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A Study on the Behavior of Dredged Soil Stratified in a Transparent Geobag

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ABSTRACT

The behavior of slurry sedimentation is presented in this study. A geobag made of a transparent PVC Film was used in the test. There were three filling phases conducted, the moisture contents of the slurry in each phase are 1000%, 300% and 100%, consecutively. Each phase consists of a series of filling and dewatering stages. After filling, the composition of the slurry in the bag changes as soil particles undergoes sedimentation process. The water on top of the sediment is removed in the dewatering stage and the bag is refilled again with slurry. Laboratory tests were performed to determine the physical properties of soil samples gathered from the stratified layer at each section of the transparent bag. The composition of the stratified soil varies within each layer all over the bag. The high settlement rate of the coarse grained soil particles causes it to settle near the geobag inlet. Fine grained soils on the other hand are distributed throughout the geobag and mostly in the upper layer due its slow sedimentation rate.

KEYWORDS: slurry sedimentation, transparent geobag, dredged soil, soil behavior.

1. INTRODUCTION

A large quantity of stones and boulders were used during the early construction of the Saemangum dike in South Korea. But the use of such construction materials has raised some concerns. The stones and boulders used in the construction were quarried from various locations in the country at a relatively high labour cost. The method of mountain quarrying has a significant impact to the natural environment. Most of these

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mountains are now environmentally protected by law. A different alternative for the dike construction is needed. One proposal suggested the use of geosynthetic tubes for the construction of the new dikes. The geosynthetic tube structures are cheaper to build compared to the conventional dikes built with rocks. The proposal was found to be feasible since the filling materials (dredged soil) of these tube structures are readily available. The dredged soil can be obtained from construction sites involving excavation where the amount of the excavated earth is larger than the amount of the soil to be reused.

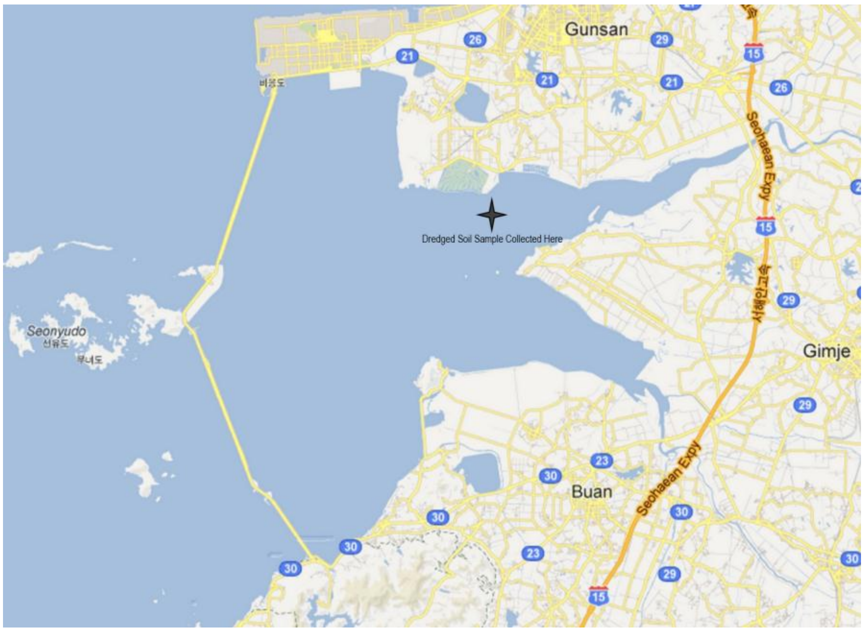

Fig. 1. Saemangum Map

The stability of a geotextile tube structure depends on the strength and durability of its geotextile membrane and the characteristics and behaviour of its soil fill. This study focuses on the observation of the natural behaviour of the soil fills. The main concerns are on how the soil particles are distributed throughout the geobag and its sedimentation and consolidation processes. The study was based on the sedimentation mechanisms and sediment formation experiments on soils conducted by Imai (1981) and consolidations tests on dredged soils performed by Yao et al. (2003) and Kim et al. (2003, 1995). Since it is hard to monitor how the soil behaves inside the actual geosynthetic tubes during the filling and sedimentation stages, a transparent PVC film was used to form the tube in this study. The observation of soil sedimentation in a three dimensional perspective was made possible.

