Geosynthetics, J. Kuwano & J. Koseki (eds)
 ISBN 90 5966 044 7

A construction case of geotextile-reinforced soil retaining walls at the waste landfill site construction of the open-air theater in Moerenuma Park

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Keywords: retaining wall, geotextile-reinforced soil, rigid facing, waste landfill site

ABSTRACT: Moerenuma Park is a comprehensive park located in the northeast part of Sapporo City. This park is constructed on the waste landfill site. In this paper, the geotextile-reinforced soil retaining walls constructed by the "GRS-RWs having FHR facings" system for a facility in this park is described.
The "GRS-RWs having FHR facings" Geotextile-Reinforced Soil Retaining Walls having Full-Height Rigid-facings) system constructs permanent retaining walls having a near-vertical wall face by reinforcing the backfill soil with a geotextile and by using a full-height rigid facing. The open-air theater was planned in this park. The maximum height of this open-air theater is 15 m.

In the original design, leaning-type retaining walls with pile foundation was planned. However, it was necessary to review this plan because several problems were found in terms of construction expenses and project period. As the result of several investigations, this system was chosen from among construction methods.

1 INTRODUCTION

Moereunuma Park is a general park planned as a core facility of the northern flatland green zone of the "Circular greenbelt plan", which aims to surround the city of Sapporo by parks and green spaces. The park has an area of 189 ha including the Moerenuma Lake, where the inland was once used as a final disposal site. The park, which was constructed on the reclaimed land, was completed in the summer of 2005.

A distinguishing feature of the park is its master plan designed by a late carver Isamu Noguchi, who designed the entire park as a single dynamic sculpture. An overview of the park is shown in Figure 1.

The project described in this paper is the construction of an open-air theater, which is shown in the figure with letter K. The theater was to be constructed by embanking soil to a maximum height of 15 m on the bed of wastes.

Figure 1. Overview of the plan for constructing Moerenuma Park.

2 DECIDING THE USE OF THE "GRS-RWS HAVING FHR FACINGS" SYSTEM

The stratum at the site consisted of wastes (mainly noncombustible wastes and incineration residue) overlain by mixture of gravels, sand and clayey soil (thickness of the stratum: about 15 to 16 m). Use of leaning-type retaining walls with pile foundation was first decided based on the investigations on the bearing capacity and settlement properties of the stratum.

However, the pile foundation was pointed out to be disadvantageous in terms of expenses, work period and workability. In the course of investigating diverse working methods, this system was named as a candidate.

The property values of the waste layer were very uneven and uncertain, and its accurate bearing capacity and settlement properties were difficult to estimate.

In this system, rigid facing is constructed after the foundation ground on which soil was embanked has undergone and finishes settlement. Thus the system can deal with uncertain settlement of the foundation ground, and was also advantageous to the leaning-type retaining wall in terms of expenses and work period. Therefore, this system was decided to be used to construct the open-air theater.

A plan and profile of the open-air theater construction project by the "GRS-RWs having FHR facings" system are shown in Fig. 2 and Fig. 3, respectively.

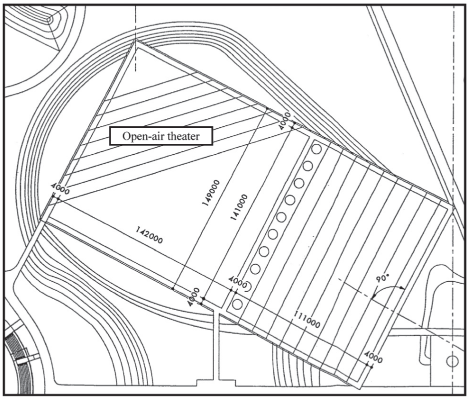


Figure 2. Plan of the open-air theater.

