Sand Spreading on Clay Slurry with Jute Sheets

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ABSTRACT: The layered clay-sand scheme of land reclamation involves the formation of thin sand seams sandwiched in between hydraulically placed marine clays. In a situation of scarce and expensive sand supply, it is desirable to minimize the losses of sand through penetration into the very soft clay slurry during the process of forming the horizontal sand seams. The factors that affect the efficacy of the jute layer in minimizing sand losses into a clay slurry are the height of drop of the sand through still water before hitting the jute interlayer, the intensity of sand spreading, the relative sizes of sand particles to the opening size of the jute fabric, and the clay slurry strength. Experiments are conducted to examine the effects of each of these factors, and the results are verified by gamma-ray density profiling of the clay column before and after sand spreading. Results indicate that the key factors that control sand penetration are the relative sizes of sand particles to jute opening, the intensity of spreading, and the slurry strength.

1 INTRODUCTION

The layered clay-sand scheme of land reclamation involves the forming of thin sand seams sandwiched in between hydraulically placed marine clays to provide shorter drainage paths for the rapid consolidation of the clay layers during surcharge application. The success of the scheme hinges on the formation of thin sand seams on top of very soft clay slurry, which is hydraulically pumped into an enclosed pond. Based on a laboratory study on sand penetration into clay slurry carried out by Inoue et al, 1991, the success of forming a thin sand seam on the top of the soft clay slurry is dependent on the intensity of sand spreading, the water depth for spreading, the grain size distribution of the sand used, and the slurry strength, which is intrinsically associated with the slurry water content. The amount of sand loss is dependent on slurry strength, and it is obvious that more sand is needed for penetration and strengthening of the clay slurry in the case of the weaker slurries of higher water content.

For this study, slurries of 2 to 5 times the liquid limit are considered. When sands are spread onto the free surface of water, the particles fall in a lump mass for a certain depth before they are dispersed into single particles, and hit the surface of the clay slurry at a certain velocity, depending on the water depth. The sand particles will reach the terminal velocity if they pass through a sufficient depth of water before hitting the clay surface. For the use of jute geotextiles in preventing sand penetration into very soft clay slurry, the parameters to be examined are : (a) The effect of depth of water through which the sand particles travel before hitting the jute sheet; (b) The equivalent thickness of sand spread to be applied at each time of spreading; (c) The effect of the sand particle size relative to the fabric opening size, and the distribution of sand particles in the sand mass used in spreading; (d) The influence of the slurry strength, which is dependent on slurry water content, in preventing further sand particle penetration after passing through the jute layer.

2 TEST SETUP AND PROCEDURE

Two test devices were used to conduct a study of sand penetration through jute geotextiles. The first section describes the sand penetration through a restrained jute geotextile into a clear water column, while the second section describes gamma ray measurements for a density profile along a clay column before and after spreading sand through a water column onto a restrained jute geotextile on top of a slurry clay column.

The jute geotextile was positioned in the water column at a height of 20cm above the base of the perspex cylinder of diameter 20cm as shown in Fig. 1. Two types of woven jute geotextiles with unit weights of $0.5kg/m^2$ and $0.6kg/m^2$, apparent opening sizes (AOS) of 5.5mm and 2.7mm, and tensile strengths of 10 to 20kgf/cm, respectively, as determined by Karunaratne et al, 1992, are used in these experiments. Before placing the jute sheet in the cylinder, the jute sheets were soaked overnight to remove air voids from the jute fibre strands. After clamping the jute sheet and the perspex cylinders, fresh water was added up to the desired height. The sand spreading device was then placed on top of the upper cylinder. Different quantities of different sand could be spread for different heights of water column.