This paper presents the first result of the series of experiments conducted for the design and optimization of geosynthetic tubes that will be used in the Saemangum project. The dredged soil used in this experiment was collected from the location marked star on the map (Fig. 1).

2. EXPERIMENTAL PROCEDURES

2.1 Materials and Apparatus

The transparent bag is made of a 0.8mm thick transparent PVC (polyvinyl chloride). The length of the bag is 4000mm and has a theoretical diameter of 500mm. The joints and edges are jointed together by a thermal sealing device. Two main gate valves, used for filling and dewatering, are attached on top of the transparent bag 2000mm apart. Two more gate valves for dewatering are attached at the ends of the bag. The bag is divided into 8 sections as shown in Fig. 2.

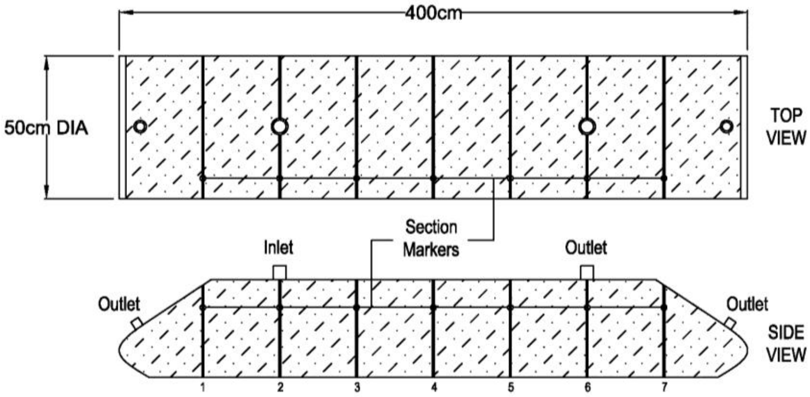

Fig. 2. Top and Side View of the Transparent GeoBag

The test was performed using the apparatus shown in Fig. 3. The main components of this apparatus are the (1) mixing tank, (2) hydraulic pump, (3) agitation tank and (4) experimental tank.

