# Two Successful Methods for Improving Extremely Soft Ground Using Geosynthetics

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ABSTRACT: Japan has more than 20 years experience in soil covering method for the conquest of extremely soft ground through artificial reclamation using geosynthetics. During these years, various field works of soil covering methods were executed successfully and the relationship between tensile strength of geosynthetics and soil strength of ground is presented. If soil improvement work and reclamation work are done simultaneously, the construction period could be reduced and it becomes more economical. The horizontal drain method has been developed for this concept.

This paper reports field work results of these two successful methods for extremely soft ground.

## 1 INTRODUCTION

A good example of an extremely soft natural ground in Japan is the tidal flat of Ariake bay in Kyushu. However, there are many examples of artificially developed extremely soft grounds in land reclamation works. In this type of extremely soft grounds, there exists a need for the foundation to develop the bearing capacity quickly to support construction equipment.

Prior to using geosynthetics, soil covering work started only after surface hardening by solar heat drying. Therefore to utilize land reclamation sites, more than 2 - 3 years were required after completion of reclamation works (Watari, 1984).

Now, soon after land reclamation work, sand spreading is done using geosynthetics. This shortens the total construction period and thereby it becomes more economical. As reclamation work and improvement work could be carried out in parallel, reclaimed ground could be used much earlier. No sooner the reclamation work is over, the improvement works can be completed using this concept of horizontal drain method developed.

## 2 SOIL COVERING METHOD

Ground surface stabilization method of extremely soft ground is classified as shown in figure-1 (Ochiai, et al., 1994). Among these methods, soil covering method is adopted in an increasing number of sites and with a variety of methods using geosynthetics. Soil covering method consists of the combination of geosynthetics reinforcement and soil spreading method. There are four variations in the geosynthetics reinforcement method. Figure-2 indicates the differences in design concept in the soil covering method (Watari, 1987).

Sheet method uses the frictional resistance between the sheet and soil for the tension force at geosynthetics edges. Net method uses the beam effect of combined net and soil. Rope and sheet method uses sheet for separation and rope is used for resistance in tension. The edges of rope are tied to the timber piles placed in the embankment. Bamboo and sheet method uses the rigidity of bamboo for supporting the soil load.

There are three ways for soil spreading. In the dry sand spreading method, the execution of work is easy, but sand spreading layer thickness must be reduced as the weight in the air and angle of slope of spreading sand edge is sharp. Slope angle in the wet sand spreading method is very gentle because the sand is hydraulically pumped with water. For this reason, sand layer thickness can be much larger under water than that

