Use of Jute Geotextile in Layered Clay-Sand Reclamation Scheme

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ABSTRACT: The layered clay-sand scheme of land reclamation involves construction of thin sand layers alternating between thicker clay layers. These sand layers serve as horizontal drains for rapid consolidation of the clay layers in the reclamation fill. The motivation behind the scheme is to replace, as much as possible, the scarce and expensive sand supply by readily available seabed clayey soils. Although the concept is simple, it is impractical to support sand on top of soft dredged clay slurry with a water content more than twice the liquid limit. In this instance, the use of an inexpensive woven jute geotextile as an interlayer on the surface of the soft hydraulically placed clay slurry is found to minimize the sand losses through penetration in the clay slurry. This paper summarizes various considerations for such an application of jute geotextile.

1 INTRODUCTION

The layered clay-sand scheme of land reclamation involves the construction of thin sand seams sandwiched between hydraulically placed marine clays. The shortened vertical drainage path leads to the rapid consolidation of the clay layers during surcharge application. The scheme has been implemented on a small scale of a 30m x 20m experimental pond at Pulau Tekong Besar (Lee et al, 1987), and on a larger prototype scale of 40 ha at Changi South Bay, Singapore (Karunaratne et al 1990, 1991).

2 CASES OF LAYERED CLAY SAND RECLAMATION

The field and laboratory studies indicate that slurry consistency below twice the liquid limit would be able to support thinly spread (about 50 mm or less) sand layer with a little sand penetration. In the Pulau Tekong field test, six passes of 50 mm sand spread were made through a water depth of 2 m on to clay slurry of 150% water content (liquid limit of 84%) over a period of 5 days to form a clean sand seam of 150 mm above a 150 mm sand-impregnated clay layer. In the Changi South Bay field trial, it was demonstrated that with multiple passes of thin sand spread of 50 mm per pass on a similar clay slurry at 200% wc, at best, the amount of clay replacing the sand fill is only about 70%. This represented a sand loss of at least 30% by weight of reclamation fill. When sand spreading intensity was increased to 200 mm per pass, sand loss of more than 60% were required to form a sand layer above the clay layer. The amount of sand loss is dependent on slurry strength (slurry water content), and it is obvious that more sand is needed for penetration and strengthening of the clay slurry in the case of weaker slurry at higher water contents.

Thus, it is evident that a low cost jute geotextile placed on the slurry surface prior to sand spreading as in Fig.1, will serve as a separator to prevent sand loss by penetration into clay slurry, and also enhance the bearing capacity of the clay slurry to support the thinly spread sand layer. For this particular application of jute geotextile, three aspects of jute slurry interaction behaviour were studied: (a) the measurement of jute slurry interface shear strength by a proposed vertical jute sheet penetration test, (b) the bearing capacity of jute/slurry system to support a thin spread of sand, and (c) the efficacy of a jute geotextile in trapping

