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Embankment technology with geogrid on very soft clay

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ABSTRACT: It is very difficult to construct the soil structure on very soft clay whose water content excesses the liquid limit. Whenever we improve the soft clay, we need the heavy machine to carry out. Therefore, Imanishi et al. have developed Geogrid Replacement Method to construct the temporary traffic road on very soft clay with economy in 1996. In recent research, we have also been developing the advanced geogrid method, which doesn't need amount of replaced sand. It can easily keep the bearing capacity on very soft clay. This paper describes the geogrid technology of these two methods.

1 INTRODUCTION

Embankment on very soft clay whose water content exceeds the liquid limit needs soil improvement methods such as soil cement mixing, and soil consolidation by prefabricated vertical drain (PVD) and sand compaction. However, these methods are very expensive and need the heavy machine to carry out. Therefore, Imanishi et al. have developed Geogrid replacement method (GRM) to construct the road on very soft clay with economy and without heavy machine in 1996. This method can be applied in the thin layer of very soft clay.

In recent research, we have been developing the new geogrid method to apply in the thick clay layer. It can construct the road without amount of replaced sand for keeping the bearing capacity on very soft clay. This method employs "the parachute effect" with geogrid on very soft clay. This paper describes two different geogrid methods applied to the temporary road on very soft ground in Japan.

Incidentally, we have indicated a geonet in the former papers. It isn't justified in this method. We change the geonet terms for geogrid from this paper.

2 PROGRESS OF DEVELOPMENT

For example, in the case of making a huge land to reclaim the dredged marine clay, the bank has to be made for the reclaimed marine clay first. Then, ground improvement should be carried out by consolidation method second. However, the reclaimed soil seems to be clay paste, which has the water content exceeds the liquid limit. It is impossible to improve the soft ground by heavy machines without the temporary road in order to keep the trafficability. The soil cement mixing method or the replacement method generally makes the temporary road construction. The former method has difficulty in improving the clay under the soil cement mixing body for consolidation. The latter method could not certainly verify the shape of replacement. Hence GRM has been developed.

GRM is one of the replacement methods using the geogrid and make a working road on very soft clay by the wrapping effect. However, the replaced mass with geogrid has to reach the stiff foundation under very soft ground. The acceptable reclaimed volume of clay to make a man-made island decreases due to its replacement. Therefore, we have been developing the advanced method, that is, Geogrid Floating Method (GFM). This method can be applied in the thick clay layer; it can make not only a temporary road but also a stable ground on the reclaimed clay with geogrid using the parachute effect. Thus, the acceptable volume in the reclaimed land does not decrease. It can easily improve very soft clay by the PVD beneath the temporary road. Figure 1 shows GRM and GFM images.

3 GEOGRID REPLACEMENT METHOD

3.1 *GRM Procedure*

The outline of GRM is shown in Figure 1 (a). The procedure for constructing the road on very soft clay ground is as follows,

(1) Put the geogrid on very soft ground with human power and spread the geogrid roll.
(2) Connect the geogrid each other.
(3) Push out the sand on the geogrid to one direction as smooth as possible by a little bulldozer.
(4) The sand's own weight forces out the very soft clay into the both sides of the sand mass with plastic flow.
(5) Replace the clay ground with the sand mass.
(6) The sand passageway exists on the soft ground.
(7) Continuing the dumping, the subsidence speed of the sand mass begins to slower and finally steadies on the stiff ground and then quits the dumping.

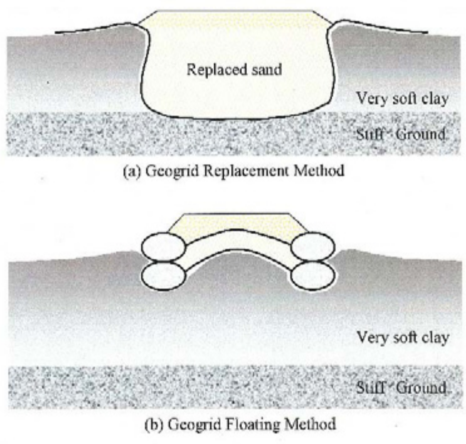


Figure 1: Outline of Geogrid Replacement Method

On the other hand, Embankment method on very soft ground with geogrid (EMG) needs to dump sand with thin layer. GRM is better to dump sand on a spot. EMG notices the small deformation. Alternatively, GRM allows the large deformation and aims to slip into soft clay keeping good shape to stiff foundation ground.