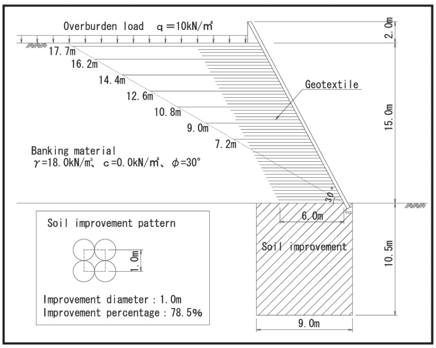


Figure 3. Profile of the open-air theater.

3 "GRS-RWS HAVING FHR FACINGS" SYSTEM

3.1 *Overview of the system*

This system involves construction of bank with almost vertical slopes by densely installing relatively short sheets of Geotexitile and constructing rigid facing of large flexural stiffness.

Characteristics of "GRS-RWs having FHR facings" system are:
(1) Banks can be build in smaller and narrower sites than by the conventional banking methods,
(2) The area for building banks can be reduced from that in the conventional banking methods,
(3) Resultant banks are stable and undergo little deformation since rigid and highly united facing is used, and
(4) Diverse kinds of banking materials can be used since reinforcing sheets are densely installed.

3.2 *Designing method*

Reinforced bank should be designed by investigating:

(1) Inner stability (against overturning and sliding) of the reinforced banking structure,
(2) Rigid facing,
(3) External stability (against circular slip), and
(4) Settlement of the supporting ground.

3.2.1 *Investigation of the inner stability*

Investigation of the inner stability involves calculating the safety factor of the facing at various loading conditions (stationary loads, temporary loads, and during earthquake) against each destruction mode of sliding and overturning using the earth pressure determined using the 2-wedge method as the driving force.

3.2.2 *Investigation on facing*

Facing, which must be stable against earth pressure, should be designed by calculating the sectional force using the earth pressure determined by the inner stability calculation and the load acting on the crest of the facing as the external forces so that the stress on the facing does not exceed the allowable stress.

3.2.3 *Investigation of the outer stability*

Investigation of the outer stability involves calculating the stability of the completed cross section (including the facing) against all sliding surfaces outside the reinforced regions. In principle, the modified Fellenius method is used.

3.2.4 *Investigation on the settlement of the foundation ground*

Stresses acting on reinforcements and facings by the uneven settlement between the facings and bank should be investigated when the "GRS-RWs having FHR facings" system is to be constructed on the ground susceptible to settlement.

3.3 *Reinforcing materials*

Reinforcing materials used were geotextiles of high tension stiffness of at least the design strength at a reduced creep ratio of 60%.

The reinforcing materials had
Design strength: Ta = 38 kN/m, and
Spring modulus: Ks = 200 kN/m.

3.4 *Measures to stabilize and control the settlement of the foundation ground*

Since the original ground did not satisfy the required safety factor for the outer stability, use of the deep mixing method of soil stabilization was investigated in order to attain the required safety factor of Fs = 1.2 (normal time).

The necessary width and depth of improvement to satisfy the required safety factor were calculated for each cross section by assuming the ground to be composite ground, improvement percentage to be $\alpha = 78.5\%$, and cohesive force to be c = 200 kN/m^2.

The settlement of the foundation ground by the weight of the bank was almost impossible to estimate since the foundation ground consisted of wastes, for which property values cannot be measured unlike in the natural bed rock. Thus, the ground was anticipated to subside, but the settlement could not be estimated.

Ordinary retaining walls are constructed simultaneously with banking, and the retaining walls may suffer deformation when the foundation ground subsides after the completion. On the other hand, in the "GRS-RWs having FHR facings" system, facings are constructed after the bank is completed, after its settlement has seized and are little affected by the settlement of the foundation ground.

In this project, the time to place the concrete of facings was to be decided by monitoring the settlement of the completed bank since the settlement of the foundation ground could not be estimated in advance.

