PERFORMANCE OF GEOGRID AND STEEL STRIP REINFORCED SOIL WALLS UNDER SEEPAGE FLOW CONDITIONS

T. FUJITA* & H.MIYATAKE
Public Works Research Institute, Japan (t-fujita@pwri.go.jp), Public Works Research Institute, Japan (miyatake@pwri.go.jp)
A. NAKANE
Public Works Research Center, Japan (nakane@pwrc.or.jp)
Y. MIYATA
National Defense Academy, Japan (miyamiya@nda.ac.jp), Your Institute, Country (eunkown@institute.org)

ABSTRACT: This paper discusses stability of reinforced soil walls. To investigate the stability, seepage flow tests were conducted. Two types of reinforced soil walls were constructed at the Public Works Research Institute test pit. One was the geogrid wall, and the other was steel strip wall. The both models were constructed with sandy soil and they had a divided facing concrete panel system. Length and spacing of reinforcement materials were determined based on the design manual of Public Work Research Center of Japan. Surcharges were applied to top surface of the reinforced soil walls as simulated surcharged embankment. The surcharges were increased step by step such as, 10, 20, 26, 56, and 112kN/m^2. After the end of surcharges, the walls were subjected to seepage flow conditions, it was applied from back of reinforced zone by using water tank prepared in the test pit. In a series of test, facing deformations and strain increments of reinforcement materials were measured.

Keywords: Reinforced soil wall, Seepage flow, Performance

1 INTRODUCTION

Reinforced soil walls (RSWs) generally exhibit higher seismic performance than other conventional retaining structures. This advantage was observed in the 2011 Great East Japan earthquake. **Miyata (2014)** reported that most reinforced soil walls performed well even when the actual seismic conditions were stronger than the design loads. However, some of the RSWs may still be damaged due to the action of water in Japan. Therefore further technical developments must be made to increase the performance of RSWs.

Elias and Swanson (1983) reported that the damaged reinforced soil walls tend to be in large fine and water content of backfills. **Barry R. Christopher et al. (1998)** reported that stability problems occurred by the loss of strength due to wetting within the reinforced fill materials. **Ingold (1981)** reported failure behavior for reinforced soil walls with clay and loaded to failure with a vertical surcharge. Such important previous achievement is limited to the performance of reinforced soil walls with clay.

In the present research, we focused on drainage malfunction due to aged deterioration and its effects on the performance of RSWs by conducting loading tests under seepage flow conditions. This paper briefly reports on the test results, which verify the importance of good compaction of the good fill material in achieving high performance of the RSWs.

2 LOADING TESTS

2.1 *Outline of the models*

Two models of RSWs were prepared under sound condition, one was the geogrid wall, and the other was steel strip wall. The fractures of some reinforcement materials and cavity of embankment were conducted at these models for other research purpose. Loading tests were conducted on the damaged models under seepage flow conditions. The behavior changes were confirmed in loading tests for each two models. The cross sections of the RSWs models are shown in **Figure 1**. The backfill used was sandy soil. The particle size distribution curve is shown in **Figure 2**. The properties of this material are summarized in **Table 2**. Degree of compaction was over 90%.

Reinforcement materials used were HDPE geogrid (T_{ult}=50.0 kN/m) and ribbed strip (T_{ult}= 245N/mm^2). The horizontal and interval length of the reinforcement materials were determined with a condition of cohesion c=0 kPa and internal friction angle ϕ=30 ° based on the design manuals of the Public Works Research Center of Japan (**PWRC, 2000**) .