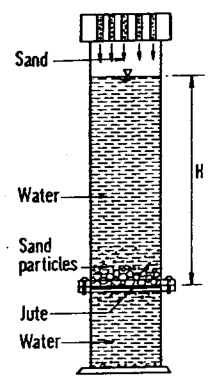

Fig 1. Set-up of apparatus for sand penetration study

3 TEST RESULTS

The grain size distribution of the sand used consists of 5% fine sand, 35% medium sand, and 60% coarse sand, typical of sand used in our reclamation works. To determine the effect of the intensity of sand spreading, six different quantities of sand, 0.2kg, 0.5kg, 0.9kg, 1.2kg, 1.6kg and 2kg are used for three different water column spreading heights of 0.5m, 0.75m, and 1.0m. Fig.2 shows the percentage of sand passing through with respect to different amounts of sand spread, for the two jute types and for different spreading heights. For the $0.5kg/m^2$ jute with AOS of 5.5mm, the trend indicates that the percentage of sand passing the jute decreases rapidly up to a sand intensity of 1kg (equivalent thickness of 4.7cm), beyond which the percentage of sand loss remains below 5%. But for the $0.6kg/m^2$ jute with AOS of 2.7mm the amount of sand that passed through was very small for all intensities of sand spreading. However, a similar trend of decreasing percentage sand loss is observed with increase in intensity of sand spread, with a stable value below 2% beyond 1kg (4.7cm) of sand spread. It is also noticeable from this figure that there is a small rise in the amount of sand that passed through the jute openings at lower spreading heights. The decrease in percentage of sand loss with increase in intensity of sand spread is expected as the larger sand spread would permit the rapid formation of "bridges" across the jute openings by the larger particles thus preventing further losses of the subsequent falling sand.

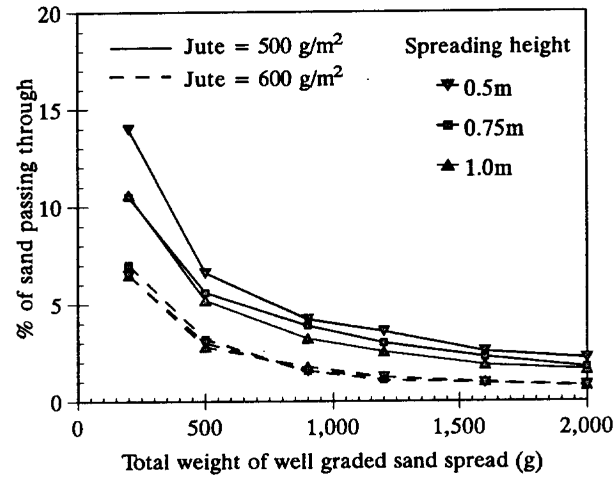

Fig 2. Effect of intensity of sand spread

To obtain a clear effect of the spreading height, controlled quantities of sand of 0.5kg, 0.9kg, and 1.2kg were spread through 0.5m, 0.75m, 1.0m, 1.2m and 1.5m heights of water column. Fig.3 shows the amount of sand passing through the $0.5kg/m^2$ jute openings versus the spreading heights in water. The spreading height has some influence up to 1.0m height of water column. Beyond 1.0m depth, the quantities of sand passing the jute are about constant for a particular intensity. This is probably due to the velocity that sand particles attained after travelling through the water column before hitting the jute sheet. Also with the larger sand mass representing larger momemtum, more sand would pass through for a fixed spreading height. It was concluded by Inoue (1991), that the minimum depth for a mass of sand particles to reach the mass terminal velocity in water is between 1.0m and 1.5m. At a water depth of less than 1.0m, the sand particles will hit the jute sheet before being fully dispersed, with higher impact energy to penetrate through the jute sheet openings. It is clear that the amount of sand that passed through the jute is not significantly influenced by the height of fall through the water, provided the jute is restrained, and the water depth exceeds 1.0m.

To get the effect of particle sizes, different individual sizes of sand particles were spread over the jute sheet through 1.0m depth of water in a 20cm diameter cylinder. Fig.4 shows the particle sizes versus the amount of sand that passed through the $0.5kg/m^2$ jute openings for six different amounts of sand. It is found that a considerable amount of sand passed through the jute openings for sand particles below 0.2mm before effective bridging could be created. Most of the sand particles remain on the jute sheet for particle sizes of 0.6mm and above. Therefore, with an AOS of 5.7mm, it is apparent that for particle sizes greater than 1/10th of the AOS the bridging effect is marked, and the jute can effectively retain nearly all of the falling particles. Generally, for any particle size, the larger the intensity of sand spread, the smaller the percentage of sand passed through, as the larger spread allows for easier formation of effective bridges which prevents further sand losses through the jute openings, of particles that landed subsequently.