4 EXECUTION

4.1 *Execution procedure of the reinforced banking structure work*

The "GRS-RWs having FHR facings" system was executed by:

(1) Executing soil improvement
(2) Constructing the reinforced banking structure
  (1) Installing reinforcing materials
  (2) Installing L-shaped steel frames
  (3) Laying sheets for preventing crushed stones from shedding
  (4) Spreading and roll compacting crushed stones for the drainage layer
  (5) Bending the reinforcement
  (6) Spreading and roll compacting banking materials
  (7) Installing horizontal drains, and Repeating (1) to (7).
(3) Constructing the rigid facing

4.2 *Drains*

Reinforced banking structures are maintained stable by the friction between reinforcement and banking materials in principle. Thus, rises in pore water pressure may destabilize the structure. The main banking materials used in this project were clayey soil, such as screenings. To drain water from the bank, plate-like drains were installed (Photograph 1).

Photograph 1. Installation of horizontal drains.

4.3 *Settlement and Rigid facing*

Settlement of the foundation ground at the point of the maximum height is shown in Figure 4.

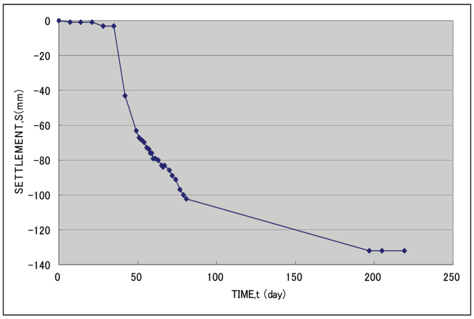
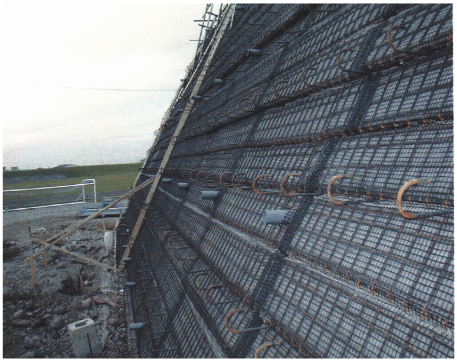


Figure 4. Settlement of the foundation ground at the point of the maximum height.

The settlement is admitted to increase gradually as the fill progresses. And the settlement speed is admitted to decrease after the fill completed. A similar tendency is shown in other points.

Before facing concrete was placed, settlement value of about 132 mm was recorded at the point. Facing concrete should in principle be placed after confirming that the consolidation settlement caused by banking does not adversely affect the structure.

In this project, facing concrete was placed when the monitored settlement was reduced to 1 to 2 mm per week (about 7 months after the completion of the



Photograph 2. View of the reinforced banking structure 1.

Photograph 3. View of the reinforced banking structure 2.

Photograph 4. Panorama of the open-air theater.

bank) and after discussing with supervisors. The settlement of the ground after placing the facing concrete was about 1 to 2 mm.

The stability of the "GRS-RWs having FHR facings" system is ensured by the anchorage between facing and reinforcement behind the facing. Thus, back formwork should be not used for facings.

5 CONCLUSION

This paper described an overview of the "GRS-RWs having FHR facings" system used to construct retaining walls for an open-air theater in a park on a former landfill site. The structure under execution is shown in Photographs 2 and 3, and a panorama of the completed structure is shown in Photograph 4. The use of this system reduced the amount of concrete to be used to construct the retaining wall from that in the initially designed leaning-type retaining wall, and needed no foundation piles. The system was easy to execute, rational, economical, and advantageous in terms of construction expenses and period.

This system has been used for railroad and road banks. It is likely to be increasingly used for other purposes since it is easy to execute and can be flexibly used.

ACKNOWLEDGEMENTS

This project was ordered by the Greening Promotion Division, Environment Bureau, Government of Sapporo City, and was designed by Createc co.,ltd. The authors thank Masaru Tateyama, who is a manager of Railway Technical Research Institute, for supervising and verifying the design of this system. We also thank all people involved.

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