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In situ construction of a geogrid reinforced soil wall combined with soil cement

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ABSTRACT: A new type geogrid-reinforced soil wall (GRW) combined with soil cement was developed in recent years by authors. A number of tests, as material property test, pullout test between geogrid and soil cement, 1G loading test (Ito et al. 2001), centrifuge shaking table test (Saito et al. 2006) and In-situ test, were conducted in order to verify the stability of new GRW. Besides, the method was applied at over 25 construction site in Japan. In this paper, two cases are selected and results of In-situ test and measurement are reported. In Case 1, the new GRW was applied to the road embankment for construction and for maintenance in a Dam construction site. The RSW of case 2 is also for a road embankment. In the site, pullout test was conducted besides measurement of earth pressure and strain of geogrid. Finally, scope of future works based on the obtained results of in-situ tests is suggested.

1 INTRODUCTION

In order to establish the economical and reasonable construction method of the reinforced soil wall, a new type GRW with a fiber-mixed soil-cement wall, was developed by Authurs (Ito et al., 2001). Fig. 1 is a typical cross section of the new GRW. The main features of this method are summarized as follows:

- Soil improved with cement and short fibers is used as a wall structure of GRW. Increased shear strength of the improved soil is taken into account in the design.

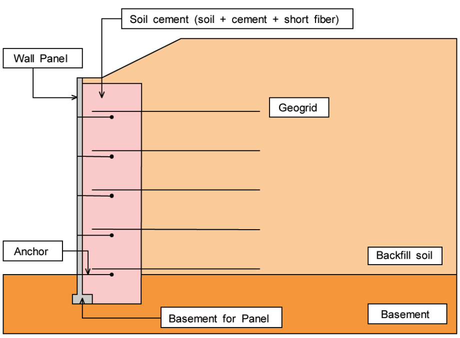

Figure 1. Configuration of the geogrid reinforced soil wall combined with soil cement.

- The amount of geogrid can be reduced because of the use of the improved soil.
- Simple concrete panels can be used as facing of the wall, because the earth pressure on the panels decreases by using the improved soil wall.
- Site waste soil can be utilized as a construction material for soil cement wall.
- Short fibers are mixed with soil cement to improve ductility and erosion resistance of the improved soil.
- The end of geogrid is not connected to a concrete facing panel but fixed in the improved soil.

This new method was applied to 25 construction sites until October 2005. Some tests and in situ measurements were conducted during five years and results of them are reported in this paper.

2 CONSTRUCTION CASE 1 – UNDER WATER

2.1 *Outlines*

A new GRW was applied to a road embankment for construction and for maintenance in the Dam construction site. Since there was water in the wall temporarily, the wall was designed assuming the water level is in the backfill soil. For drainage, nonvwovens with 300 mm width were laid from the panels to the end of geogrids at intervals of 1 m in height and 2 m in breadth. The outline of construction is summarized in Table 1 and cross-section is shown in Fig. 2.

Table 1. Outline of construction Case 1.

Name	Road for dam construction
Period	Jan. 2001–Feb. 2001
Scale	Approach = 28 m Max. height = 5.5 m Wall area = 155 m^2
Backfill soil	Cohesive soil with debris
Geogrid	High density polyethylene (Tensile strength = 21.6 kN/m)
Soil cement	Soil: sandy soil Cement: Portland blast-funace slag cement Amount of mixture: Design = 60 kg/m^3→ In situ = 84 kg/m^3
Measurement	Vertical earth pressure: × 2 Horizonta earth puresure: × 2 Strain of geogrid

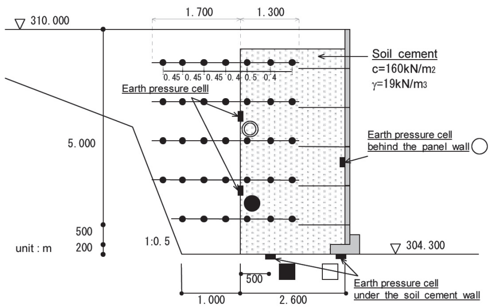

Figure 2. Cross-section of construction Case 1.