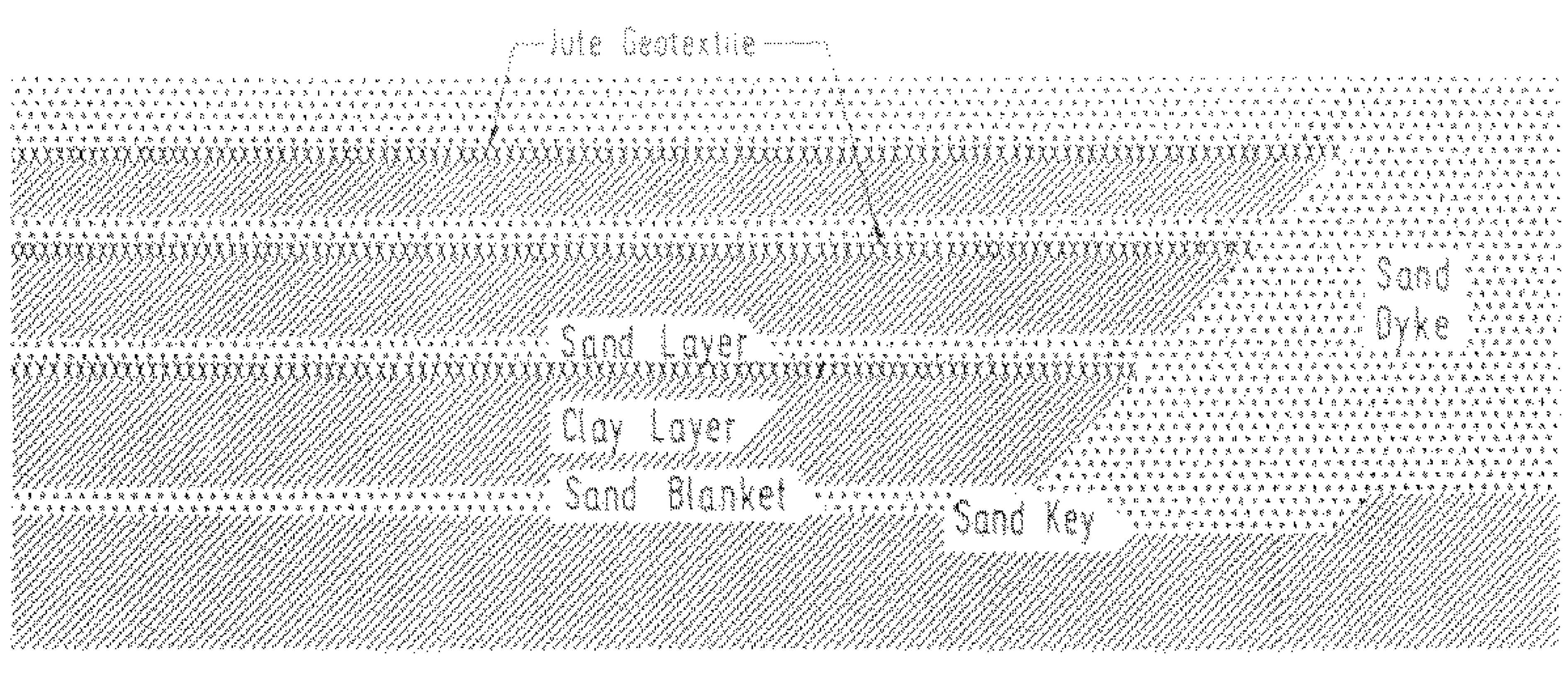

Fig 1. Scheme of layered clay-sand reclamation fill

sand falling through still water. For the scope of this paper, only a brief discussion of each of these studies is presented, since the details will be made available elsewhere.

3 JUTE SHEET PENETRATION TEST

It is difficult to measure the jute/slurry interface friction by a conventional pull-out test in the horizontal direction, as the slurry keeps on settling at high water contents. Instead, it is proposed that a vertical sheet penetration test be used. The principle of this test is similar to the thin plate penetration test for measuring slurry strength at 150% to 300% water contents (1.5 to 3 times the liquid limit), as proposed by Tan et al (1991). The test set up is shown in Fig.2, consisting of a jute sheet geotextile, stiffened at the top and bottom by thin perspex clamps, and weighted down using a lead plate.

