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Geotextile–Bamboo Fascine Mattress for Filling over Very Soft Soils in Malaysia

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ABSTRACT

Very soft deposits such as peat, marine clays and tin mining slime are found extensively in Malaysia. Severe problems are encountered when filling over such deposits. Woven and nonwoven geotextiles have been used to assist in fill deposition over such very soft deposits. This paper describes the desired properties of geotextiles for this purpose, methods of placing the geotextile and deposition of the fill. A nonwoven geotextile with a bamboo fascine mattress is found to be most effective.

INTRODUCTION

This paper pertains to the use of geotextiles as a separator and bamboo fascine mattress as a reinforcement to enable controlled fill deposition over very soft deposits. In Malaysia, such deposits take the form of peat, very soft marine clays, and unconsolidated silty clays (slime) found in disused tin mining land.

Different types of geotextiles and methods of laying have been attempted. Highly extensible nonwovens placed over a bamboo fascine mattress was found to be the most appropriate and economical method.

SOFT DEPOSITS

Peat which is mainly found in low-lying poorly drained depressions or basins in the coastal areas occur over a total of 2.6 million ha corresponding to 8% of the total land area of Malaysia. Approximately 1·7 million ha of peat are found in the state of Sarawak (Mutalib *et al.*, 1991).

The peat is characterized by:

(i) high and variable water contents ranging over 200–2000%;
(ii) low bulk densities of the order of 10 kN/m^3; and
(iii) low shear strengths generally of the order of 5–10 kPa.

Soft marine clays of Quartenary age are found throughout the coastal plains of Malaysia, giving rise to broad structures of flat to gently undulating terrain. Descriptions and properties of soft clays in Malaysia are given by Ting *et al.* (1988), Malaysian Highway Authority (1989), Raj and Singh (1990), Chee (1991) and Chee *et al.* (1992). Generally, the vane shear strengths of the upper regions range over 8–15 kPa with the strength increasing with depth. The thickness of the soft clay deposits may extend to more than 30 m.

Unconsolidated silty clays (slime) are the end result of tin mining activity. Such activities were concentrated mainly in the Kinta Valley and the Kuala Lumpur–Langat tin fields, resulting in significant areas in and around present day Ipoh and Kuala Lumpur being underlain by tin tailings. Methods for reclaiming disused tin tailings are given by Toh (1989) and Toh *et al.* (1992). These unconsolidated sediments found within tailing ponds are generally characterized by very low to low undisturbed vane shear strengths typically less than 5 kPa.

DEPOSITION OF FILL

Deposition of fill into very soft deposits often results in the following problems:

(i) excessive lateral movements;
(ii) remoulding of the very soft deposits with heave of remoulded material and the formation of mud waves;
(iii) mixing of fill with the very soft material and the trapping of soft clay pockets within the fill; and
(iv) consequential significant differential settlement.

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Fig. 1. Heave and displacement from end tipping into peat.

The above problems are more severe for peat and unconsolidated mining slimes than marine and alluvial clays.

Figure 1 illustrates the results of end tipping into peat. The tilting of the trees on both sides of the fill indicates excessive lateral movements. Toh *et al.* (1990) demonstrated the effectiveness of lowering the ground water table to improve the peat for the purpose of fill placement without the problems described above. However, in areas where drainage for the purpose of lowering the water table cannot be effected, a geotextile on a bamboo fascine mattress as described in the following sections of this paper has been found to be very effective. Other methods for filling over peat include the use of planks and timber placed side by side to form a continuous mat.

Figures 2 and 3 illustrate the end results of uncontrolled filling by end tipping into a disused tin mining slime pond. The resulting heave causes soft material to rise to occupy the remainder of the pond. Unless the pond water depth is significant and structures exist near to the pond, dewatering is normally carried out before placement of fill. Working in the dry permits speedier operations, compaction of fill by normal compaction plant and the use of residual soil fill, sand fill being more expensive. Dewatering, however, poses difficulties in the laying of geotextiles since

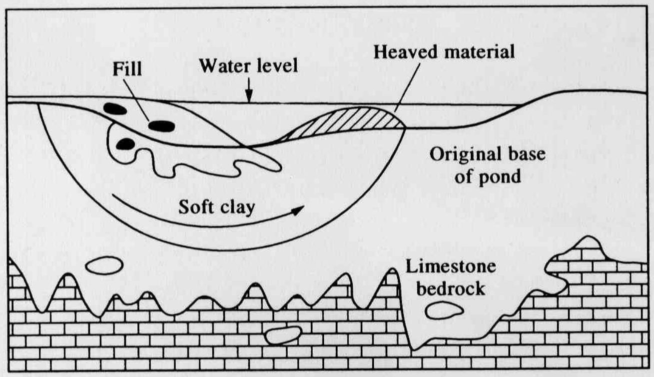

Fig. 2. Heave and displacement of soft material from uncontrolled filling of a slime pond.