3.2 *Reinforcement effect of geogrid*

Figure 2 shows six reinforcement effects of the geogrid in GRM. These are the tensile reinforcement effect, the material separation effect, the sand restraint effect, the direct support effect on the stiff ground, the load dispersion effect, and the consolidation effect around the replaced sand.

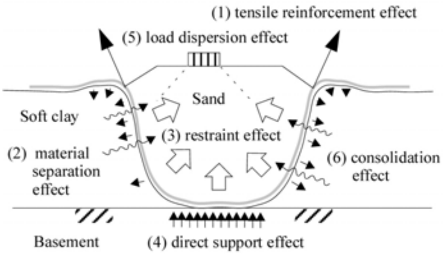


Figure 2: Reinforcement effects of geogrid in GRM

3.3 *Performance*

The geogrid mechanical properties are shown in Table 1. The water content of very soft clay is approximately 100 percentages, which is 1.2 times of the liquid limit. The vane shear strength of very soft clay is 2 to 4 kPa.

Table-1: Geogrid mechanical properties

Material	Polyester textile with PVC	
Mehcanical properties	Tensile strength of geogrid	100 kN/m
	Tensile strain of geogrid	25 %
	Tensile strength of sewing line	80kN/m
	Tensile strength of geogrid joint	80 kN/m
	Mesh space	6.0 mm
	Unit mass	0.45 kg/m^2
	Thickness of geogrid	1.2 mm

Geogrid deformation at every load step is clearly defined in Figure 3 by the observational method. According to this figure, the geogrid formed a hammock shape on the initial step. The sand mass subsided into the soft ground leaning toward the left side. In proportion to the sand load increasing, the bottom of the geogrid vertically subsides with a little extension. However, the geogrid deformation changes a hammock shape to a U-shape ditch form so that the sand mass subsides into the soft ground keeping a U-shape ditch form. Finally, the bottom of sand mass reached 1.5 meters beneath the boundary between the marine clay and the reclaimed clay. Figure 4 shows calculation results and observed data of deformation and tensile stress on the geogrid. It is found that the observed data are very close to the calculated results. Figure 5 shows the shape of the geogrid from bird's view in the other case. The geogrid seems to be an U-shape ditch form.