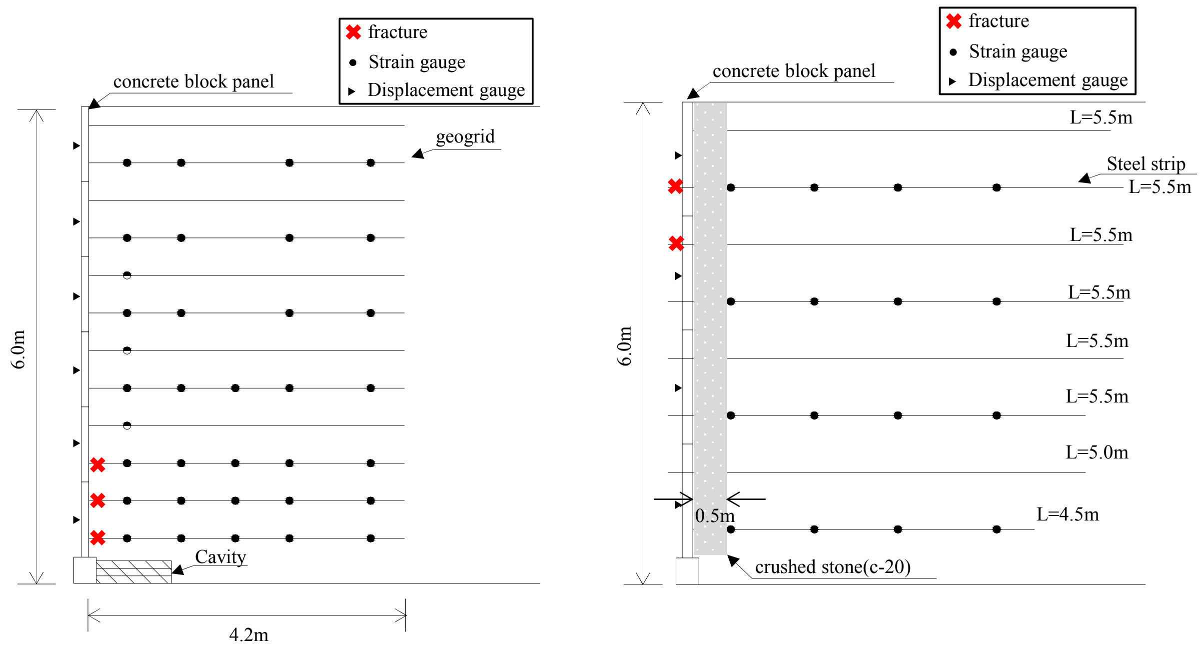


Figure 1 Cross section of models

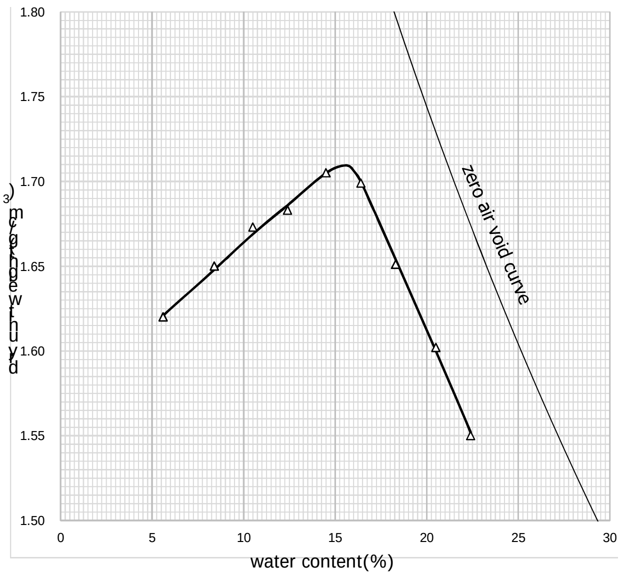


Figure 2 Particle size distribution

Table 1 Physical properties of the backfill

Particle density (g/cm^3)	2.687
Fine content (%)	10.12
Maximum dry density (g/cm^3)	1.734
Optimum water content (%)	15.3

2.2 *Loading conditions*

Surcharges were step-by-step increased on top surface of the reinforced soil walls as simulated surcharged embankment as shown in **Table 2**. Surcharges were loaded by build-up of steel plates and sandbags on embankment. Surcharge was increased in steps of 10, 20, 26, 56, 112 kN/m^2. After each loading, seepage flow was acted. Water level in water supply tank set behind embankment was 4 m for seepage flow acting. Water levels in embankment are briefly shown in **Figure 3**. **Figure 4** shows changes in safety factor for over slippage by the loadings. The safety factors of Step5 are around 1.15 which is below 1.2 predetermined in design on PWRC manuals. The safety factors of Step6 are around 0.9 which is below 1.0