Fig. 3. Mud waves from end tipping into a disused tin-mining slime pond.

the very soft consistency of the slime does not permit access by plant, machinery or human beings. Further geotextiles cannot be rolled directly on to the slime without the roll sinking into the very soft material. As for peat areas, a geotextile placed over a bamboo fascine was found to be the most effective method of overcoming the above problems.

GEOTEXTILE

The geotextile for use with a bamboo fascine mattress for filling over soft material is intended to serve as a separator to prevent fill mixing with the soft deposits causing remoulding and excessive heave and thereby resulting in loss of control of the filling process. Intermixing of fill and soft deposits will also result in the loss of mechanical properties of the fill material. In order for the geotextile to serve effectively as a separator, it must be able to withstand the construction stresses caused by the filling operation. Hence, the selection of the appropriate type and grade of geotextile must take into consideration the survivability criteria.

The geotextile properties necessary for the fulfilment of the above function and survivability criteria are:

(i) a high puncture resistance. Puncture can be a common occurrence caused by debris at the base of the pond and wood pieces in peat areas. Resistance to puncture may be best achieved by use of nonwoven geotextiles with continuous filaments which serve to provide a compact and entangled structure. Geotextiles with low puncture resistance would require a high tearing resistance;
(ii) a high percentage elongation at break because of the large strains due to heave ahead of the filling front;
(iii) a high resistance against bursting due to the upward pressure on the geotextile caused by the mud wave ahead of the filling front;
(iv) high permeability to enable rapid dissipation of pore pressures of the mud wave built up by the filling operation;
(v) strength isotropy to ensure against weakness in any particular direction.

While high tensile strength is an added advantage, such increased strengths are generally associated with significantly higher costs. Due to the possibility of prolonged exposure on site, the geotextile should have a high UV resistance.

SEWN SEAMS

Tearing whenever encountered invariably occurred along the sewn seams and attention had to be focussed on achieving high seam efficiencies.

'Flat' or 'Prayer' type seams sewn in two rows are prefered over 'Butterfly' or 'J' seams (Dias, 1985) due to ease of sewing on site especially for thicker geotextiles.

Polyester threads with dtex 3 × 1100 with break strength of 19 kg was

Table 1
Seam Strength Tests

Test no.	*Strength (N/200 mm)*	*Observations*
1	3 754	Rupture of fabric
2	4 558	Rupture of thread
3	3 170	Rupture of fabric
4	4 200	Rupture of fabric
5	4 038	Rupture of fabric
Average	3 944	

found to be satisfactory. Polyester threads are prefered due to higher UV resistance and better resistance to effects of prolonged exposure to moisture.

'101' Single Thread Chainstitch sewn in two rows or '401' Two-Thread Chainstitch (Dias, 1985) sewn in one row both with stitch densities of 3·5 stitches/in were found to be adequate. Seam strength tests (ASTM, 1990) were carried out on Polyfelt TS720 geotextile samples sewn together using a '401' Two-Thread Chainstitch with a stitch density of 3·5 stitches/in. The test results summarized in Table 1 indicate seam efficiencies of 100%.

BAMBOO FASCINE MATTRESS

It is not possible to lay and to effectively connect together sheets of geotextile over large areas for which access is a major difficulty.

The functions of the bamboo mattress are:

(i) to enable the initial necessary human access into the pond; and
(ii) to provide a platform for laying and sewing the geotextile. The configuration of the bamboo fascine must be such that the geotextile may be rolled directly on to it.

The bamboo fascine mattress also serves as a reinforcement at the base of the fill by providing bending and tensile resistances, and by so doing:

(a) increases the factor of safety against bearing capacity failure;
(b) reduces the magnitude of mud waves ahead of the filling front; and
(c) allows the machinery access after deposition of about 300–500 mm of sands or gravels.

Some laboratory tests demonstrating the enhanced bearing capacity of footings on soft clay by use of rods possessing both tensile and bending stiffness with a geotextile were reported by Yusuf *et al.* (1989).

