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Behavior of Geotextiles in Embankment Reinforcement

Le comportement des géotextiles comme renforcement de remblai

A shallow embankment was constructed across an area of deep black marsh muck. A spunbonded polypropylene geotextile was placed between the muck and granular fill and evaluated for embankment reinforcement.

After construction and traffic use, test pits were excavated over the fabric. Plate bearing tests were run on the fabric and, by cutting the fabric, on the muck beneath.

It was shown that there is a membrane effect from the geotextile. The effective elastic bearing capacity of the soil was increased from π c to $(\pi+2)$c.

On a évalué un tissu spunbonded en polypropylène, utilisé pour renforcer un remblai peu profond; ce dernier a été construit sur un terrain se composant de boue noire de marais. On a posé le géotextile entre la boue et le remblai granulaire.

Après une période d'usage normale, on a creusé des trous de sondage au-dessus de tissu; ensuite, on a fait des chargements d'épreuve sur le tissu et, en coupant le tissu, sur la boue en-dessous.

Ces essais montrent que le géotextile exerce une action de membrane. La limite effective de charge élastique du sol a été augmentée de π c à $(\pi+2)$ c.

INTRODUCTION

Papers presented at the First International Conference on the use of fabrics in geotechnics reported that fabrics influenced the behavior of granular fill only under large deformations [Jarrett, et al. (1)]. It was argued that such large deformations cannot occur in a structure in use. Otherwise, a roadway or embankment would fail. Subsequent work has shown that large deformations do take place during the construction of a roadway or embankment on soft soil [C. B. H. Cragg (2)].

My occupation as a geotextile engineer for a large geotextile producer has taken me to every major continent of the world during the past decade. My position involves field development and supervision of projects concerned with roadways, embankments, and slab foundations for small buildings. These projects are almost universally on soils having a shear value of 55 kPa (8 psi) or less. I have noted that from 30 to 50% less fill is required to attain a given elevation with a geotextile than without one. I have further noted that pavements with base material underlaid by a geotextile exhibit less localized base failure.

TEST SITE AND SOIL PROPERTIES

In the course of a test program, a shallow embankment was constructed across an area of deep black marsh muck. Ground water level was at or slightly below the surface (Figure I).

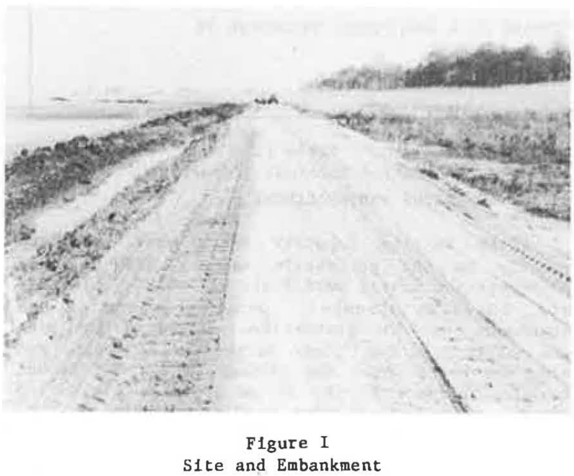

Figure I
Site and Embankment

Extensive soil explorations were conducted on the site prior to construction using a Farnell Model 245 soil assessment cone penetrometer. The cone has a base area of 129 mm^2 (0.2 in.^{2}) and a base diameter of 13 mm (0.5 in.). This instrument reads directly in California Bearing Ratio Units. The average CBR was found to be 1.1 and by conversion, the vane shear 31.8 kPa (4.6 psi). As it was not possible to move plate bearing capacity equipment onto the site prior to construction of the shallow embankment, plate bearing capacity on the in-situ soil was supplied by the Delaware State Department of Transportation.