Table 2 Surcharge condition

Step	Condition	Step	Condition
1	SF-1	4	LO-3(26kN/m^2)+SF-4
2	LO-1(10kN/m^2)+SF-2	5	LO-4(56kN/m^2)+SF-5
3	LO-2(20kN/m^2)+SF-3	6	LO-5(112kN/m^2)+SF-6

NOTE: SF=seepage flow; LO=loading(surcharge)

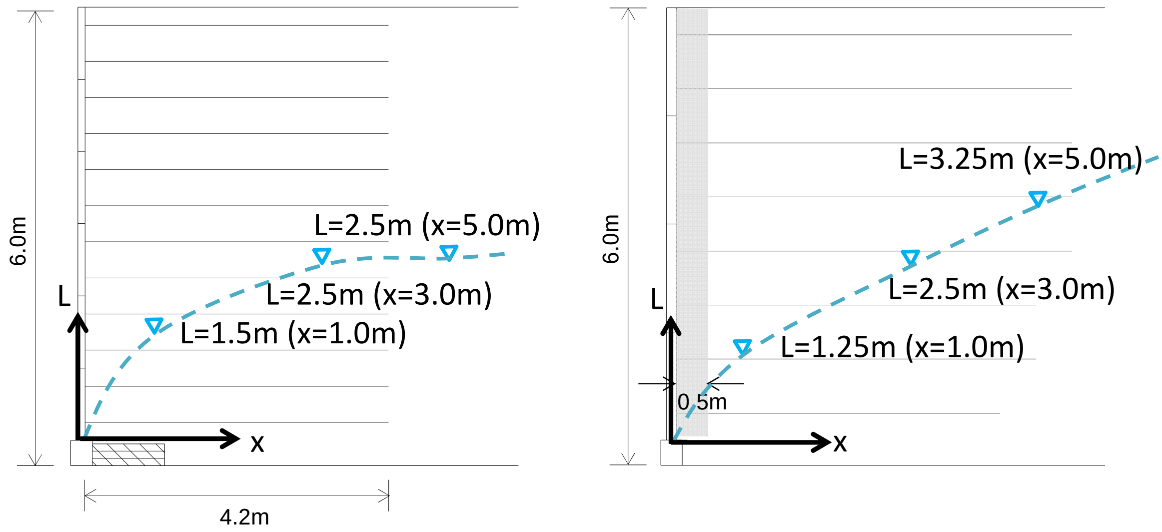


Figure 3 Water level in embankment

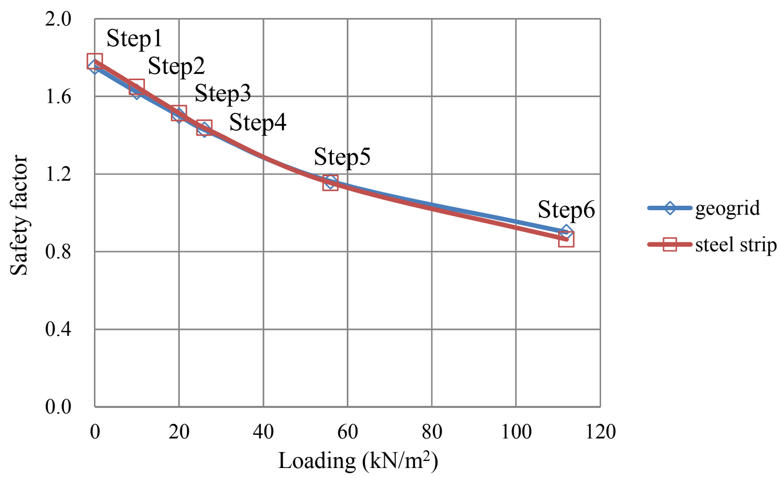


Figure 4 Safety factor

3 TEST RESULTS

3.1 *Horizontal displacement of the facing panels*

Although a total of 5 steps of loading and seepage flow, shown in **Table 1**, were applied to the RSW models, the models did not collapse. Thus, in this paper, we discussed the effect of the loaing and surcharge condition. **Figure 5** shows maximum displacement versus load after each steps for two models. The relations between them tend to be linear. This indicates the importance of recording events and its displacements for each RSW so as to evaluate its performance throughout its design life.

