Geosynthetics, J. Kuwano & J. Koseki (eds)

Geosynthetics reinforcement for marine structure with soil stabilization

Miyata, Y.
National Defense Academy, Japan

Ichi-I, K.
Formerly, Port and Airport Research Institute, Japan. Currently, Hiroshima university, Japan

Suzuki, Y.
Formerly, Port and Airport Research Institute, Japan. Currently, Niigata Port Construction Office, Japan

Hirai, T.
Mitsui Chemicals Industrial Products, Ltd, Japan

Takaba, Y.
Mirai construction Co., Ltd, Japan

Fukuda, M.
Geo-Research Institute, Japan

Keywords: geogrid, reinforcement, marine structure, sand, shaking table test

ABSTRACT: A new technology (SG-Wall) is proposed for quay wall construction. The proposed method is the combining technology of stabilization technique of dredged material (S) and geogrid reinforced soil wall technique (G) for the quay wall (Wall). The authors examined the feasibility to practical construction field and developed a main construction scheme. Shaking table test was also performed for 1/24-scale model of a quay wall with -16 m water depth. The reduced model for SG-wall showed high seismic resistance. In this paper, outline of SG-wall method is introduced and a main construction method is also summarized. Additionally, shaking test result is shown and its high seismic resistance performance is discussed.

1 INTRODUCTION

Quarry wall is important port facilities. Many quarry walls are traditionally box caisson type. More rational method should be developed to reduce costs or environmental impact. This paper discuss about new geosynthetics technology for the quarry wall.

In the recent construction works of quarry wall, it is an important problem how to utilize dredged soft soil. Typical utilization method is to use as fill material by mixing with stabilizing agent (usually cement). Until now, numerous mixing techniques have been developed and applied for port development project (e.g. Kitazume and Satoh, 2003).

Quarry wall should have high ductility against various actions caused by earthquake, wave, and moving of transportation. Some improvement may be needed for quarry wall with stabilized soil because the stabilized soil is basically a brittle material.

The authors invented new method (SG-Wall method) by combining technology of stabilization technique of dredged material (S) and geogrid reinforced soil wall technique (G) for quay wall (Wall). The target of the technology is both new construction of a quay wall and renewal of an existing quay walls for very large ships, which requires a large water depth in front of the quay. In this paper, outline of the SG-wall method is explained briefly and construction scheme is also summarized. Additionally shaking test result is shown and feasibility of this test is considered.

2 THE SG-WALL METHOD

2.1 *Outline*

Typical cross section of SG-wall is shown in Figure 1. The wall consists of cement mixed soil, geosynthetics and sheet pile facing. This can be classified into geosynthetics reinforced soil wall. This method may be effective for renewal of old quay

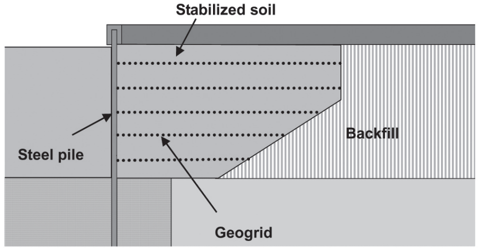

Figure 1. The SG-wall method

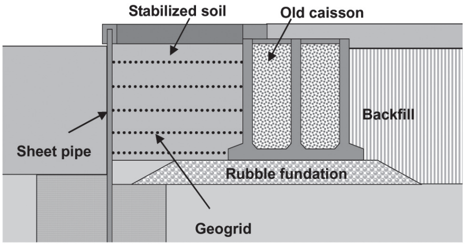

Figure 2. The SG-wall method for renewal case for old caisson quay wall.

wall. In the case of renewal of old caisson wall, application shown in Figure 2 may be effective.

In the SG-wall, high strength geogrid is used to reduce the tensile strain of soil and to prevent progressive crack in the cemented soil. Evaluation method on the required stiffness for geogrid is now under the review. In the construction period, the effect of pH on the stiffness of geogrid should be also examined by referencing previous works (e.g. Allen et. al.).