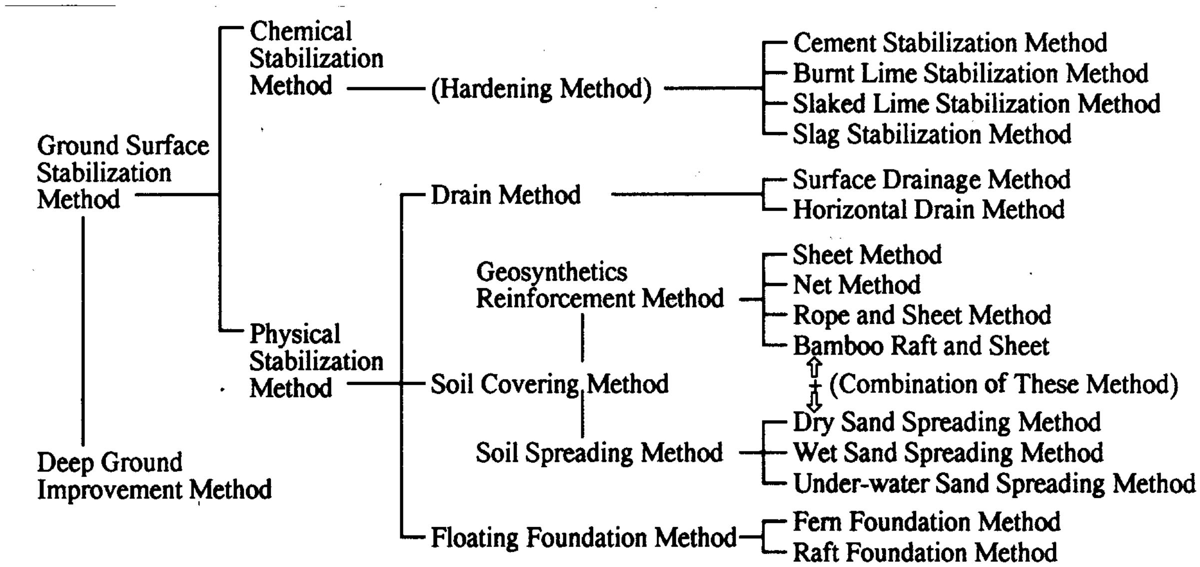


Fig. 1 Classification of Ground Surface Stabilization Method

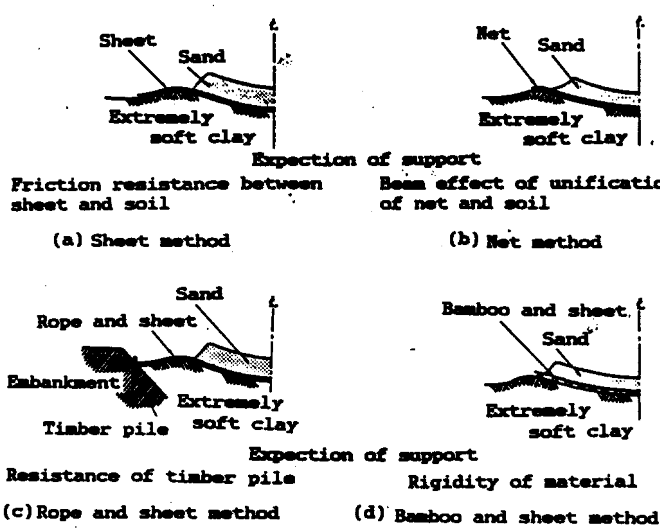


Fig. 2 Difference of Supporting System at Soil Covering Method

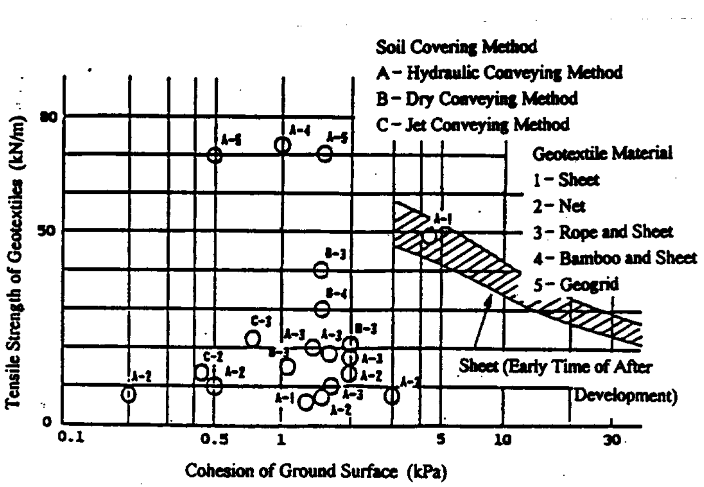


Fig. 3 Relationship between Tensile Strength of Geosynthtics and Cohesion of Ground Surface

in the dry method. The thickness of sand layer can be larger under water, but controlling thickness is difficult. The soil covering method is decided according to the strength of ground surface, field operation conditions and economical factors.

Figure-3 indicates the relationship between tensile strength of geosynthetics and cohesion of ground surface of actual nearly 20 field works based on quality of geosynthetics materials and kind of sand spreading method (Watari, et al., 1991). The shaded part indicates the soil covering method using sheet in early time of this method. Recently, this method has been used even in a ground with surface strength of 0.2 kPa and tensile strength of geosynthetics of 10 – 40 kN/m.