Figure 6 shows the vertical distribution of horizontal displacements of facing panels for geogrid RSW. Left figure shows the displacements after every steps and right figure shows these increment for the every seepage flow. The different deformation modes due to same seepage flow acting can be identified before and after SF-5 as shown in right figure. **Figure 7** shows these for steel strip RSW. Right figure shows same manner as the geogrid RSW was confirmed before and after SF-5. **Figure 8** shows the maximum displacement increment versus safety factor. Displacement increment was notable when the safety factor was below 1.2. This indicates the importance of good design and construction to continue utilizing deformed RSWs with monitoring.

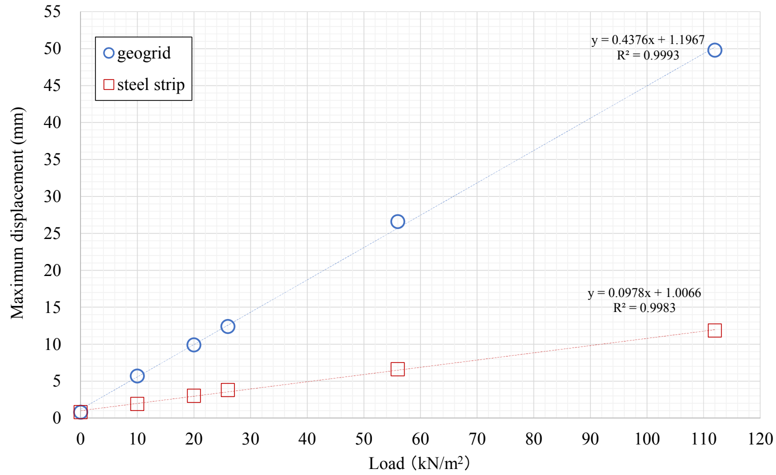


Figure 5 Horizontal displacement for RSWs

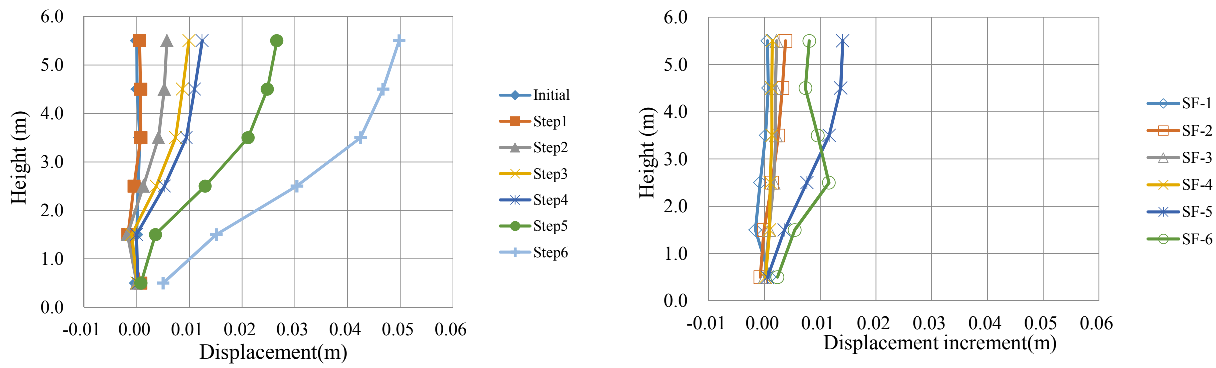


Figure 6 Horizontal displacement for geogrid RSW

