Geotextile Applications for a Soil Improvement Project in Singapore

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ABSTRACT

This paper discusses the application of geotextiles as a solution for the engineering requirements of a soil improvement project in Singapore. The site was a swamp covered in thick lalang vegetation. The subsoils consisted of very soft silt, peat, peaty clay and marine clay, overlying the Old Alluvium. The design and selection of the geotextile fabrics are presented. Construction details and difficulties encountered on site during the placement of geotextile fabrics are highlighted. The problem with formation of the initial working platform on the soft soils for the installation of vertical drains was resolved by using a geotextile separator for temporary support. The use of high strength geotextile reinforcements enabled the successful erection of the surcharge embankment, whilst allowing the excavation and construction of a concrete lined canal close to the toe of the embankment to progress unhindered.

1. INTRODUCTION

A soil improvement project involving surcharge preloading with vertical drains, was recently completed for the new Temasek Polytechnic campus at Tampines in Singapore. A quarter of the site consisted of a swamp covered with thick lalang vegetation. Due to the swampy conditions, the thick vegetation and the presence of very soft subsoils, it was necessary to carry out site clearance, excavation and construction of a temporary platform before vertical drain installation and embankment build up could proceed. A low strength woven polypropylene geotextile was used to provide temporary support for the working platform as well as separation from the soft soils below. The design of the surcharge embankment was complicated by the excavation of the ground near the toe of the embankment for the construction of a neighbouring 20 m wide and 4 m deep concrete lined canal along the common site boundary. The large unbalanced forces due to the excavation would result in potential instability of the embankment. The length of canal affected was about 650 m long. A conventional retaining system using contiguous bored piles or sheet piles with ground anchors would be very costly in such a situation. High strength woven polyester geotextile reinforcements were therefore used to improve the stability.

2. SUBSOIL CONDITIONS

The subsoil geology at the site consisted of an upper layer of very soft silt, peat, peaty clay and marine clay, overlying the Old Alluvium at depth. The total thickness of soft soils was between 12 m and 17 m across the swamp. There was hardly any fill material at the surface of the ground. The soils were extremely soft and normally consolidated. The water table was located virtually at the ground surface. The typical geotechnical properties of the soils encountered are given in Table 1.

Table 1 Typical properties of subsoils

Soil	Bulk Density (kN/m^3)	Undrained Shear Strength (kN/m^2)	Water Content (%)
Clayey Silt	13.5	3 - 10	133
Peat	10.0	5 - 25	557 - 995
Peaty Clay	11.9 - 14.2	6 - 13	103 - 145
Marine Clay	12.1 - 14.3	8 - 18	103 - 200
Old Alluvium	19.0	-	-

3. DESIGN AND SELECTION OF GEOTEXTILE FABRICS

The existing ground level at the swamp varied between +106.5 MOD and +107.0 MOD. The final ground level was to be raised to between +108 MOD and +110 MOD. Preliminary estimates had shown that total settlements due to the raised ground would be expected to be between 1.5 m and 2.7 m respectively. The surcharge embankment required to effect preloading of the soft soils were constructed to approximately +111 MOD and +113 MOD. The embankments included a 1 m thick working platform and a 1 m thick drainage sand blanket. The material forming the working platform and embankment was a silty clayey sand.

3.1 Stabilization of surcharge embankment

The design of the temporary surcharge embankment was required to take into consideration the excavation of the ground near the toe of the embankment for the construction of the 4 m deep concrete lined canal. The construction of the canal involved bakau piling at the base of the excavation and casting of the concrete structure insitu, and was therefore very susceptible to differential settlement and lateral movement caused by the surcharge embankment. The large height difference would cause a potential slip failure through the underlying soft clays. Stability analysis carried out using the Simplified Bishop's Method indicated factors of safety of 0.3 to 0.5. The typical failure surface passed through the bottom of the peat layer. A minimum factor of safety of 1.2 was required to ensure adequate stability of the embankment and to limit ground deformation so as to allow the construction of the canal to progress without hindrance. (Fig. 1).