Facing of the SG-wall is sheet pile and it is connected to geogrid. Tatsuoka (1992) noted that rule of facing rigidity on the stability of geosynthetics reinforced soil. The other side, sheet pile has high axial, shear and bending rigidity. Sheet pile facing is also expected to contribute for reduction of the tensile deformation of stabilized soil.

The sheet pile is installed into base ground to fix the toe of facing. El-Emam & Bathurst (2005) reported the effect of facing toe condition on response of geogrid reinforced soil wall to simulated seismic loading. Toe fixing condition of SG-wall method also can be expected.

2.2 *Construction scheme*

Construction scheme of SG-wall method is shown in Figure 3. At the beginning, we set sheet pile on the sea base. Next, we fill stabilized soil into back of the sheet pile and install geosynthetics. Geosynthetics is connected to the facing. Filling of stabilized soil and installing of geosynthetics are repeated until the end of construction. In the above scheme, installation of geogrid and connecting it to the facing may be the most important and difficult works. The authors have already developed the special construction method. Its workability will be confirmed in the real scale test that is under planning.

3 SHAKING TABLE TEST

3.1 *Outline*

Seismic resistance is an important issue for port structures. To investigate the performance of the SG-wall, the authors performed shaking table test for 1/24-scale model of a quay wall with -16 m water depth. This test was performed at the Port and Airport Research Institute, Japan. Used shake table is circular whose diameter 6 m, and it is installed in the bottom of a square pool 13 m long and 2 m deep. The shake table has two horizontal and one vertical axis with a maximum displacement of ±30 cm, and a maximum acceleration of 2G.

3.2 *Test condition and Materials*

The authors performed shaking table test for reduced models of the SG-wall. Cross section for reduced model is as shown in Figure 4. In order to predict the behavior of prototype models at full scale, the model walls were designed in accordance with simulation rules proposed by Iai (1989).

Three different shaking motions and sinusoidal waves were applied. The loading steps are summarized in Table 1. Hachinohe wave is the recorded motion at Hachinohe site in 1968. The sinusoidal type wave in this test and the Hachinohe wave are most commonly

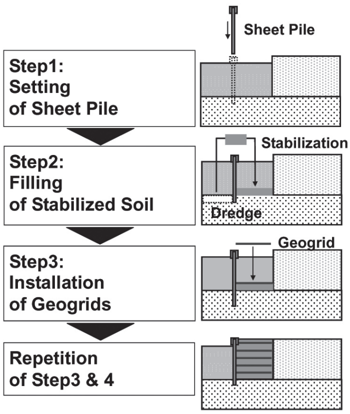

Figure 3. Main construction schemes.

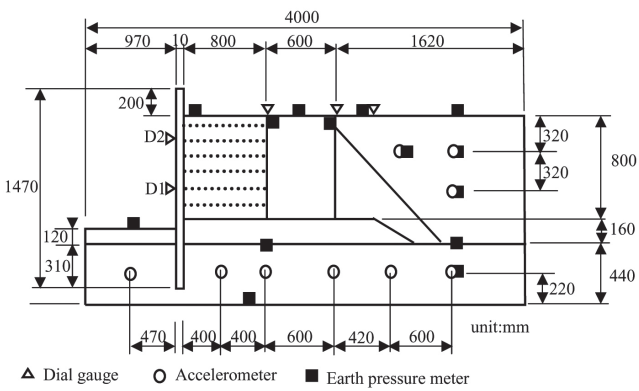

Figure 4. Cross section of reduced model of the SG-wall.

Table 1. Loading step in the shaking table test.

Step	Wave type	Max. acceleration
1	Sinusoidal type 10 wave 10.9 Hz	100 Gal
2	Hachinohe wave	170 Gal
3	PI wave	817 Gal
4	L2 wave	487 Gal
5	Sinusoidal type 10 wave 10.9 Hz	100 Gal
6		200 Gal
7		300 Gal
8		600 Gal

used as the design motion for Japanese port structures. Haneda motion is a synthesized motion for Haneda site and supposed to be a typical shaking for inter-plate earthquake in Japan. Port Island wave is the recorded motion at Kobe Port in 1995, and supposed to be a typical ground shaking for intra-plate earthquake. Note, these waves are applied to the same model and the latest case should be affected by the results of former cases. The shape and the actual acceleration level were slightly different in each case due to the limitation of shake table performance. The maximum acceleration level compiled in table 1 is only the target acceleration level. At some points, distribution of acceleration in the model was checked. The test material used in this test was shown in Table 2. The model materials are summarized in Table 2. Treated soil was prepared as the stabilized sludge by pre-mixing method. Unconfined compressive strength test for the treated soil was performed for sample cured in the water for 4 days because the shaking test were conducted at the 4th day from the construction of the model on the shake table.