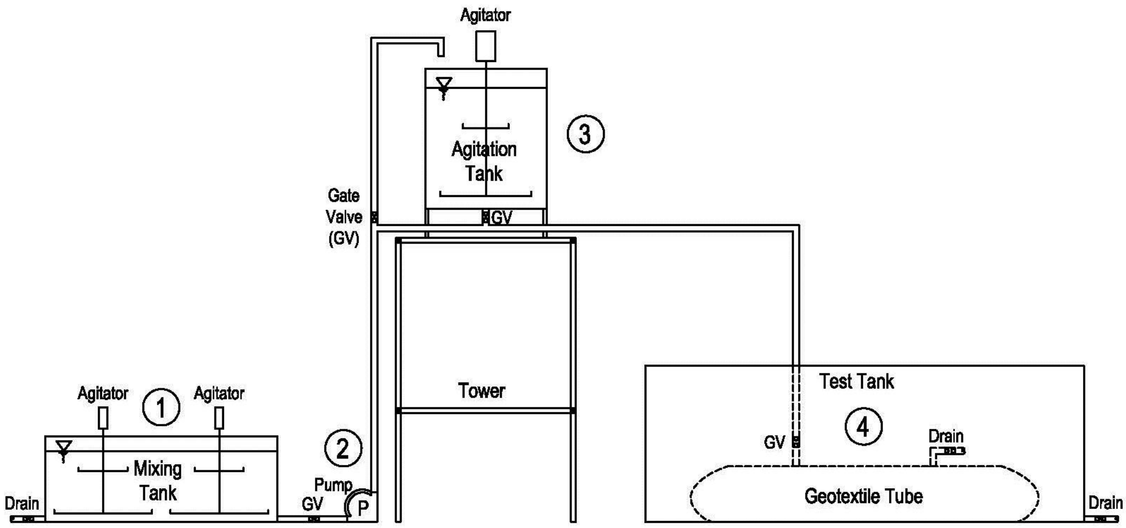

Fig. 3. Schematic Diagram of the Experiment Apparatus

The preparation of the slurry is made inside the mixing tank (1). Two hand held agitators were used to combine the water and soil. The slurry is then pumped into the agitation tank (3) above the tower. An electric agitator installed above the agitation tank agitates the slurry to ensure the consistency of the mixture. The slurry is filled into the transparent bag laid inside the test tank (4) thru a hose that connects from the bottom of the tank to the inlet of the transparent bag.

2.2 Dredged Soil

The dredged soil used is a non-plastic classified as Poor-Graded Silty-Sand (SP-SM) by the Unified Soil Classification System (USCS). The grain-size distribution is shown in Fig. 4 and the physical properties of the soil is shown in the table below.

Table 1. Soil Properties

Item	**Quantity**
Natural water content, w	28.70%
Specific gravity of soil solids, G_s	2.57
Plastic Limit, PL	N.P.
Plasticity Index, PI	N.P.
Percent passing No. 200 U.S. sieve (0.075mm opening)	47%
Unified soil classification	SP-SM

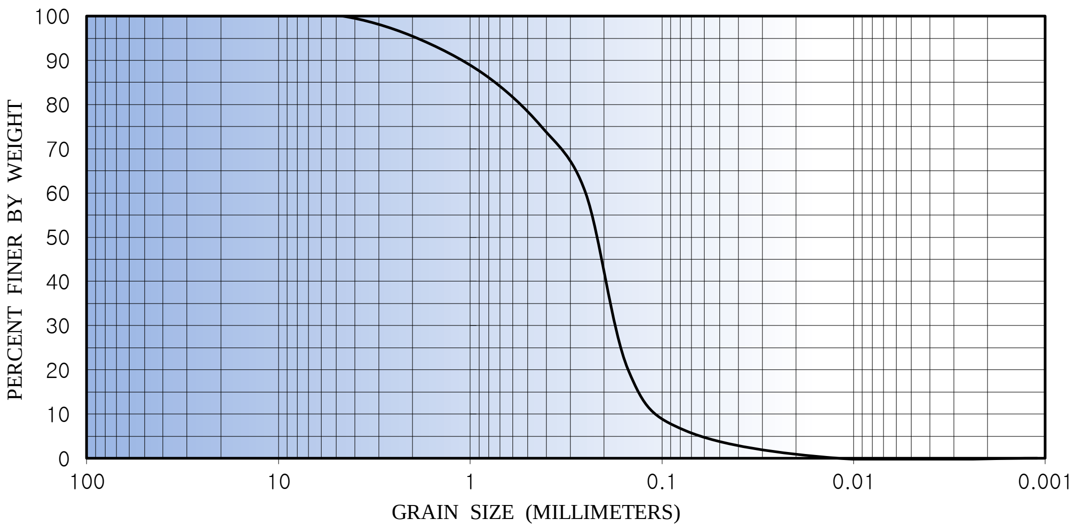

Fig. 4. Grain Size Distribution

2.3 Filling and Dewatering

The transparent geobag is laid inside the test tank. The slurry is filled thru the hose connecting the agitation tank and the transparent geobag. Fig. 5 illustrates the filling and dewatering stages of the geobag. The empty transparent geobag is shown in “A” before the first filling stage. The fully filled bag is then illustrated in “B”. The soil particles in the slurry mixture is then allowed to settle at the bottom. When the water above the soil layer becomes clear as illustrated on “C”, the drain valves are opened to start dewatering. The dewatered state is shown in “D”. The filling process was repeated after dewatering.