2.2 *Results and discussions*

Figures 3 and 4 show behaviors of earth pressure acting on the soil cement wall or wall panels and strain generated in geogrids. The results obtained from these measurements showed that

- Earth pressured hardly acted on the wall panel also in construction and only water pressure acted.
- In general, tensile strains were observed in geogrids. This makes it clear that geogrid played a role as tensile reinforcement. Moreover, strains in geogrids did not change even though water level rose.

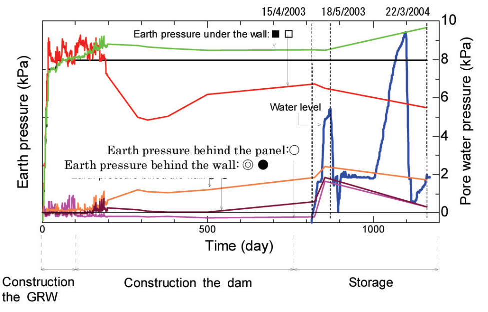

Figure 3. Time histories of earth pressure, height of the wall water level.

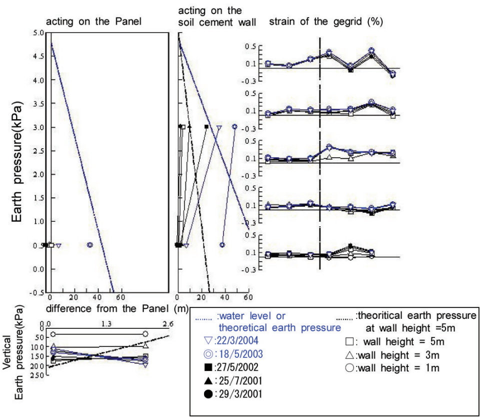

Figure 4. Earth pressure at various location and strain in geogrids.

Photograph 1. GRW under construction (Mar. 2001–Oct. 2002).

Photograph 2. GRW used for construction road.

3 CONSTRUCTION CASE 2 – IN SITU TEST

3.1 *Outline*

Properties of construction are summarized in Table 2 and a typical cross-section is shown in Fig. 2. Photograph 4 shows the wall after construction.

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Photograph 3. GRW under water (18. 5.2003)

Table 2. Outline of construction Case 2.

Name	National highway
Period	Oct. 2002 – Feb. 2003
Scale	Approach = 28 m Max. height = 5.5 m Wall area = 155 m^2
Backfill soil	Sandy soil
Geogrid	High density polyethylene (Tensile strength = 30 kN/m & 36 kN/m)
Soil cement	Soil: sandy soil Cement: Portland cement corresponding to hexavalent chromium Amount of mixture Design = 59 kg/m^3 → In situ = 73 kg/m^3
Measurement	Strain in geogrid
In situ test	Pullout test

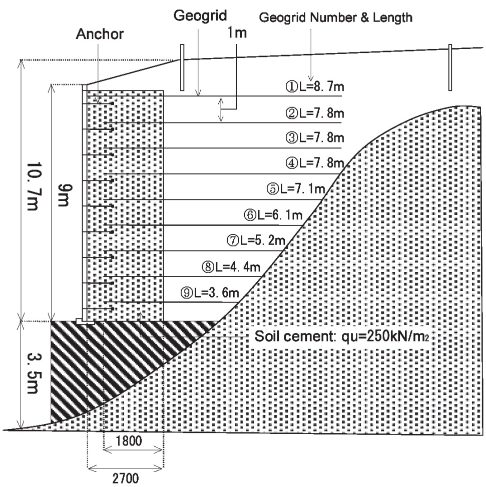

Figure 5. Cross-section of the construction case 2.

3.2 *Measurement of strain in geogrid*

Strains generated in geogrid were measured in order to evaluate the stress condition in the reinforced area quantitatively. Table 3 shows tensile stress calculated from measured strain in geogrid and tensile stress used in the static and seismic design procedure. The result indicated that measured tensile stress acting on the geogrids was rather smaller than that of design value in usual. As stability of soil cement wall itself was very high and the displacement of the backfill soil could be restricted to small range, tensile stress of geogrid was small.