Table 2. Main test material.

Caisson	Aluminum box filled with sand
Facing	Aluminum palate (thickness = 10 mm)
Geogrid	HDPE geogrid (Tensile strength = 17 kN/m)
Sand	So-ma sand (Relative density = 90%)
Treated soil	Cement mixed Kibu-shi clay (Unconfined compressive strength = 150 kPa)

3.3 *Test results and Considerations*

Displacement of facing at measurement point D2 (see Figure 4) – time histories are shown in Figure 6. Total facing displacement at any time was a combination of recoverable dynamic component and permanent outward component. Their magnitude and ratio of permanent component to recoverable component were dependent on maximum acceleration and wave type. When maximum base acceleration was over 200 gal, permanent component is remarkable. Permanent displacements at point D1 and D2 (see Figure 4) in each loading step is shown in Figure 7. If the displacements were translated to real scale by using scale factor, maximum displacement was about 60 cm to the 600 gal base acceleration. The reduced

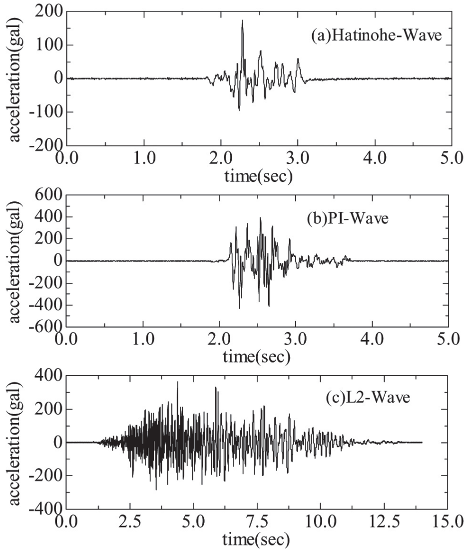

Figure 5. Time history of input seismic wave.

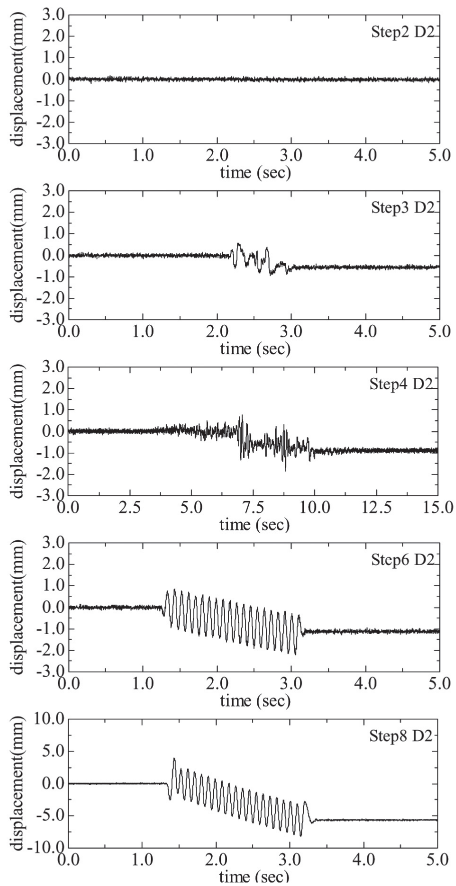

Figure 6. Horizontal displacement of facing.