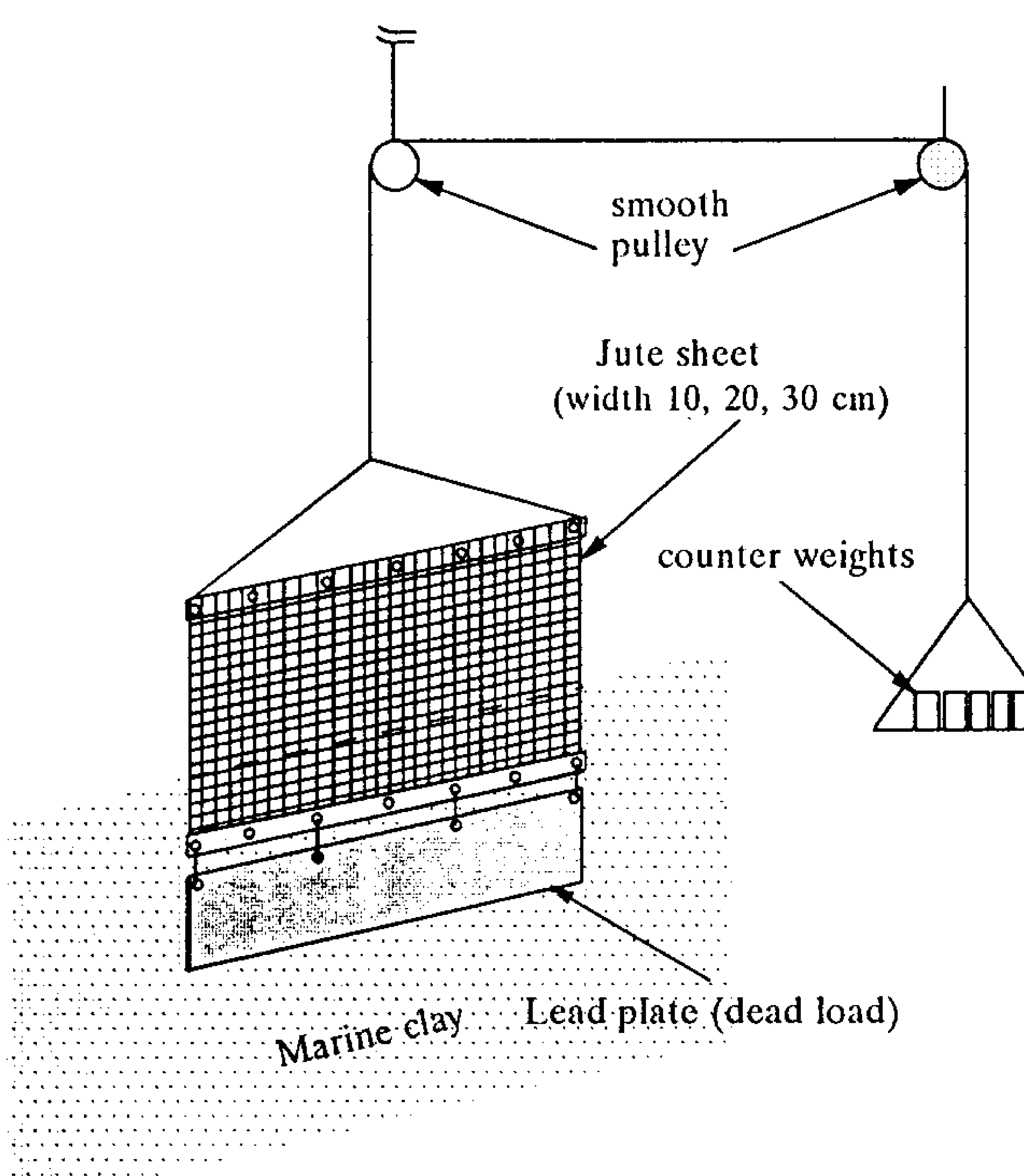

Fig 2. Vertical Jute Sheet Penetration Test

Incremental load is applied by means of careful removal of small weights from the pan, thus allowing the jute sheet to penetrate into the clay slurry until equilibrium is re-established between the incremental load and the jute/slurry interface force together with the resultant incremental uplift buoyancy force from the volume of slurry displaced by the soaked jute sheet. At equilibrium, the balance of forces will give:

$$\tau_g = \frac{\frac{dw}{dz} - tb\gamma_c}{2\,(b+t)} \qquad (1)$$

where τ_g is the interface friction force between geotextile and clay slurry, dw and dz is the load and penetration increment on soaked jute sheet of width b and thickness t, and γ_c is the unit weight of clay slurry. The unit weight of the clay slurry is directly related to its water content *w* by

$$\gamma_c = \frac{\gamma_w G_s (1+w)}{1+eG_s} \qquad (2)$$

where G_s is the specific gravity, e the void ratio and γ_w is the unit weight of water.

A woven jute geotextile of unit mass 500 g/m^2 was tested in Singapore marine clay (LL= 80% to 85%, PL=40% to 45%) slurries of water content 200% to 600% and the calculated interface shear strength was obtained as a function of water content as shown in Fig.3. It is observed that τ_g is independent of sheet width tested, and it varies from 40 Pa to 5 Pa for slurry consistency of 200% to 600% water contents. Detailed results of this study is reported in Tan et al (1993).

4 BEARING CAPACITY OF JUTE SLURRY SYSTEM

In constructing thin sand seams on soft clay slurry, the interface friction determined from the jute sheet penetration test is useful to evaluate the bearing capacity of jute-geotextile-overlain clay slurry at water contents between 200% and 300%, which is the range of interest in the field projects. The general bearing capacity theory has been extended to large anchored geotextile surface reinforcement of very soft clay (shear strength less than 2 kPa) by Yamanouchi et al (1992).