Photograph 4. After construction of GRW.

Table 3. Measured tensile strain & stress.

Geogrid No	Measured value: Tensile stress (kN/m)	Measured value: Tensile Strain (%)	Designed tensile stress: Static	Designed tensile stress: Seismic
①	1.56	0.11	7.38	28.05
②	–	–	7.61	19.09
③	0.63	0.04	10.54	20.40
④	–	–	13.47	21.70
⑤	0.28	0.02	16.41	23.01
⑥	–	–	19.35	24.31
⑦	5.13	0.28	22.29	25.62
⑧	–	–	25.23	26.93
⑨	0.90	0.05	21.13	21.17

3.3 *In situ pullout test*

In situ pullout test was made in ordet to confirm the pullout resistance between geogrid and soil cement. Figure 6 shows the setup of the pullout test and Photograph 6 shows a setup of the test. Length and width of geogrid was 1.8 m and 0.5 m respectively and the edge of geogrid was connected to a clamp, which was connected to heavy equipment used for reaction wall. Pullout tests were conducted at the

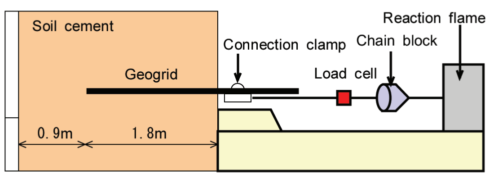

Figure 6. Setup of the pullout test.

pullout speed of 10 mm/min on 3 different vertical pressures, which were changed by changing the height of overburden embankment as shown in Table 4. Pullout displacement was measured by dail gage attached to the connection clamp. Curing time of soil cement was 1 week after making the test samples.

Table 4. Pullout test cases.

Case	Height of overburden embankment	Remarks
Case 1	0.5 m	–
Case 2	0.5 m	Same case with Case 1
Case 3	1.0 m	–

Figure 7 shows the relationships between pullout resistance and pullout displacement. Pullout resistance increased gradually with an increase in pullout displacement and geogrid ruptured when the pullout resistance reached to 40 kN/m. Design tensile strength: T_A and maximum tensile strength: T_{max} of geogrid used in this test was 30 kN/m and 50 kN/m respectively. The maximum tensile stress acting on the geogrid: T_{imax}, which was determined from the design procedure, was 28.05 kN/m. As a result, following relationship could be confirmed. Pullout resistance > T_A > T_{imax}.

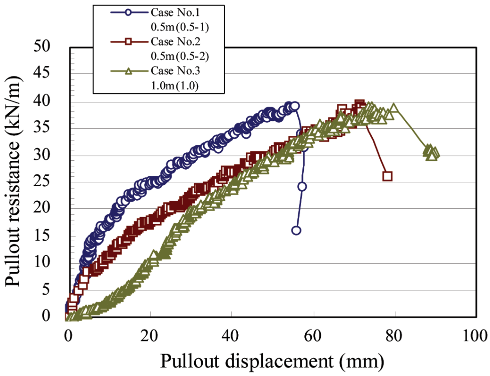

Figure 7. Relationships between pullout resistance and pullout displacement.

4 CONCLUSIONS & COMMENTARY

This paper reports case history of a new type geogrid reinforced soil wall combined with soil cement constructed during last 5 years. In conclusion, I would like to state the following points.

- Earth pressured hardly acted on the wall panels in construction because of the high stablity of soil cement.
- Measured tensile stress in geogrids was rather smaller than that of design value because the displacement of the backfill soil could be restricted to small range.
- Strains in geogrids did not change even though water level in the wall rose.
- It was confirmed that the tensile strengh of geogrid mobilized in situ was larger than design value from pullout test.

For this period, more light and thin wall panel was developed in order to reduce cost. Furthermore, it is to be considered that design concept leaves room for reconsidering the width of soil cement wall or length of geogrid. The stability of the new GRW greatly depends on the quality of soil cement. Therefore, improvement of mixing method and development of quality control method will be needed to propose more reasonable design method.

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