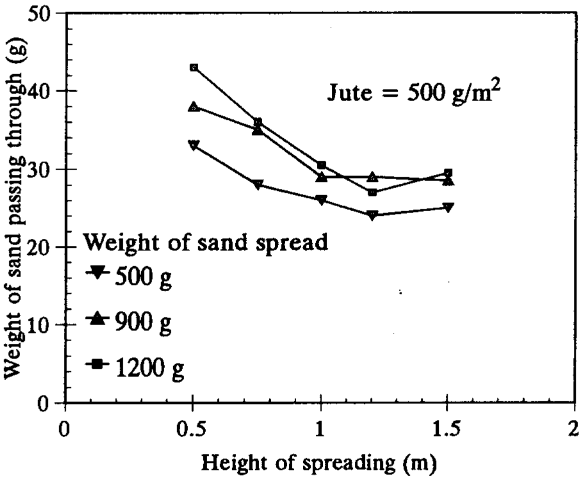

Fig 3. Effect of height of spreading

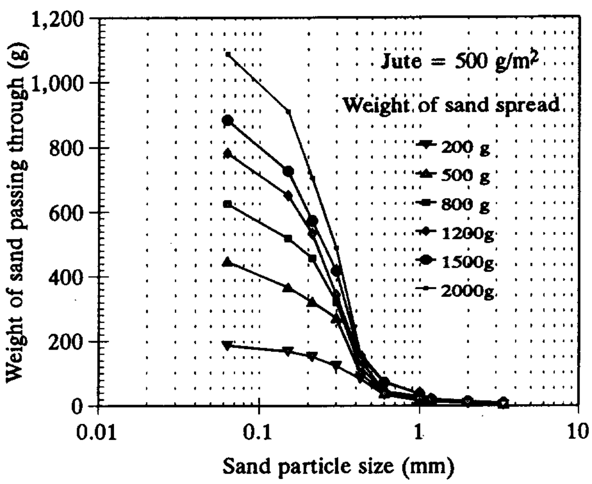

Fig 4. Effect of particle size

To study the effects of clay slurry strength which is intrinsically related to its water content, tests were conducted with different sizes of sand particles spread at three different intensities of 0.5kg, 1.2kg, and 2kg, through a water depth of 1.0m, onto a restrained 0.5kg/m^2 jute sheet placed on the surface of clay slurries at water contents of 200%, 300% and 400%. Figs.5 shows the typical test results as the percentage of sand passed through for a 9.3 cm sand spread. From the results, it is obvious that particles greater than 1/10th of the AOS are effectively retained by the jute sheet. But, for particles smaller than 1/10th of the AOS, the slurry strength plays a major role in reducing the percentage of sand penetrating into the slurry. For fine sand, reducing the slurry water content from 400% to 300%, reduces the percentage of sand penetrating from 40% to about 30%. But reducing the slurry water content from 300% to 200% dramatically cuts down the percentage of sand loss from 30% to 5%. This result is supported by the measured values of slurry/jute interface friction for the jute sheet as reported by Tan et al. (1993), whose measurement is made by a vertical jute sheet penetration test into clay slurries at varied water contents. The jute/slurry interface strength increases dramatically when going from 300% to 200% water content of clay slurry, which accounts for the large reduction in percentage of fine sand penetrating into clay of 200% water content.

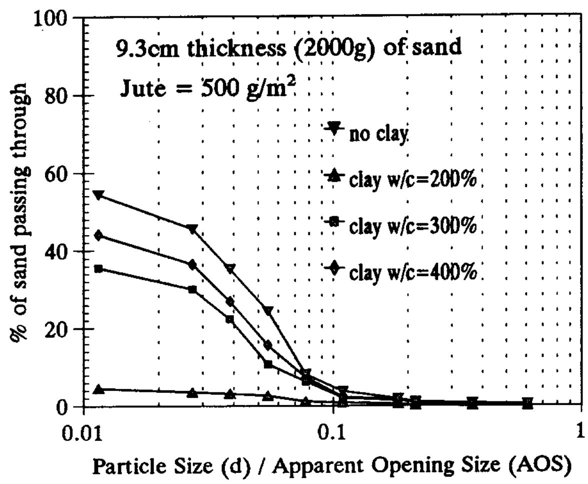

Fig 5. Effect of clay slurry strength

The results of the sand penetration into the clay slurry through the jute openings was determined by measuring the density profiles of the sand penetrated clay immediately before and after spreading the sand through the water column. Figs.6 shows the density profiles of the clay column at 300% water content before and after the spreading of about 15cm of sand with the grain size distribution (GSD) used. Without jute, the slurry at 300% is too weak to prevent sand penetration, and nearly all of the sand spread penetrated into the clay slurry. However, with a restrained jute sheet, nearly all the sand poured, both for the distributed and the fine sand cases were retained above the jute sheet.