High strength woven polyester geotextiles were used to reinforce the embankment and enhance its stability. In the computation of tensile forces, it was assumed in the analysis that vertical tension cracks would develop within the embankment due to the potentially large deformations involved and no contribution from the shear resistance of the embankment material was considered (Rankilor, 1992). The coefficient of friction at the geotextile - soil interface was taken to be 0.5. The anchorage lengths for the reinforcements were designed for a factor of safety of 1.5 on the ultimate pullout capacity. The anchorage lengths were provided up to the slip circle that gave a factor of safety against slip failure of at least 1.2. The allowable tensile strength of the geotextile reinforcement was determined by applying a factor of safety of 2.0 on the material strength (Koerner et al, 1987). The properties of the high strength geotextile fabric used are shown in Table 2.

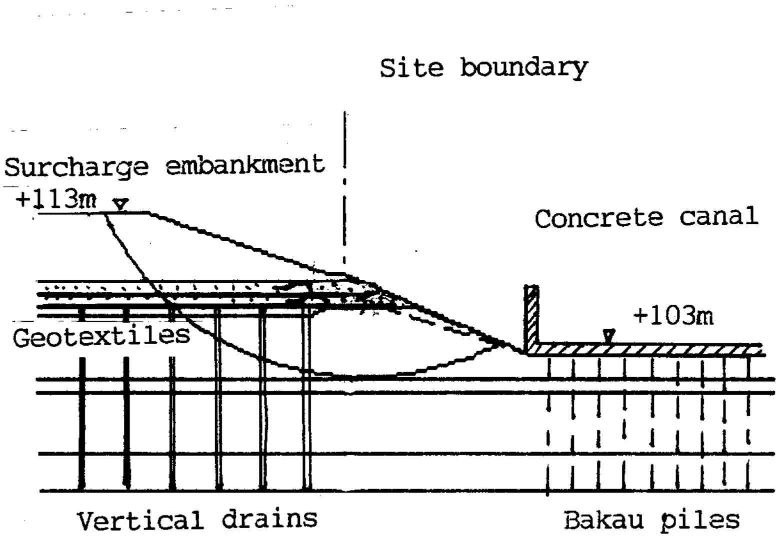

Fig. 1 Application of geotextiles in embankment stabilisation

Depending on the allowable tensile strength required, the reinforcements were used either in one layer or in two layers (Koerner, 1986). Where reinforcements of different strengths were adopted in combination, it was necessary to ensure that the strains at which the respective strengths would be mobilized were compatible. As can be seen from Fig. 2 the stress strain curves for the Stabilanka 800/100A and 400/50A geotextiles were very similar and hence compatibility could be achieved.

