H=100m by using wooden planks and bamboo reinforcement as natural reinforcement techniques.

4 REFERENCES

All the references presented in the text can be found in the first volume of the International Symposium on Earth Reinforcement – IS KYUSHU 2001.

Gutierrez, V. And Tatsuoka, F. 1988, Role of facing in reinforcing cohesionless soil slopes by means of metal strips, Proc Int. Symp. Theory and Practice of Earth Reinforcement, IS KYUSHU '88: 289-294.