The embankment constructed was 83 meters (600 ft) long by 3.6 m wide (12 ft) at top and 0.45 m (18") deep. The spunbonded polypropylene geotextile was placed in the base of the embankment. (See Table 1 for physical properties.) The embankment was constructed on the geotextile using a fine to medium sand containing a trace of silt, having an optimum moisture content of 11% and a maximum dry density of 2024 kg/m^3 (126.5 pcf) by ASTM:D698 - Standard Proctor Test. The sand was placed by back-dumping from a truck and spreading with a D-7 Caterpillar bulldozer. Compaction was to a minimum of 95% Standard Proctor using a steel wheeled vibratory compactor. The embankment was traversed 450 times by a fully loaded sand truck having a rear axle load of 50,000 kg (23 Kip) and a front axle load of 20,000 kg (9 Kip). Plate tests were run after this traffic loading.

GEOTEXTILE	GRAB TENSILE STRENGTH	ELONGATION
TYPAR® SPUNBONDED POLYPROPYLENE, STYLE 3401 136 g/m^2 (4 oz/yd^2)'	600 N (135 LBS)	62%
• TYPAR® IS A REGISTERED TRADEMARK OF E. I. DU PONT • DATA BY DU PONT		

Table 1
Geotextile Physical Properties

TESTING APPARATUS AND PROCEDURE

Plate bearing capacity tests were conducted directly on the geotextile as per ASTM-D1196-57 "Nonrepetitive Static Load Tests of Soils". Six test pits, 90 cm in diameter, were excavated in the embankment over the geotextile. Three of the pits were constructed for "plate on geotextile" tests and three for tests where the geotextile was cut around the circumference of the 30 cm diameter plate. A reactive force was provided by the rear hitch of a D-4 Caterpillar bulldozer. The load was applied to the 30 cm plate by a calibrated hydraulic cylinder. Major adjustments for depth of pit were made with a hydraulic truck jack in series. The deflection beam was a 0.15 m x 5 m aluminum I beam supported by concrete blocks.

Figure 2 shows the plate test apparatus.

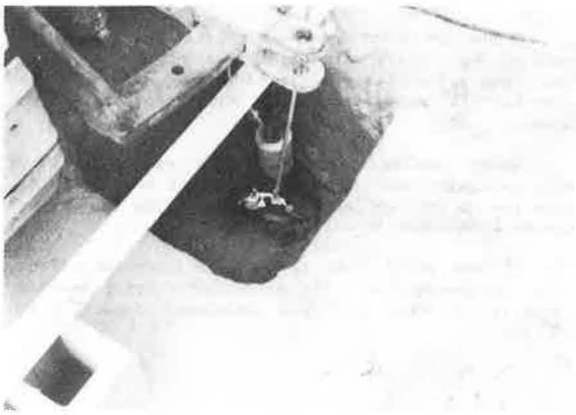

Figure 2
Plate Test Apparatus

A number of trials were run in an attempt to measure deflection with dial indicators. The rate of deflection was so great that an accurate reading could not be made. A meter stick was substituted for the dial indicators and found to be satisfactory. Rather than pause at given loads or deflections, readings were taken on the fly. Deflection took place at approximately 5 cm/min.

DISCUSSION

Rodin (3) and Whitman and Hoeg (4) state that the onset of plastic deformation occurs in frictionless soils (θ=0) under loading when

$$Q_e = \pi c$$

Where Q_e = elastic bearing capacity of the soil and

c = undrained shear strength of the frictionless soils.

Complete bearing failure occurs when

$$Q_{ult} = (\pi + 2)c$$

Rodin modified this expression to state Q_{ult} = (6.2)c for a circular footing.

Table 2 tabulates results of the plate tests.