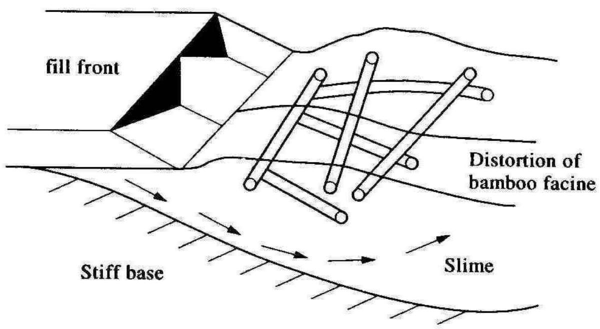

Fig. 4. Distortion and displacement of bamboo fascine.

The bamboo pieces must be properly tied together by wire to form a rigid and secure frame and properly anchored in place at the edges to prevent the lateral movements of the soft deposit displacing and distorting the bamboo frame away from the geotextile in the manner illustrated in Fig. 4.

INITIAL LAYER OF FILL

The first fill layer should preferably be sand and be of a thickness which ranges over 300–600 mm in order to ensure against excessive stresses on the geotextile due to earthworks equipment as well as to ensure against bearing capacity failure and excessive heave. Spreading of the initial sand layer is best done by use of light equipment such as backpushers. The fill stockpile should be kept a minimum distance of 20 m behind the filling front in order to avoid bearing capacity failure.

CASE HISTORIES

Case 1

Figures 5–7 illustrate the first use of a nonwoven geotextile sheet with a bamboo fascine mattress to enable earth filling over a 30 000 m^2 initially inaccessible slime pond at Sungei Besi on the outskirts of Kuala Lumpur. The thickness of slime was generally 20 m but was up to 33 m in localized areas. The undisturbed vane shear strength of the slime was about 5 kPa.

The geotextile used was Polyfelt TS700, a nonwoven continuous filament needle-punched geotextile with a strip tensile strength of 18 kN/m and an elongation at break of 50–80%. Approximately 3 000 m^2 of geotextiles with bamboo fascine mattress was layed in a 10 h working day.

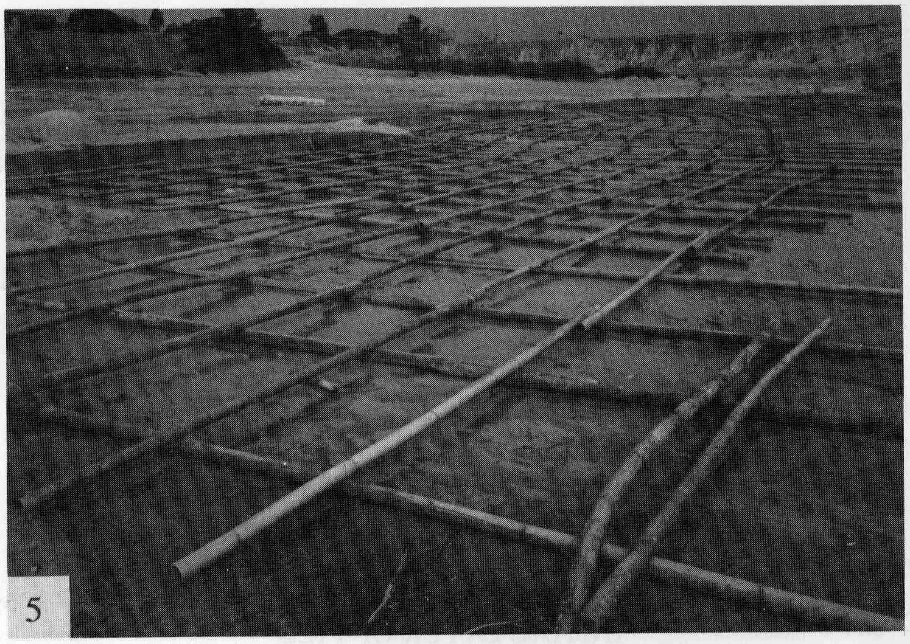

Fig. 5. Bamboo fascine mattress on a slime pond.

Fig. 6. Sand deposition onto geotextile–bamboo fascine mattress over a slime pond.