Photograph 1: GRM performance

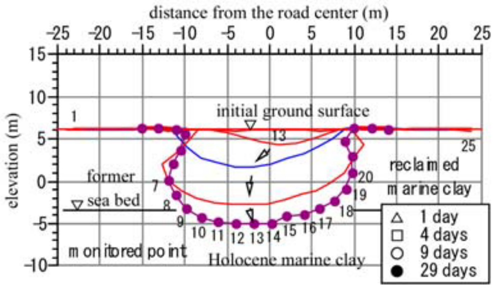


Figure 3: Deformation of geogrid in GRM

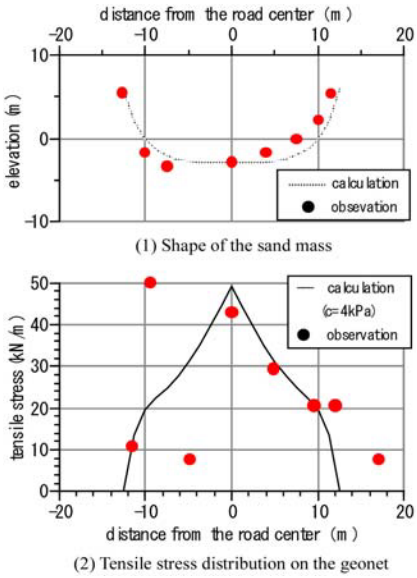


Figure 4: Calculated and observed results of GRM

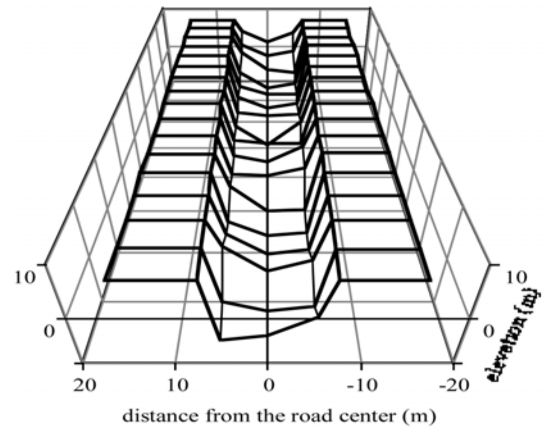


Figure 5: Shape of geogrid from birds view

4 GEOGRID FLOATING METHOD

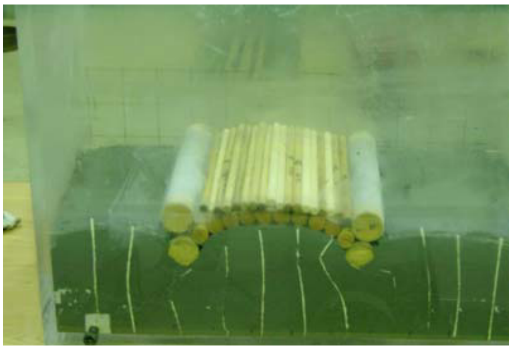
4.1 *Procedure of GFM*

The outline of GFM is shown in Figure 1 (b). The procedure for constructing the embankment on very soft clay is as follows,

(1) Put the geogrid unit on the very soft clay. The geogrid unit is the product connected with counterweights of its both ends.
(2) Counterweight is slurry bag, wrapped sand or heavy stuff, etc.
(3) Wait for the stable state of the geogrid unit.
(4) Subside counterweight on both ends into soft clay, then the geogrid among them forms the parachute shape.
(5) Push out the sand with thin layer on the geogrid to one direction smoothly by the little bulldozer.
(6) Don’t replace the clay ground with the sand mass.
(7) If it doesn’t keep its stability, put another unit onto the former unit.
(8) Cover the sand layer flatly.

4.2 *Reinforcement of geogrid*

The laboratory test of GFM can be seen in Photograph 2. Figure 6 shows four reinforcement effects of the geogrid in GFM. These are the tensile reinforcement effect, the material separation effect, the clay restraint effect by parachute shape, and the un-consolidation effect under the geogrid.



Photograph 2: Laboratory test of GFM

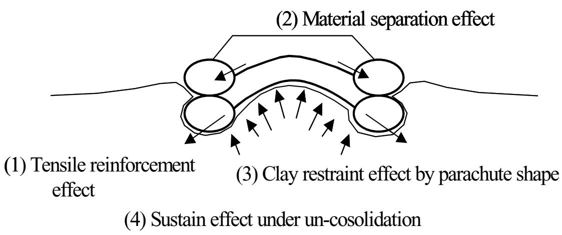


Figure 6: Reinforcement effects of geogrid in GFM

4.3 *Model test of GFM*

We have carried out the laboratory model test to confirm the sustainable mechanism of GFM. We have also carried out the conventional EMG test in same conditions and compared each other.

The soil tank used for the test has the high rigidity and the acrylic resin plate in front to see the clay deformation directly. Its boundary condition was the undrained state. We put the monitoring points inside the acryl resin plate and spaced the points out evenly.

In addition, we put the electrical deformation meters on the clay surface, and set the earth pressure meters and the piezometers to monitor the excess pore water pressure inside the clay for the restraint effect of geogrid. The clay is from the reclaimed land in Hakata bay. Figure 7 shows the grain size distribution of this clay. Its water content is 151 percent and shows approximately 1.4 times of the liquid limit. The pure clay content of this soil is 73 percent.

The miniature of the geogrid unit consists of the square fly net and polyvinyl chloride pipes on its both ends. It is shown in Photograph 3, and it indicates the loading test on the geogrid above very soft clay. Loading products are wooden bars of 20 mm in diameter and steel bars of 12 mm in diameter. The procedure for testing is as follows,

(1) Put the miniature of the geogrid unit on very soft clay.
(2) Set loading bars on the fly net.
(3) Put the second unit on the loading bars.
(4) Set loading bars on the second unit again. Then two units and loading bars unify together as a parachute shape.

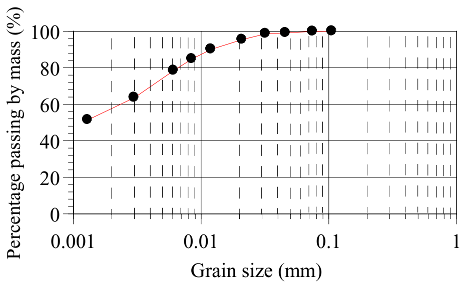


Figure 7: Grain size distributions used in laboratory test

Photograph 3: Miniature of geogrid unit in GFM

4.4 *Results and considerations*

Figure 8 shows clay deformation during the experiment of GFM. Figure 9 shows the result of EMG on the same conditions. In the case of EMG test, the fly net was laid over the surface on very soft clay. Otherwise, the GFM unit that consists of the fly net and two counterweights was laid on very soft clay. Then put the loading bars of the fly net. Comparing the ground deformation of GFM with that of EMG, the ground deformation of EMG concentrates the lower part of the center mound against that of GFM. Ground deformation of GFM is not only the lower part of the center but also the whole of the clay. It tells us that the load is sustained by the whole of clay ground under the lording area. Therefore, GFM has the load dispersion effect.