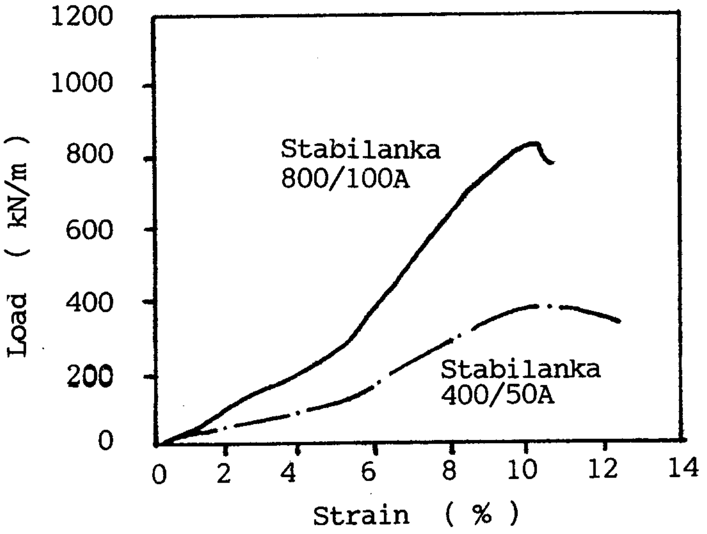

Fig. 2 Load-strain curves for geotextiles

3.2 Separation and stabilization of temporary working platform

The upper soil layer was very soft with undrained shear strength Cu= 3 to 10kPa with a sensitivity ratio of 2.0 to 5.0. It was theoretically just possible to support only a height of working platform of about 1 m with a nominal factor of safety of 1.1. It was therefore necessary to provide an initial layer of geotextile fabric for separation and temporary support to allow the placement of the 1 m high working platform for the installation of vertical drains. Further construction of the embankment would be required to be done in stages with time allowed for consolidation of the subsoils and gain of shear strength. The geotextile separator adopted was a HaTe 6G/125/SA woven polypropylene fabric with a tensile strength of 25 kN/m in both warp and weft directions. The separator was to be spread on the soft soil with 1.5m overlaps on both sides in order to accommodate the anticipated large movements of soil below and to minimise building up of tensile stresses in the separator. The separator fabric has a low modulus and was chosen to ensure that stretching may be accommodated during the placement of the working platform so as to avoid tearing of the fabric. The test results of the fabric are given in Table 2.

Table 2 Properties of woven geotextile reinforcements

Type	Tensile Strength (kN/m)		Maximum Strain (%)	
	Warp	Weft	Warp	Weft
Stabilanka 800/100A	805.1	109.7	10.46	8.41
	806.3	113.8	10.59	9.17
	820.9	108.6	8.84	9.57
	839.0	112.6	10.05	9.51
	855.3	112.5	10.31	8.97
Stabilanka 400/50A	408.0	59.62	10.90	10.88
	427.7	59.13	10.22	11.81
	398.3	53.07	10.25	10.75
	401.4	56.47	10.89	9.90
	397.4	59.69	10.60	10.45
HaTe 6G/125/SA	27.40	27.72	20.0	16.0

4. INSTALLATION AND PERFORMANCE OF GEOTEXTILES

The geotextile separator was to be installed at the bottom of the excavation for the temporary platform. It was not possible to roll the geotextile directly on the ground to spread it as the soft soil could not support the weight of the roll. Stretching the fabric by workers whilst keeping the roll at a higher firm ground was also not successful because the workers would sink into the soft ground while attempting to spread the fabric. After several trials it was decided that the geotextile would be unrolled on firm ground and cut into pieces of 100m length each. These were folded into half successively, so that each piece could be made into a bundle of 1m width (keeping the full dimension in the weft direction, i.e. about 5.0m). The bundles were then transported to the site and unfolded gradually until the full length of geotextile was spread on the soft ground. The geotextile was temporarily fixed to the ground with the aid of steel rods. Approved earth was gradually dumped on the geotextile in controlled small quantities and in stages.

Numerous problems were encountered while forming the working platform even though the geotextile separator offered some temporary support. Earthmoving equipment such as lorries, bulldozers, and excavators had to be restricted from approaching the edge of the working platform to minimize the ground heaving. A safe distance of 20 to 30m from the platform edge was maintained for this purpose. The soil below was extremely soft and at some locations, the consistency of the soil resembled that of a thick soup due to remoulding. The weight of the working platform and the static and dynamic forces caused by the earthmoving equipment created a situation similar to that of a mudwave (Fig. 3).

The ground heaving in front of the working platform was sometimes as high as 2 to 3m. This caused the platform to subside gradually. As the geotextile separator sank beneath the platform, additional quantities of geotextile were required due to the increase in surface area. Subsequently, more earth had to be dumped in the working platform to restore it to the specified level. The additional backfilling resulted in further mud waves being created, hence setting off a chain reaction. At some locations, the heaving was so severe that the geotextiles punctured and the soft soil beneath oozed through the gap created to the surface of the platform. The punctured area had to be re-excavated and repaired. A fresh piece of geotextile was placed over the gap with 1.0m overlaps on all sides and rebackfilled using the earth material excavated from