2.4. Data Collection and Soil Sampling

Section markers were taped around the surface of the geobag (Fig. 2) to indicate the locations where to measure the height and width of soil. In the filling stage, soil height and width measurements were taken after the water above the sediments becomes clear, in the dewatering stage, the measurements were taken after all the water in the bag has been removed.

After the geobag test, soil samples were collected from the top and bottom layer in each section of the stratified soil across the length of the geobag. A laboratory experiment was performed to determine the physical properties of the soil samples acquired.

3. OBSERVATIONS AND DISCUSSIONS

3.1 Change of Shape

During full stage, an almost circular shape of the geobag can be observed, but as the soil particles settles at the bottom, the shape of the geobag becomes elliptical. The width of the tube increases as the height decreases. The increase of the geobag width is caused by the spreading of the contained soil inside the geobag.

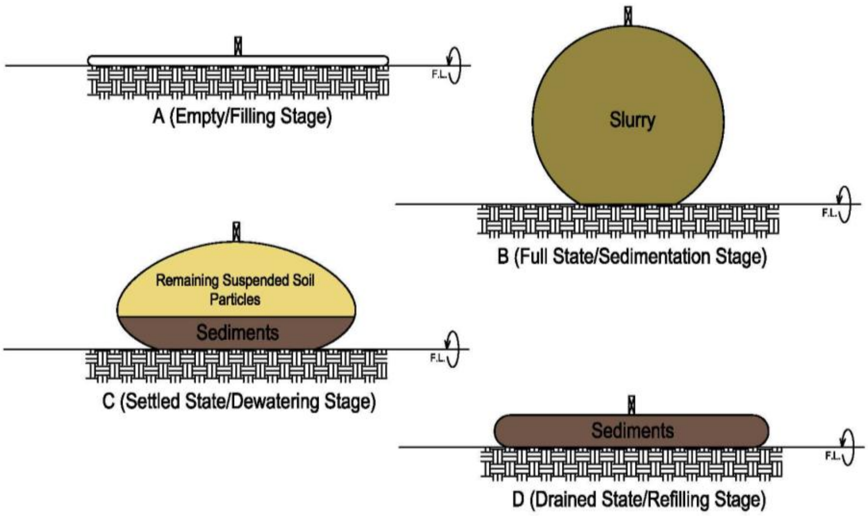

Fig. 5. Filling and Dewatering Stages

3.2 Soil Behavior

There were three main stages of soil behavior observed during the test; the flocculation stage, settling stage and the consolidation stage. Flocs are formed all over the bag in the *flocculation stage* after the filling of slurry. Shortly after these floc formations, soil particles begin to settle at the bottom of the bag, this is known as the *settling stage*. As the soil particles settle on top of each other, the lower portion of the soil layer undergoes *consolidation stage* due to the increase of the weight of the overlaying soil.

There were three filling phases performed in the test, each filling phase using slurry of moisture contents 1000%, 300% and 100% consecutively. These are marked “triangle”, “square” and “x” the graphical representations in Figure 6 and Figure 7. The graph in Figure 6 represents the soil sediment elevations of the undrained bag and the graph in Figure 7 represents the elevations of the stratified soil in the drained bag. Each graphical curve represents the final height (y-coordinate) of soil in each section (x-coordinate) of the transparent bag after every filling phase.