At 400% water content, from Fig.7, it can be seen that nearly all of the 15cm of sand is retained, but in the case of the fine sand with GS<0.2mm, about 30% of the sand penetrated into the clay slurry, with the sand evenly distributed throughout the clay column. For the distributed sand with about 60% coarse sand, the larger particles would fall faster through the water depth than the finer particles, and hence form effective bridges across the jute openings to prevent the finer particles from passing through, thereby, retaining most of the sand above the jute geotextile.

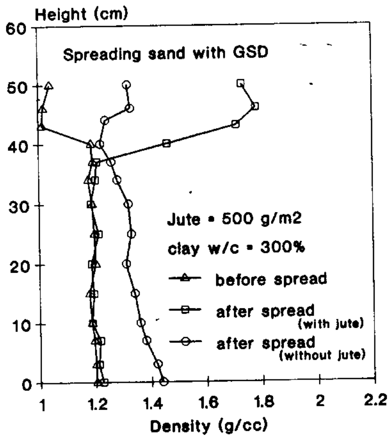

Fig 6. Density profiles of 300% clay, w and w/o jute

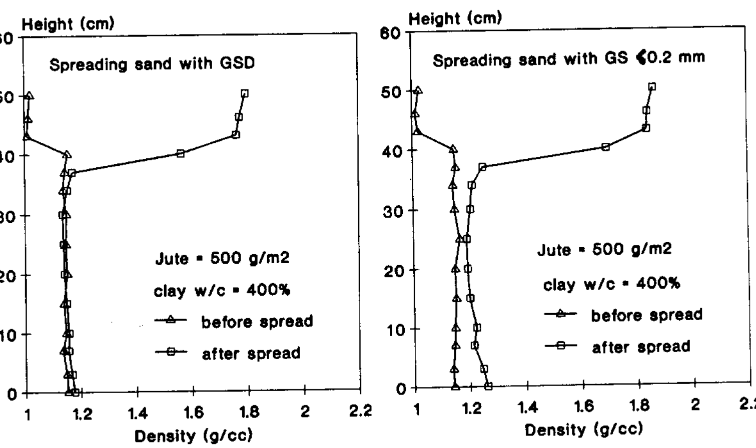

Fig 7. Density profiles of 400% clay after sand spread

4 CONCLUSIONS

From the above study, the following conclusions can be made about the efficacy of jute geotextiles of 0.5kg/m^2 and 0.6kg/m^2 in restraining sand penetration in a very soft clay slurry :

(1) Penetration of sand particles through a jute sheet does not depend significantly on the water depth through which the sand fall, provided that depth greater than 1.0m is used, which is adequate to ensure that the mass terminal velocity is reached by the falling sand before impacting the jute sheet.

(2) The effect of the intensity of sand spreading for the 0.5kg/m^2 is that with the larger intensity of sand spread, a smaller percentage of sand would pass through the jute sheet because of the bridges formed by the larger particles across the jute openings, thus preventing further sand loss from the sand that deposits subsequently. However, the jute must be restrained and the bearing capacity of the jute/slurry system must be adequate to sustain the sand load. This effect is not clear for the 0.6kg/m^2 jute since with an AOS of 2.7mm, nearly all sizes of sand are effectively retained by the jute.

(3) The most significant factor controlling sand retained on jute is the ratio of the particle size to the AOS of the jute geotextile. It is apparent that for particle sizes greater than 1/10th of the AOS, nearly all of the sand particles are retained by the jute.

(4) For particle sizes finer than 1/10th of the jute AOS, the slurry strength plays the most important role in preventing large sand penetration. With the use of a 0.5kg/m^2 jute interlayer, a thin sand seam with fine sand can be formed above a slurry of water content about 5 times its liquid limit with minimal sand losses.

5 ACKNOWLEDGEMENTS

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