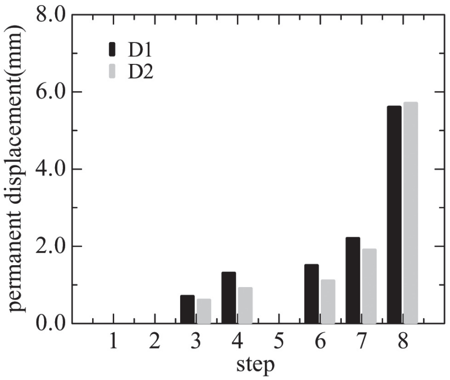

Figure 7. Permanent displacement of facing at the each loading step.

model was prototype of quay wall whose height 16 m. SG wall method showed high seismic resistance performance. The difference between D1 and D2 was very small. Many researchers have observed the rotation mode was remarkable in shaking table test to geosynthetics reinforced soil wall. However, in this test, wall did not rotate and slid along the base foundation. If the installing depth of sheet pile were more enough, the wall showed higher performance and different deformation mode.

Figure 8 shows the reinforcement strain distributions along the length of each layer at different input wave. The values in these figures were taken at times corresponding to the maximum strain. The distribution pattern was independent on the wave type and layer height. The reinforcement strains were the greatest at near the connection.

Figure 9 shows the bending moment distribution along the sheet pile at different input wave. This value also is maximum moment at each loading step. The maximum bending moment was observed at the toe of facing and one in the upper poison of facing was very small. These results consist with the deformation of horizontal deformation of facing shown in Figure 7.

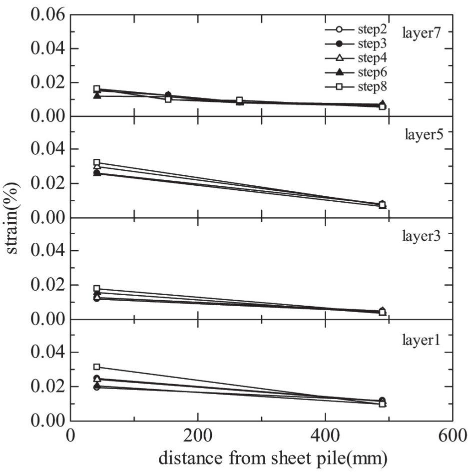

Figure 8. Strain distributions along the reinforcement.

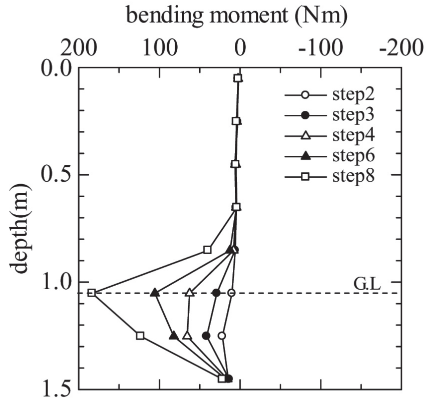

Figure 9. Bending moment distributions along the sheet pile.

4 SUMMARY

A new technology (SG-Wall) was proposed for quay wall construction and main construction method was also summarized. Shaking table test result for 1/24-scale model of a quay wall was shown. The reduced model for SG-wall showed high seismic resistance. Development of design method and numerical method are future task.

ACKNOWLEDGEMENTS

This research is a result of research project “development of earth reinforcement technique for the port facilities” in the Port and Airport Research Institute, Japan. The authors greatly appreciate all members who attend this project.

REFERENCES

El-Emam, M.M. and Bathurst, R.J. (2005). “Facing contribution to seismic response of reduced-scale reinforced soil walls”, Geosynthetics International, 12, No. 3, 215-238.

Iai, S. (1989). “Similitude for shaking table tests on soil-structure-fluid models in 1g gravitational field”, Soils and Foundations, 29, No. 1, 105-118.

Kitazume, M. and Satoh, T. (2003). “Development of a pneumatic flow mixing method and its application to Central Japan International Airport construction”, Ground Improvement, 6, No. 3, 139-148, 2003.

Tatsuoka, F. (1992). “Role of facing rigidity in soil reinforcing”, Keynote lecture, Proc of 2nd International Symposium on Earth Reinforcement, Vol. 2, Fukuoka, Japan, pp. 831-870, 1992.