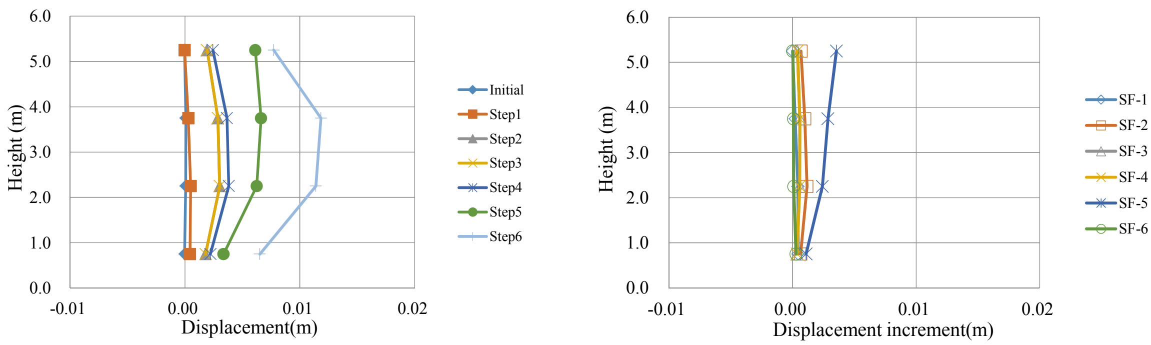


Figure 7 Horizontal displacement for steel strip RSW

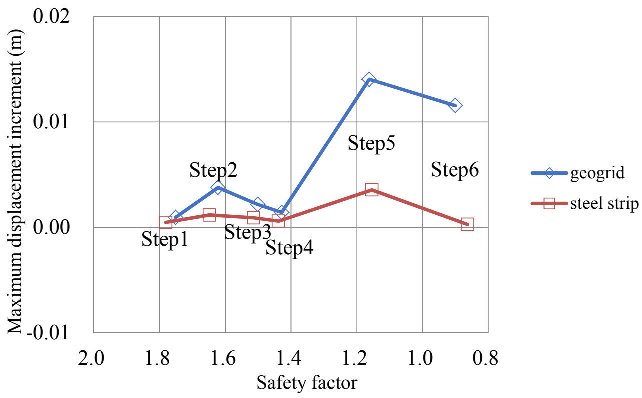
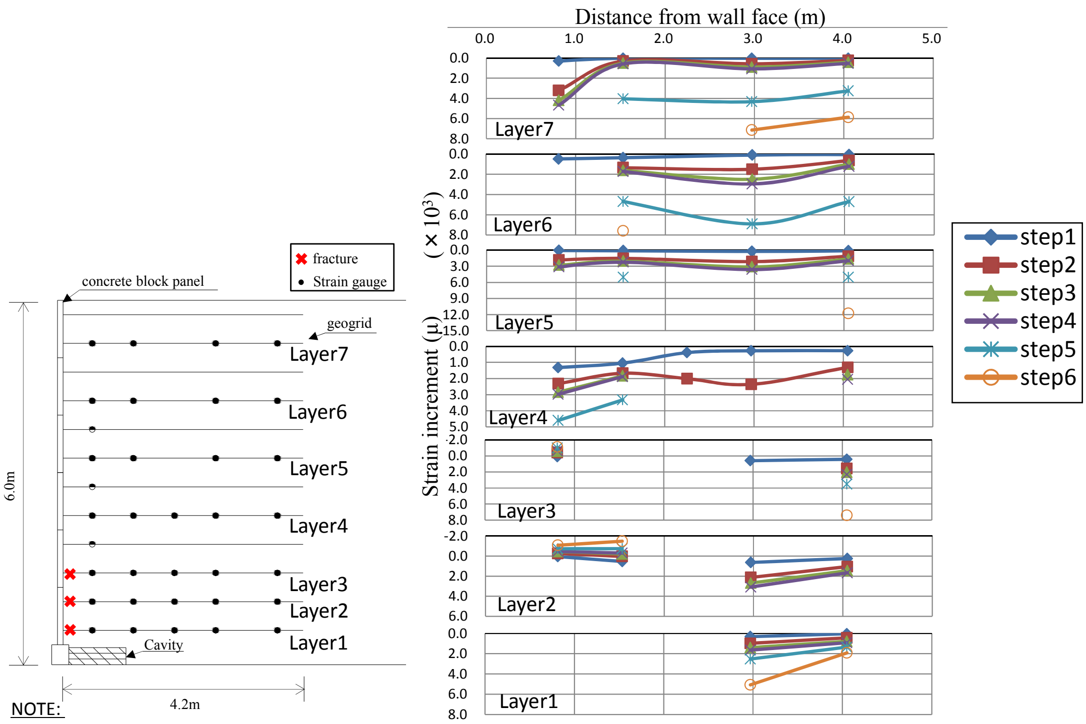


Figure 8 Maximum displacement increment of the panels versus safety factor

3.2 *Strain of the reinforcing materials*

Figure 9 shows the strain increment for geogrid RSW. Tensile strain increase of each layers excepting for fractured reinforcement materials(Layer1～3) was observed. Moreover strain of fractured reinforcement materials also changed. Generally speaking, tensile strain of reinforcement materials contributes to stability of a geogrid RSW. **Figure 10** shows the strain increment for steel strip RSW. Tensile strain increase was roughly confirmed at each layers excepting for Layer1. A few data were observed and the data was unstable for Layer1. Strain gauges at Layer1 were likely to be malfunction.