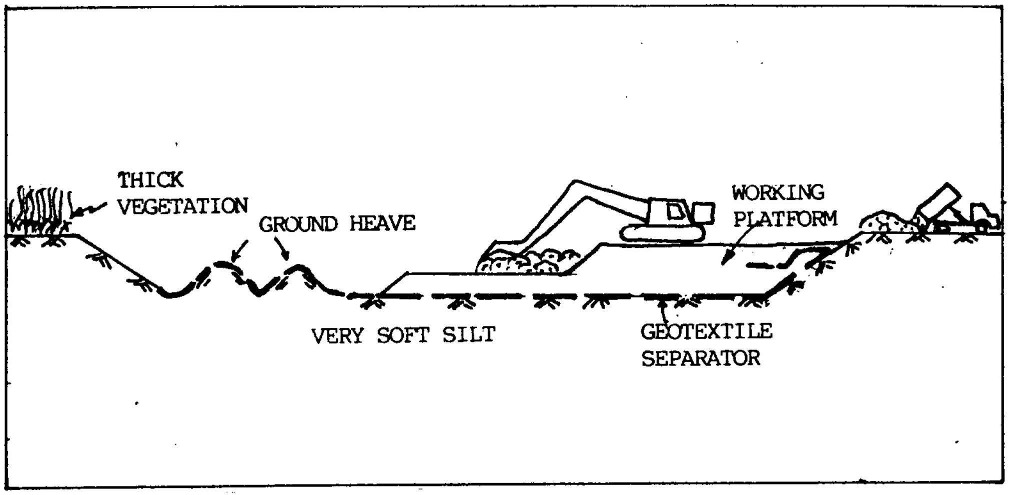

Fig. 3 Construction of working platform

the working platform. To minimize the loss of geotextile and to maintain its continuity in the length and breadth directions of the site, alternate roll widths were stitched on site, with the remaining joints formed by 1.5m wide overlaps.

As the excavation, laying of geotextile separator and formation of working platform progressed from one end of the site to the other, the degree of heaving increased drastically, due to the increased depth of soft soils and also the cumulative and time dependent effects of the factors mentioned above. The final quantity of geotextiles used for the whole site increased by nearly 50% of that estimated based on a theoretical plan area of 8 hectares. Despite the various difficulties encountered, the project demonstrated the importance of appreciation of soft soil behaviour and appropriate handling of geotextile fabrics, which are necessary for the successful construction of working platforms on extremely soft soils. The vertical drain installation rigs could move safely on the working platform once it was constructed to its final level.

On completion of the installation of vertical drains, a drainage sand layer 1.0m thick was placed above the working platform. Further construction of the embankment involved the spreading and compacting of fill material in 300mm thick layers to the required embankment heights. Due to the large site area, the embankment was built up in phases. Internal stability of the temporary embankment profile was maintained by limiting the height difference to less than a gradient of 1:50 to avoid opening of joints in the weft direction.

High strength geotextile reinforcements were installed in the sand blanket layer using the conventional method. Adjacent layers of reinforcement were joined together by prayer seams following the recommendations of the manufacturer. Two seams were made side by side into the selvedge with PES thread. Sewing was done with handheld sewing machines. Prayer seams were formed 2.0cm and 2.2cm from the selvedge.

Inclinometers installed within the surcharge embankment and the subsoils confirmed that deformation of the ground was contained within 450 to 500mm and adequate stability was maintained by the geotextile reinforcements. At certain areas, tension cracks were observed at the top of the embankments. The surcharge embankments were successfully erected, whilst allowing the excavation and construction of the concrete lined canal adjacent to the embankment to progress unhindered.

5. CONCLUSIONS

The application of geotextiles for a soil improvement project in Singapore is presented in this paper. Problems with placement of the initial working platform on the soft soils for the installation of vertical drains was solved by using a geotextile separator. The use of high strength geotextile reinforcements enabled the successful erection of the surcharge embankments, whilst allowing the excavation and construction of a cast insitu concrete lined canal close to the toe of the embankment to progress unhindered.

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