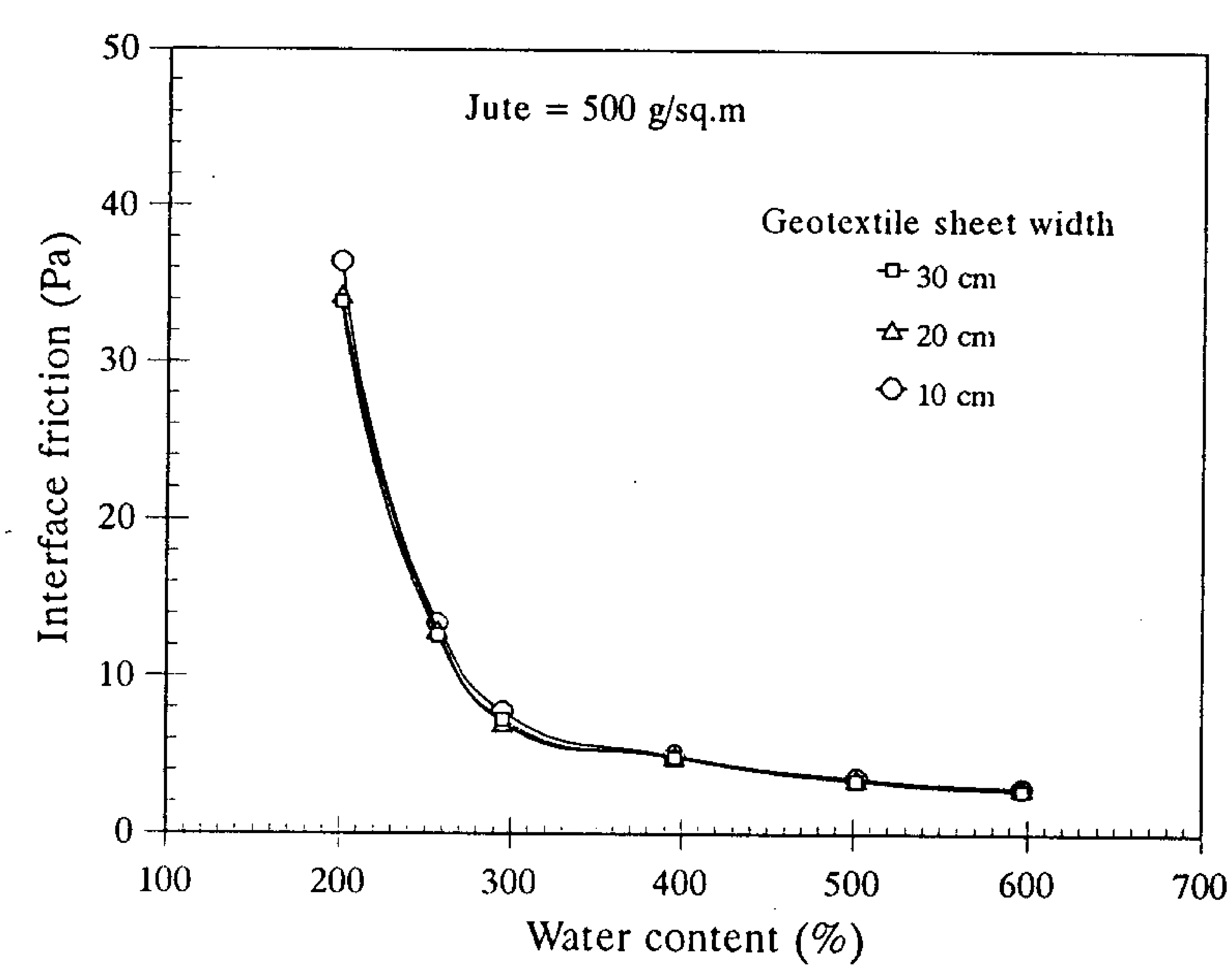

Fig 3. Variation of Jute Geotextile/Clay Slurry Interface Friction with Water Content

In this application, the jute sheet will not be anchored at one end and, therefore, little support from the tension developed in the jute sheet can be relied upon. Load tests on unanchored jute sheet floating on clay slurry were made in the apparatus shown in Fig.4. Typical results of the net vertical pressure under the jute sheet versus its penetration into clay slurry is shown in Fig.5, which shows that equilibrium can be reached after about 20 to 60 mm settlement has occurred. The net pressure can also be re-interpreted as the jute/slurry interface shear strength times a bearing capacity factor, from which it is shown that N_c lies between 5 to 6.5 for woven jute sheet on slurry of 150% to 300%. These values are agreeable with shallow footings on saturated clays, whose lower bound solution (assuming punching shear failure) gives N_c of 4, and upper bound solution (assuming circular rotational failure) is 2π. The full description of this investigation can be found in Tan et al, 1994. For practical applications, the values of τ_g from Fig.3 and Nc obtained above can be used to estimate the thickness of sand that can be supported on an unrestrained jute overlying a slurry of known consistency.