## 3 HORIZONTAL DRAIN METHOD

The advantages of development of horizontal drain are:

1) The shortening of reclamation and soil improvement construction period leading to greater economy.
2) Accommodation of more dredged materials in the reclamation site.

The technical problems associated with this development are:

1) The difference due to load pressure application and application of pressure by vacuum.
2) Problems of sealing related suction pressure of vacuum action.
3) Drainage resistance in long drain.
4) The method of setting up horizontal drain.

To solve these problems, model experiments and field tests were performed. And the results of experiments done on vacuum and direct application agreed well

(Watari, et al., 1993). The results of model experiments show that, Barron's theory is applicable to horizontal drain method. When the water content is very high, the problems of sealing are not seen. When water content decreases, cracks appear on the surface through which extremely soft clay begins to flow from nearby and reseal the cracks.

Resistance to water flow in long plastic board drain was reported and it is called well-resistance (Yoshikuni, et al., 1974). To solve this problem, 200m length horizontal drain was set in the ground and applied consolidation load by atmosphere pressure (Watari, et al., 1987).

At the point of 50m, it was measured that water content decreased, but point of 100m water content, the rate of dropping was not same as point of 50m and at point of 150m, the water content did not decrease. Analysing the time-subsidence curve and taking coefficient of well-resistance of L=5, it could be seen that all the subsidence curves match with the theoretical values. According to these results, generally 50m is the maximum length of traditional plastic board drain with no well-resistance.

Therefore, plastic board drains with a large section were developed for long drains as shown in Table-1.

Figure-5 indicates the drain installation pontoon for horizontal drains.

Figure-6 indicates an example of decrease of water content and the resistance of cone penetration value in a site. Here due to consolidation the water content drops to 100% (Watari, et al., 1993) in 30 days.

Table-1 summarizes the field improvement works.