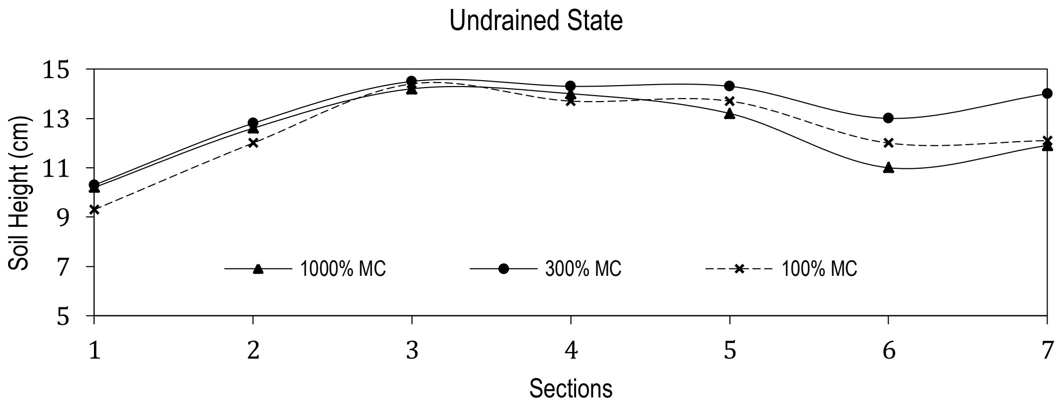

Fig. 6. Soil Layering at Undrained State

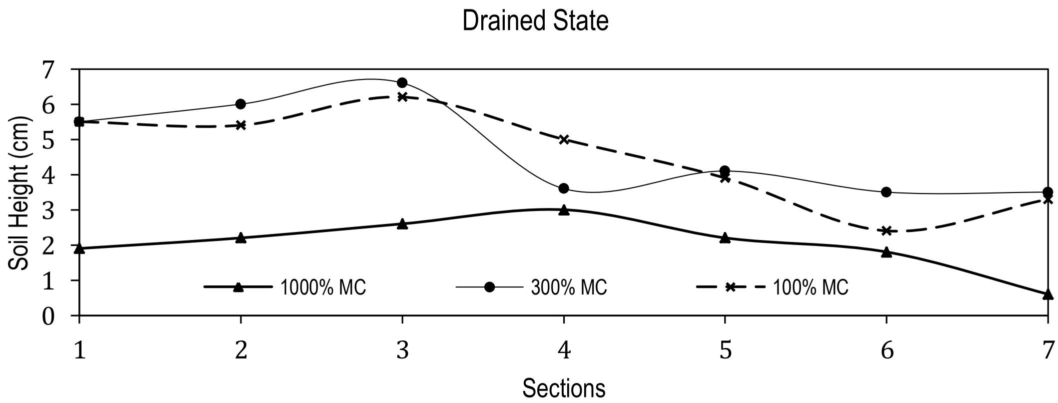

Fig. 7. Soil Layering at Drained State

The inlet of the bag is located at section 2. During undrained condition (Fig. 6), it can be seen that the soil particle settlements in the middle of the geobag has a small elevation difference. In the drained state however (Fig. 7), a significant amount of soil drop can be observed from sections 4 to 7 (2^{nd} & 3^{rd} filling phases). This is due to the amount of water occupying on the voids of the fine grained soil in these sections (during full state). After the water was drained from the bag, these soil particles are condensed together occupying the spaces of the expelled water. The packing of these very loose soil particles caused the reduction of the height of soil layers in these sections. In the sections near the inlet however, the height of drop is less than that of the other sections. This can be explained by the amount of coarse soil deposited around the area. When water was expelled, there was only a small amount of void spaces to fill, thus allowing a small amount of settlement. The coarse soil particles are gathered near the inlet because of its dense weight. As the slurry enters into the inlet of the bag, these dense soil particles are attracted by gravity to quickly settle at the bottom around the inlet area.

At drained state, the depression of the curves of the 2nd and 3rd filling in-between section 1 & 3, as seen in Fig. 7, indicates a crater formation inside the geobag. These craters are caused by the phenomenon known as the hydraulic jump. The craters are formed due to the turbulence created by the pressurized slurry as it enters the geobag.