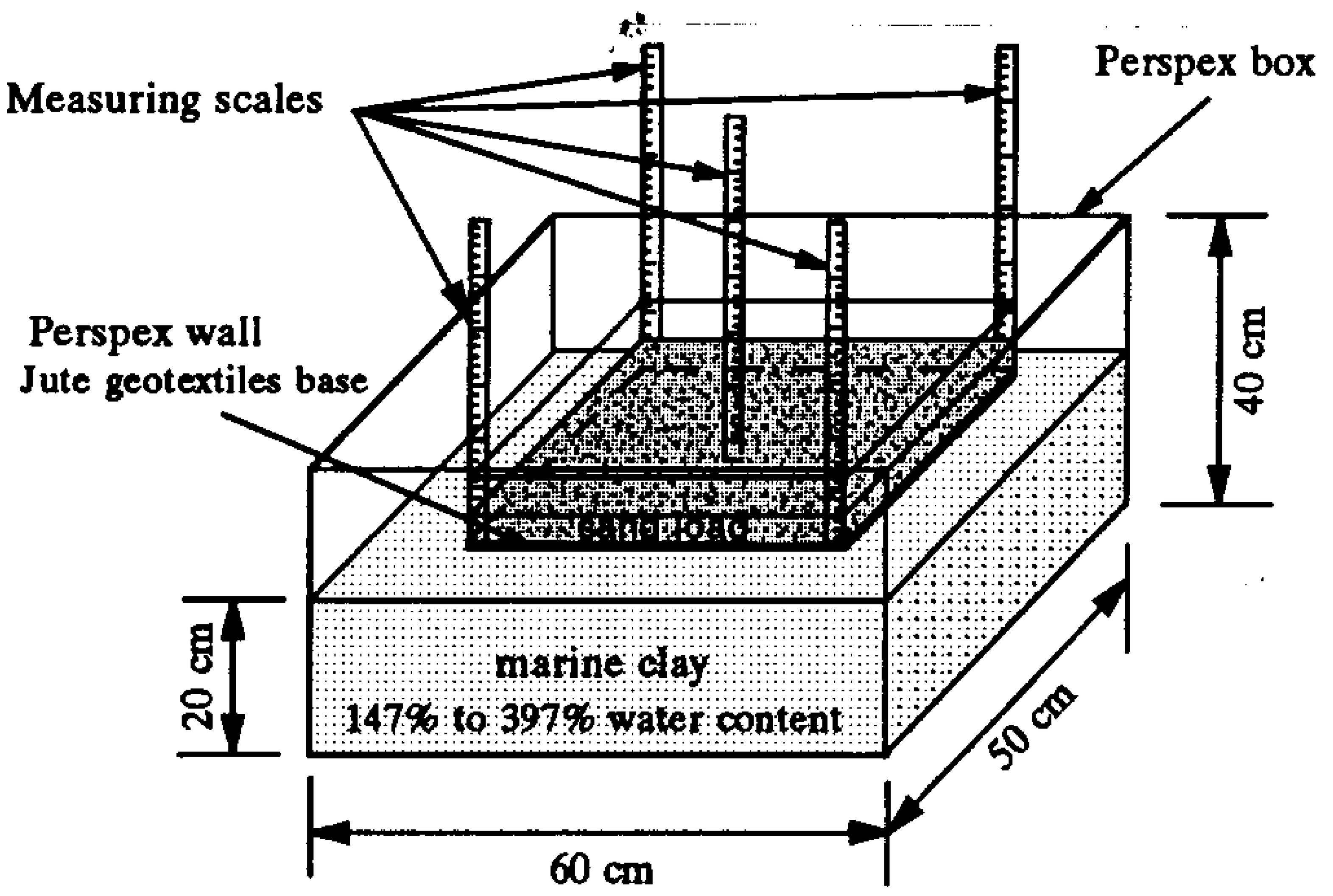

Fig 4. Bearing Capacity Test on Clay Slurry

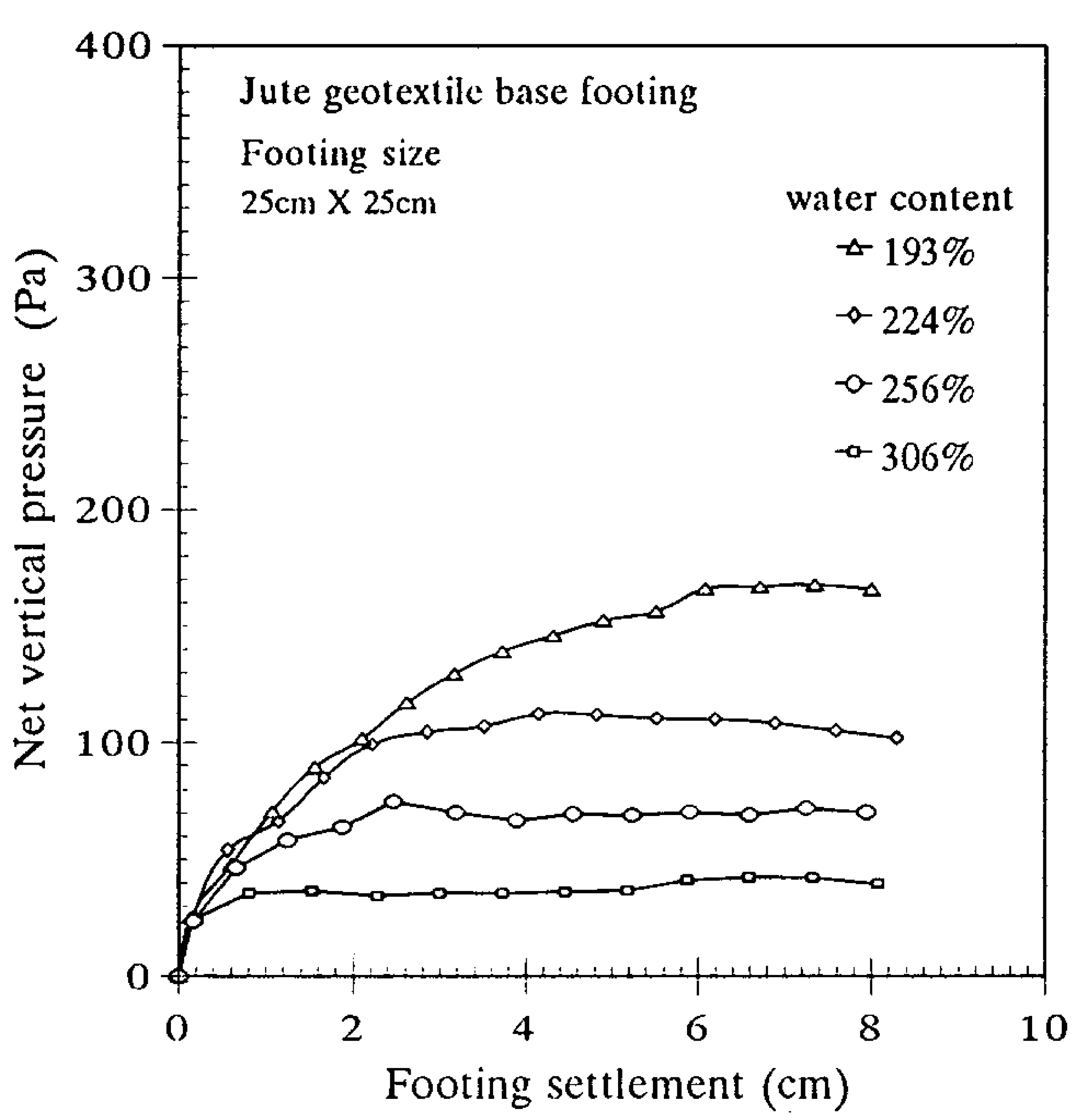

Fig 5. Jute Geotextile Load-Penetration Behaviour

5 SAND PENETRATION IN THE CLAY SLURRY THROUGH JUTE SHEET

For field application of jute geotextile in layered clay-sand reclamation, it is necessary to examine the behaviour of sand penetration into clay slurry falling through a water depth before impinging onto the jute layer. Careful experiments were conducted in the laboratory to examine the effects of water depth, sand thickness, sand particle size and slurry strength on the result of sand penetration into the clay slurry when falling through an unrestrained jute layer. The apparatus for this study is shown in Fig.6. The typical density profile of the clay column with and without a jute layer is shown in Fig.7, where it is obvious that with a jute layer very little sand penetration had occurred after sand spreading. The detailed results of this study was reported in Tan et al (1994).