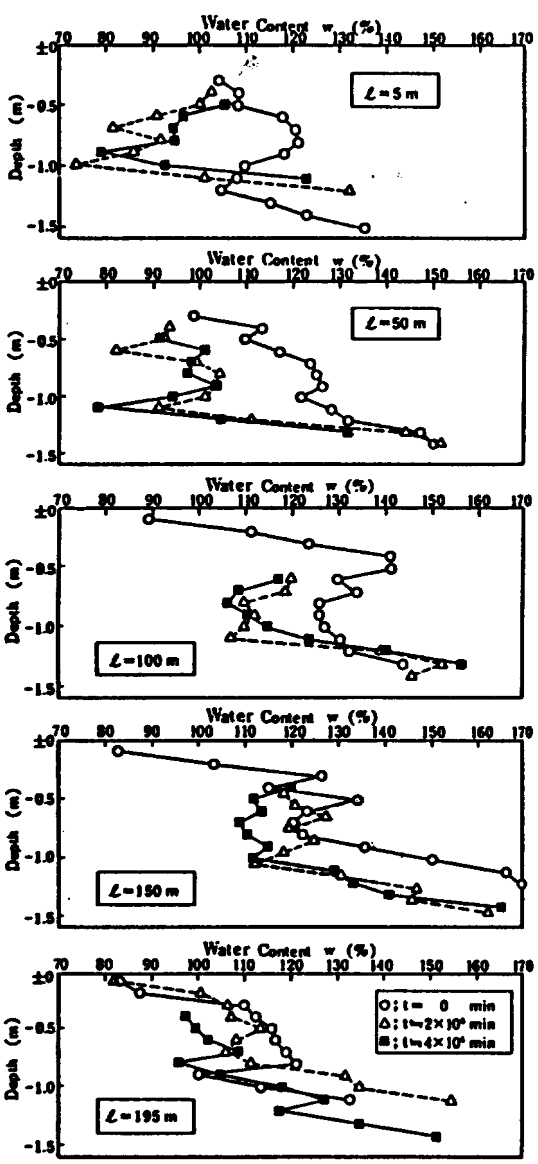


Fig. 4 Measurements of Water Contents after Consolidation

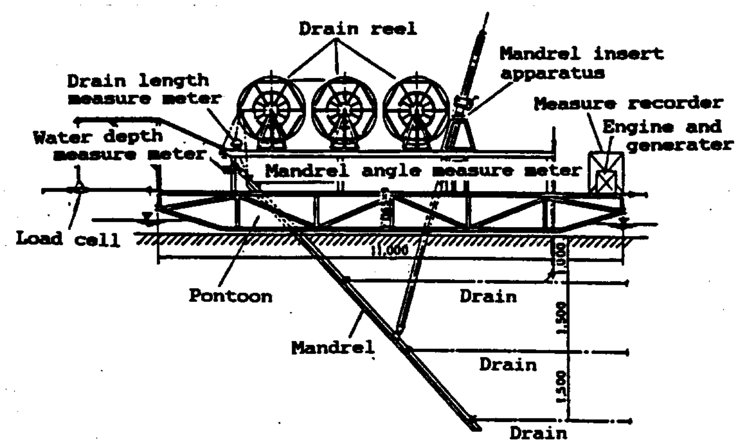


Fig. 5 Drain Setting Pontoon

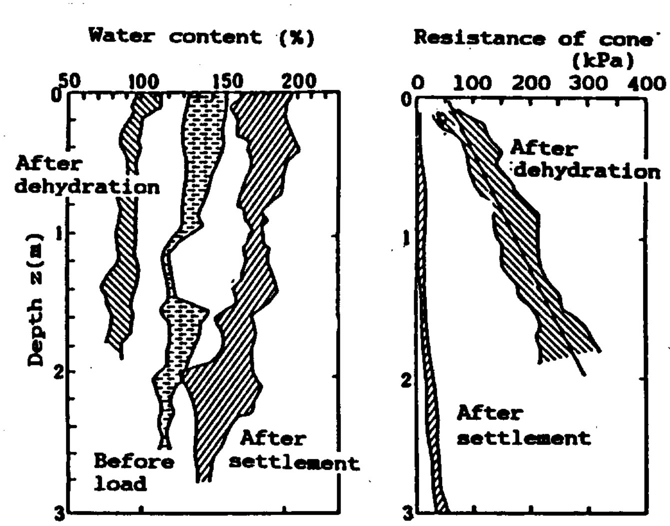


Fig. 6 Distribution of Water Content and Resistance of Cone Penetration

Table 1 Field Site Improvement Works of Horizontal Drain Method

| | Construction A (Experiment) | Construction B | Construction C |
|---|---|---|---|
| Period | '87/8 – '87/11 | '88/12 – '89/7 | '90/3 – '90/11 |
| Soil | Alluvial clay | Industrial refuse | Organic clay |
| Liquid Limit | 110% | 200 | 110 |
| Plastic Limit | 40% | 90 | 50 |
| Improvement Area | 350 m² | 40,000 | 25,000 |
| Thickness | 2.8 m | 4.5 | 2.8 |
| Drain dimension and length | mm<br>100 x 3, 50 m | 100 x 3, 100 m<br>100 x 6, 100 m<br>100 x 12, 100 m | 150 x 6, 125 m |
| Drain pitch | m<br>0.7, 4 steps | 1.5, 3 steps | 0.7, 4 steps |
| Quantity | 40 pieces | 204<br>162<br>30 | 588 |
| Water content<br>Initial<br>Completion | 200 – 300%<br>90% | 300 – 600<br>150 – 180 | 200 – 300<br>90 |

## 4 CONCLUSION

Two methods for extremely soft ground improvement method have been introduced. Soil covering method has been used extensively in extremely soft ground in Japan and recognized as a useful method. The relationship between tensile strength of geosynthetics and soil strength is made clear.

In the development of the horizontal drain method, the technical problems associated with sealing and the solutions for these have been presented. These methods are very effective for achieving improvement of extremely soft clayey ground.

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