An overlapping between the graphical curves of the second and third filling phases can be seen in Fig. 7. This means that after the filling of the slurry of 300% MC, a substantial amount of soil consolidation occurs at the underlying layers. This event was not visible between the 1st and 2nd filling phases. This is due to the minimal amount of soil particles in the slurry mixture in those phases. The higher the moisture content in a soil body, the more void spaces are present. Conversely, the less there is water in the soil body, the more compact and denser it becomes. In the first two phases, the weight of the 2nd layer has a little effect on the consolidation of the 1st layer. After the 3rd phase, there was an enormous amount of weight in the 3rd layer to cause water from the 1st and 2nd to expel, accelerating its consolidation on the process. This made possible the lowering of soil elevation greater than the 2nd phase. Increasing the self-weight of the soil body also increases its consolidation process.

3.3 Moisture Content Variation and Grain Size Distribution

Soil with low moisture contents are found in sections 2, 3, 4 and 5 (Fig. 8). This sections indicates a highly consolidated area. The difference on the moisture contents between the lower and upper layer at each section indicates the degree of consolidation of the sediment. The low water content stratified soil on the bottom is highly consolidated compared to the high water content soil at the top. Due to the shallow depths of soil in sections 6 to 7, the difference of water contents on the upper and lower layer is indistinguishable. The consolidation rate of soil on these sections are very low.

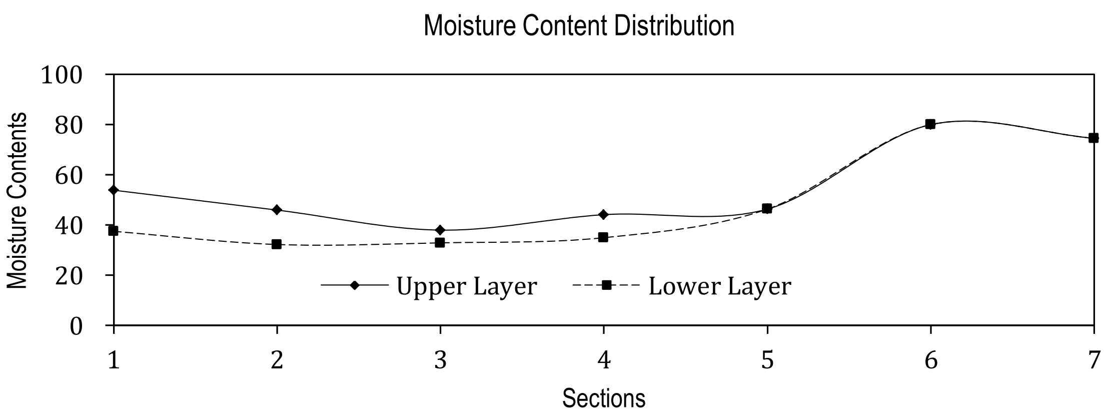

Fig. 8 Moisture Content Distribution

The results of the laboratory sieve analysis of the soil samples taken from each section of the bag shows that the soil deposited near the inlet has a higher amount of coarse particles than the ones distributed at the far end of the geobag.

4. CONCLUSION

Coarse soil particles accumulates near the inlet of the transparent geobag because it is denser than the fine grained soil, the coarse soil particles are attracted by gravity and settles immediately near the bottom after entering the inlet. Fine grained soils on the other hand are distributed throughout the length of the bag because it has a slow sedimentation rate. The weight of the new layer of soil added help accelerates the consolidation of the underlying soil layer. The decrease of soil solid volume in the consolidated areas causes the expulsion of water. Highly consolidated areas has less amount of moisture content and has the most coarse soil particles.

Draining the water from the bag also influences the consolidation process. As water was drained from the geobag, the consolidation of the soil particles also increases.

ACKNOWLEDGEMENT

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