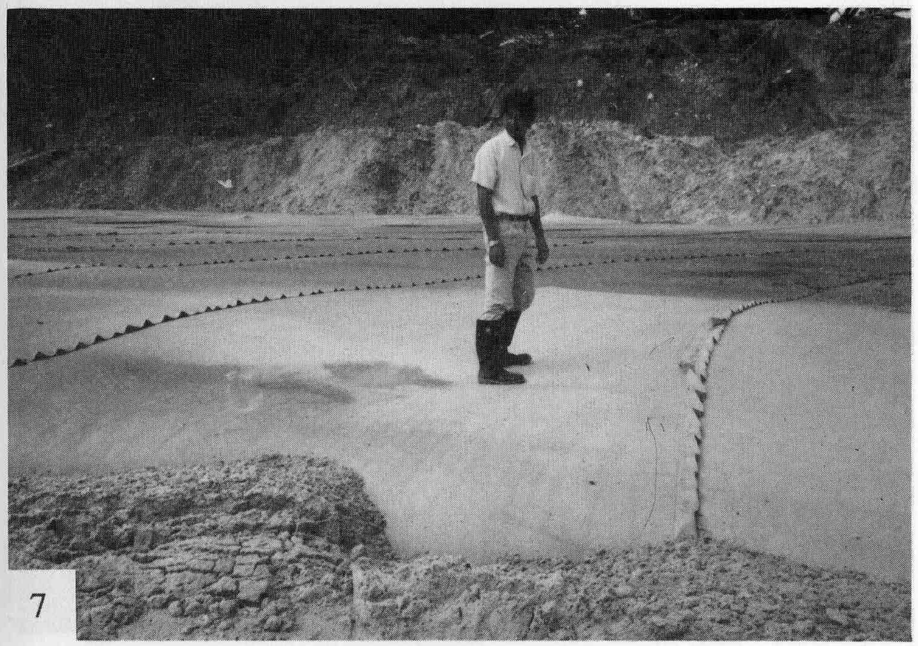
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Fig. 7. Controlled heave ahead of filling front on a slime pond.

Tearing of the geotextile did not take place despite the relatively low tensile strength of 18 kN/m. However, seam tearing did take place (Fig. 8) and this led to the improvements to seam sewing discussed earlier.

Puncture of the geotextile due to distorted bamboo pieces did occur at several places but propagation of tear did not take place due to the mitigating effects of the entangled structure of the needle-punched nonwoven filaments.

Case 2

Figures 9 and 10 illustrate earthfilling operations over a geotextile bamboo fascine mattress at the 5 km Ring Road, Kuching. The subsurface takes the form of peat (moisture contents 200–600%) over soft clays.

Delays in the commencement of earthwork resulted in the geotextiles being exposed for a period of about 3 months. Tensile tests (ASTM, 1986) were carried out on samples of the geotextile, Polyfelt TS700, after that period of exposure to sunlight; the results are summarized in Table 2.

The strength after about 3 months exposure is still higher than the strength value recommended by the manufacturer, viz 18 kN/m. The results show that the recommended values are conservative and that the

Fig. 8. Seam tearing and puncture of geotextile.

Fig. 9. Geotextile–bamboo fascine mattress over peat.

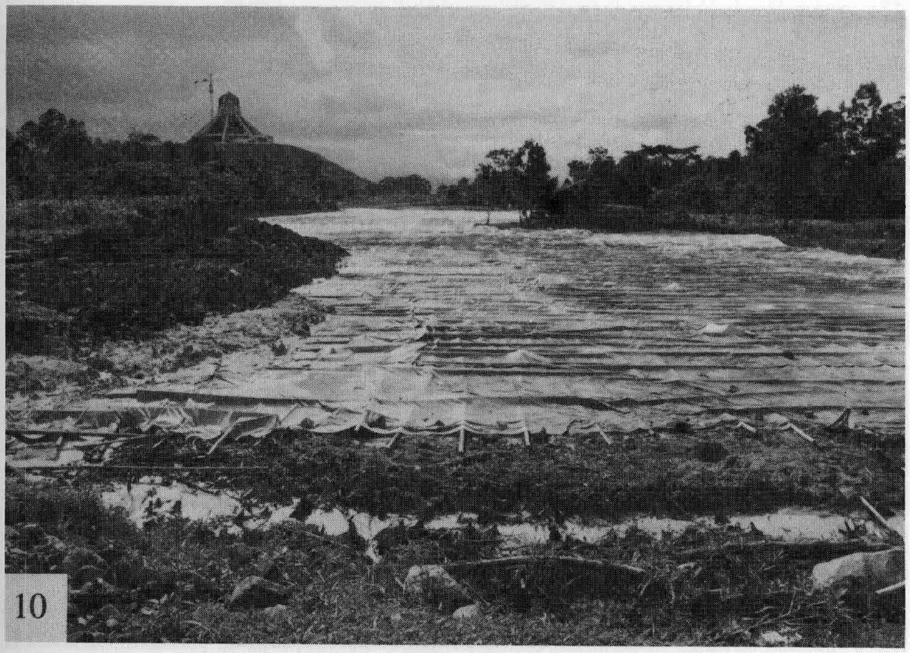

Fig. 10. Geotextile–bamboo fascine mattress over peat.