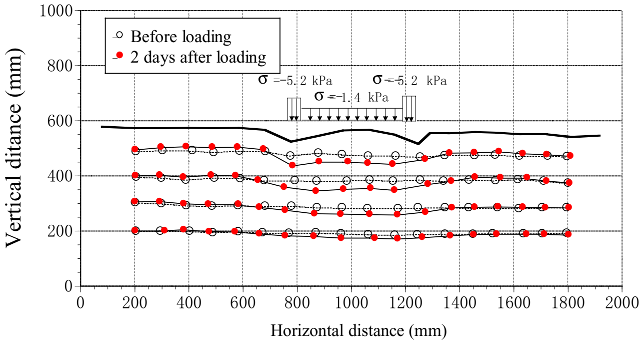


Figure 8: Deformation during experiment of GFM

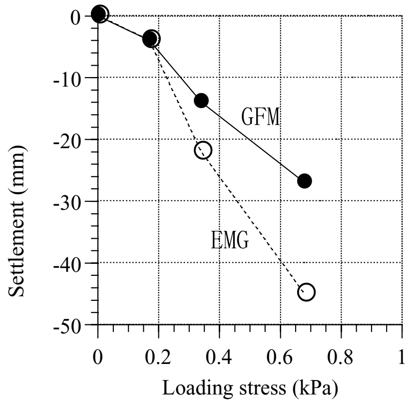


Figure 11: Sustained effect of geogrid

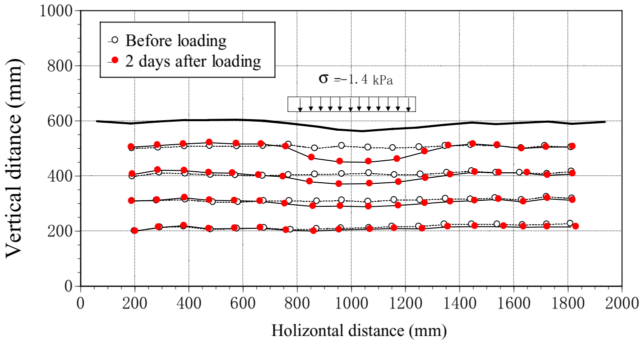


Figure 10 shows the relationship between the settlement in the middle point of the embankment and the time. It says that the settlement difference of two methods increase as time rolls on. Moreover, the settlement of GFM also gradually converges. The settlement of EMG is still progressing.

Figure 11 shows the stress-settlement curve. The sustained effect of geogrid emerged in this figure. Now we are going to make a design method with the theoretical considerations, and apply GRM to the field works.

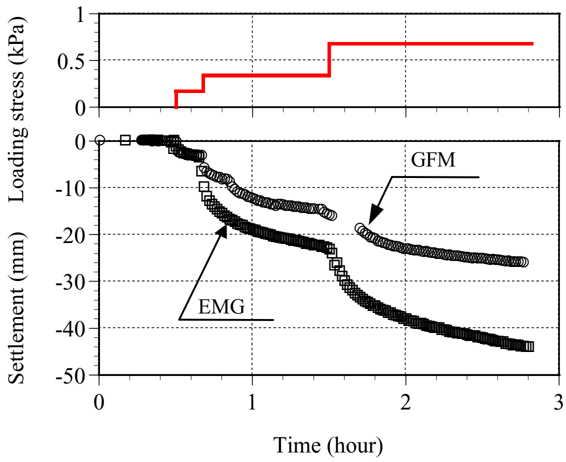


Figure 10: Settlements in the middle point of geogrid with load

5 FINAL REMARKS

Keeping the water passageway in the harbor for industry, we have to dredge the soft clay from the seabed. It is very difficult to treat this soft clay, because the clay paste water content exceeds the liquid limit. Otherwise, there are many places that need the infrastructures such as embankment, road, etc. for lives on very soft clay in delta areas and marshes in lowland.

We have thought that the very soft clay is one of the very important sources as not wastes but recycled products. We have to make lands to live on such soft ground with measures. Although, the cement mixing is one of the solutions, it isn't gentle to their environment. The geogrid doesn't chemically treat the soft soil itself.

Wrapping is the one way to use the geosynthetics for strengthening the soft soil. We have introduced two geogrid methods based on Japanese wrapping clothes named "Furoshiki" in this paper.

6 REFERENCES

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