This indicates the importance of recording events and the strain changes for each RSW so as to evaluate its performance throughout its design life.



NOTE:
・Many missing data exist because of out-of specification or deterioration .
・Strain increment is change from initial value at this loading test.

Figure 9 Strain increment for geogrid RSW

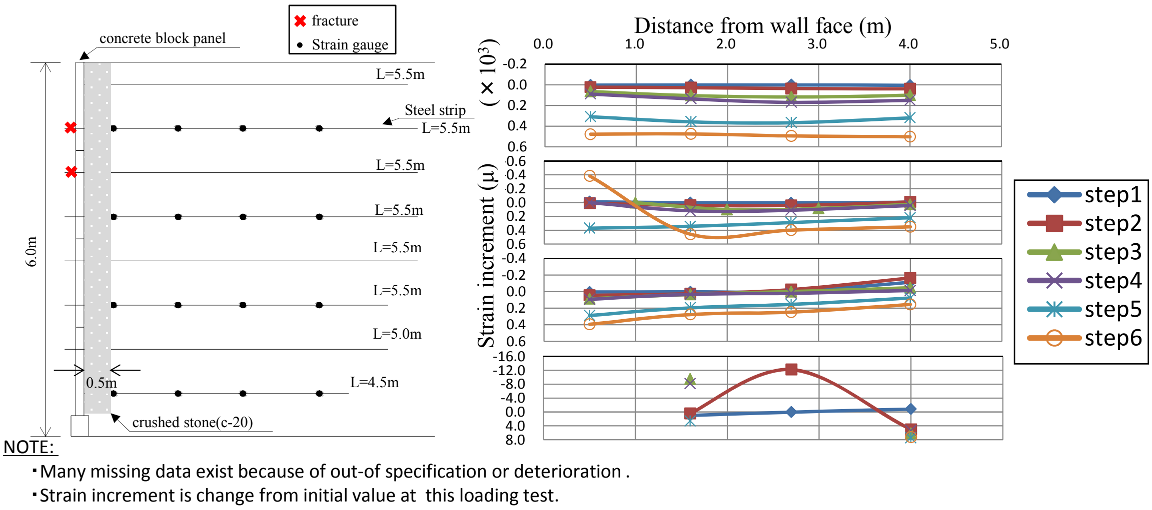


Figure 10 Strain increment for steel strip RSW

4 CONCLUSIONS

Regarding the effects of drainage malfunction due to aged deterioration on the performance of RSWs, the following conclusions were obtained from the results of the loading tests under seepage flow conditions.

(1) RSWs performed well under seepage flow condition with proper soil material use and good construction.

(2) It is importance to record events, the wall displacements and reinforcement material strains for each RSW so as to evaluate its performance throughout its design life.

REFERENCE

Christopher, B.R., Zornberg,J.G. and Mitchell, J.K.1998. Design Guidance for reinforced Soil Structures with Marginal Soil Backfills,

Elias, V. and Swanson, P. 1983. Cautions of Reinfroced Earth with Residual Soils,*Transportation research Record 919*, pp.21-26.

Ingold, T.S., 1981. A Laboratory Simulation of Reinforcded Clay Walls, *Geotechnique*, Vol.31, pp.399-412.

Miyata, Y. 2014. Reinforced soil walls during recent earthquakes in Japan and geo-risk-based design, *Earthquake Geotechnical Engineering Design* (eds. Maugeri, M., and Soccodato, C.), Springer, p.20.

PWRC. 2000. *Design and Construction Manual of Geosynthetics Reinforced Soil*, revised version, Public Works Research Center, Tsukuba, Japan, p.305 (in Japanese).