Table 2
Strength Tests on Geotextiles (3 months exposure to sunlight)

Test no.	*Direction*	*Tensile strength (N/200 mm)*	*Tensile strength (kN/m)*	*Elongation at break (%)*
1	1st direction	4 223	21·1	78·0
2	2nd direction (perpendicular to 1st direction)	4 528	22·6	41·0

hindered amine light (HAL) stabilizer used by the manufacturer to mitigate the degradative effects of UV rays is effective.

An initial sand fill of 300 mm was placed over the geotextile–bamboo fascine before placement of compacted residual soil fill. Minimal heave was reported throughout the filling process which was entirely within control.

Case 3

Figure 11 illustrates the laying of the bamboo fascine mattress on amorphous peat and organic clays after excavation of 3 m of the more fibrous

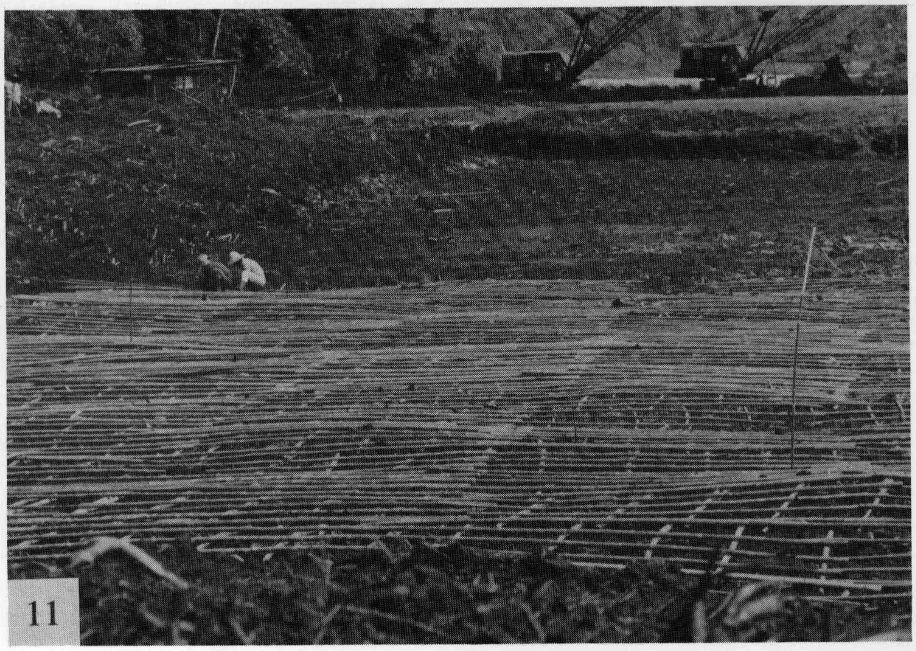

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Fig. 11. Bamboo fascine over peat.

peat. Polyfelt TS720 (tensile strength of 19·5 kN/m) was placed over the bamboo fascine mattress. A 300 mm thick gravel layer placed over the geotextile was sufficient to support heavy equipment for installation of prefabricated vertical drains through the geotextile and soft clays beneath.

SUMMARY AND CONCLUSION

The geotextile bamboo fascine mattress has been successfully used to enable deposition of fill over very soft deposits such as slimes and peat without the problems of mixing of fill with soft deposits, remoulding, mud waves and general loss of control of the filling process.

The bamboo fascine mattress facilitates access, provides a platform for rolling on and sewing geotextiles, increases bearing capacity and significantly reduces mud waves. These properties permit the use of a relatively low strength nonwoven geotextile. It is important that the geotextile used be of high extensibility, possess a high resistance to bursting, be able to mitigate tear on puncture, and be of high permeability. Care should be exercised when sewing the geotextile sheets to ensure a high level of seam efficiency.

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