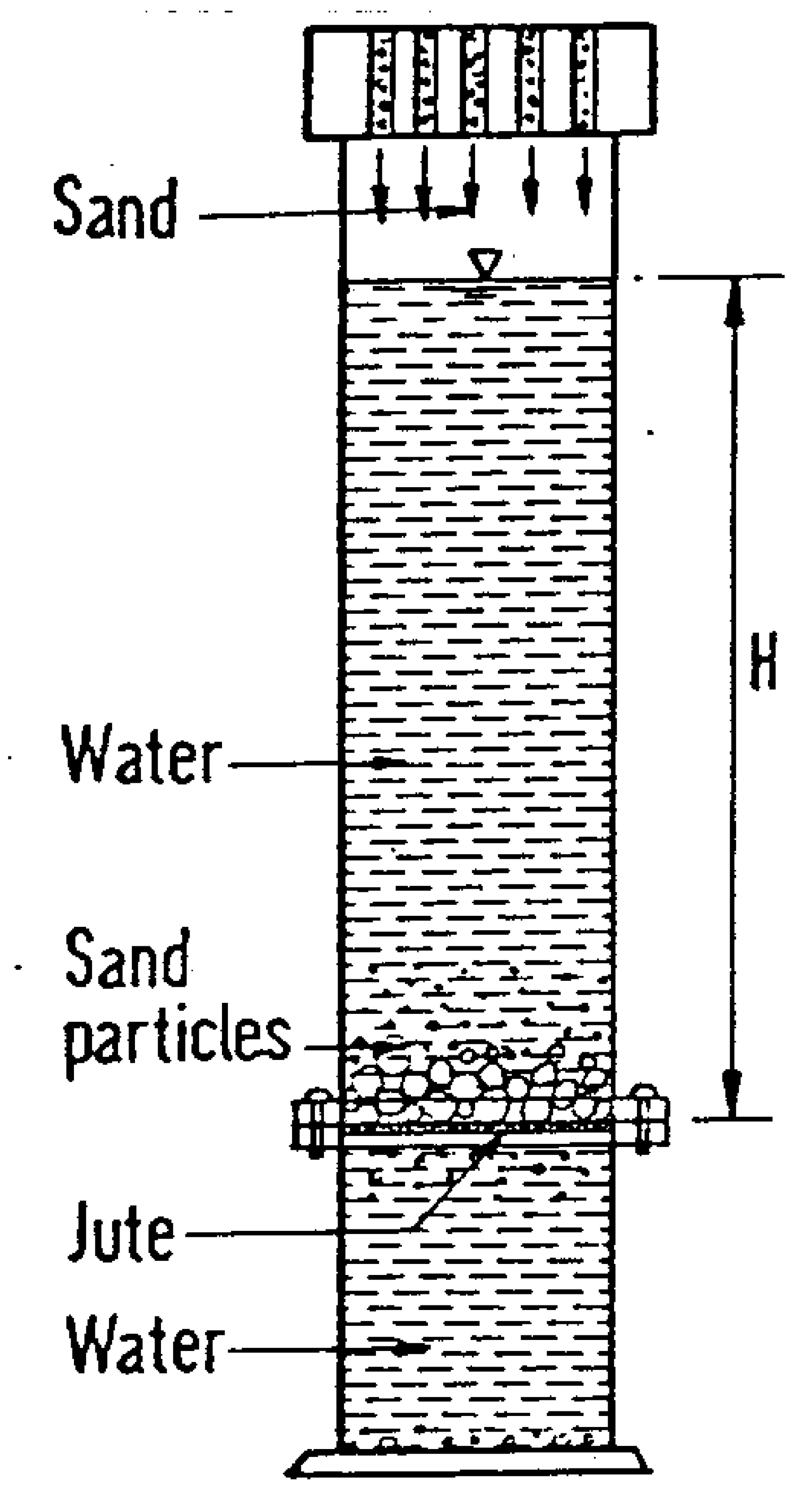

Fig 6. Apparatus used in Sand Penetration Study

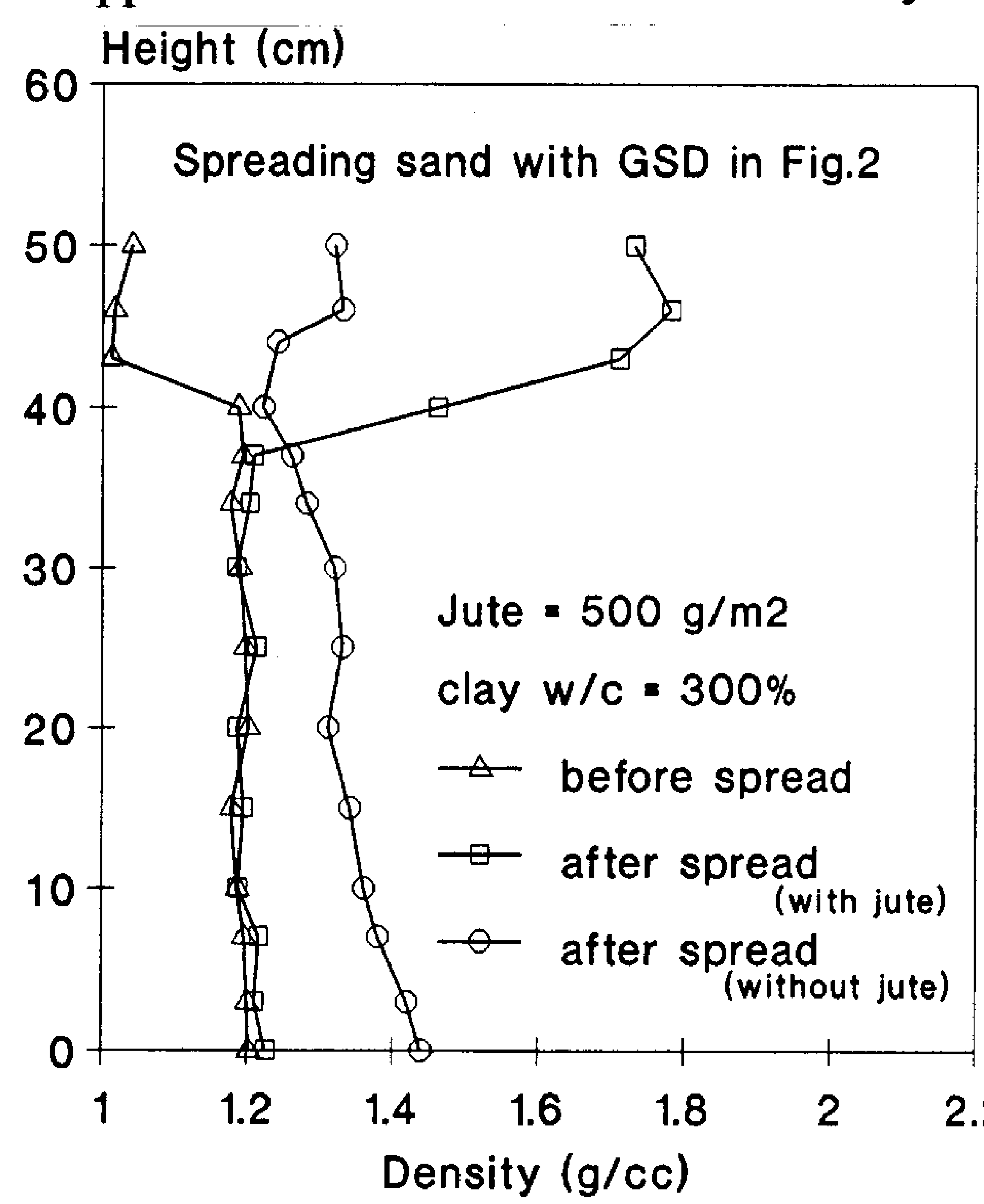

Fig 7. Sand Penetration with/without Jute Geotextile

The study shows that, penetration of sand particles through a jute sheet does not depend significantly on water depth through which the sand falls, provided the terminal velocity has been reached. With a higher intensity of sand spread a smaller percentage of sand would pass through the jute sheet apparently due to the formation of bridges across the jute openings by the larger particles. The most significant factor controlling sand retained on jute is the ratio of the particle size to the AOS (Apparent Opening Size) of the jute sheet. It is shown that particles larger than 1/10th of the AOS will be trapped by the jute sheet without penetrating into the slurry below. For particle sizes finer than 1/10th of AOS, slurry strength plays a dominant role in retarding sand penetration.

6 CONCLUSIONS

From the above study, it is shown that a jute geotextile that is carefully laid onto a soft clay slurry upto 300% water content (3 times the liquid limit), can greatly assist in forming a thin sand seam of upto 50 mm thickness with minimal sand losses. Thicker sand layers can be formed by subsequent sand spreading 50 mm at a time, after allowing some time for the slurry surface to strengthen through rapid consolidation via the jute geotextile and the sand seam formed initially.

7 ACKNOWLEDGEMENTS

The research in this paper is partially funded by the National Science and Technology Board of Singapore under the RDAS Grant No. ST/86/05. The financial assistance of National University of Singapore and the assistance of Messrs PT Indonesia Nihon Seima, Jakarta, Indonesia, in providing jute geotextiles are gratefully acknowledged.

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