TEST	ULTIMATE BEARING CAPACITY Q ULT	INCREASE IN Q ULT PERCENT	MODULUS OF SUBGRADE REACTION K_S	INCREASE IN K_S PERCENT
In Situ Soil	**197 kPa** 28.6 PSI	———	**1613 KN/m³** 10.3 KIPS/FT³	———
Soil Under Geotextile	**275 kPa** 39.9 PSI	**39%**	**2703 KN/m³** 17.2 KIPS/FT³	**67%**
Plate on Geotextile	**335 kPa** 48.6 PSI	**70%**	**4839 KN/m³** 30.8 KIPS/FT³	**200%**

Table 2
Results of Plate Tests

Failure is indicated in Figure 3 by arrows. Failure was characterized in all cases by a sudden punching of the plate through the geotextile or soil.

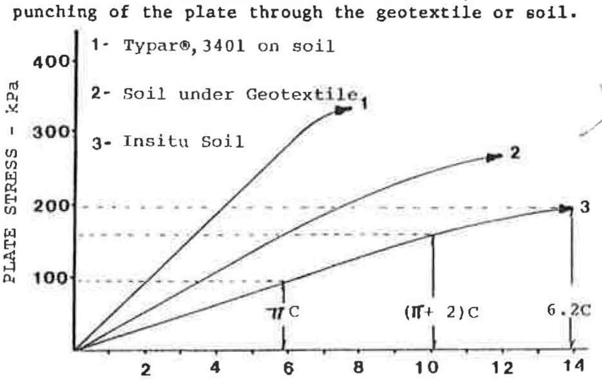

Figure 3
Plate Displacement vs. Stress

The soil under the geotextile increased in effective bearing capacity at failure (Q_{ult}) by 39%. Steward and Mahoney (5) noted this phenomenon in the United States Forest Service Quinault Test Road. A further 31% increase in Q_{ult} was realized with the geotextile. This increase is theorized to be due to the modulus or membrane effect of the geotextile.

As one concerned with field projects, I am interested in the practical application of such information. One section was built without a geotextile. The contractor noted that he used twice as many loads of sand per station to attain the same elevation without a geotextile as he did with a geotextile. No plate tests were run on this section as there was a great deal of admixture of sand with soil. It is theorized that the excess sand went to areas of local shear failure and that the reason for excessive fill consumption was due to the lower modulus of subgrade reaction K_s and an irregular cross section of the embankment without a geotextile.

Anyone who has conducted soil explorations knows that no matter how careful one is there will be areas of low bearing capacity that will be missed. It is not economical to design for such omissions. Potholes in roadways and uneven embankment profiles are evidence that this occurs in everyday life. The stress on the subgrade has exceeded πc. A study of the plate curves will show that even when conventional design procedures for embankments are used, the designer can be more comfortable with his factor of safety when a spunbonded polypropylene geotextile is used at the base of the embankment because stress at the subgrade can safely be between πc and $(\pi+2)c$. Practically, a "floating" embankment can be built with confidence. The author has been involved with two embankment projects 8 kilometers long and a building on a slab foundation that successfully utilized these principles.

In the test described in this paper, the spunbonded polypropylene geotextile has modified the response of the soil under load. The elastic response of the soil has been extended from πc up to $(\pi+2)c$. The modulus of subgrade reaction (Ks) has been increased by as much as 200%.

CONCLUSIONS

1. There is a definite membrane effect from the use of geotextiles in the base of an embankment.

2. When a spunbonded polypropylene is used at the base of an embankment, the effective elastic bearing capacity of the soil Q_e can be raised from πc to $(\pi+2)c$.

REFERENCES

[1]Jarrett, P.M., Lee, R.A., Ridell, D.V.B. 1977, "The Use of Fabrics in Road Pavements Constructed on Peat". International Conference on the Use of Fabrics in Geotechnics.

[2]Cragg, C.B.H., 1980 "Geotextile Applications Within Ontario Hydro, Proc. First Canadian Symposium on Geotextiles".

[3]Rodin, S., "Ability of a Clay Fill to Support Construction Plant", Journal of Terramechanics, Vol 12, No. 4, 1965, pp. 51-68.

[4]Whitman, R.V. and Hoeg, K., "Development of Plastic Zone Beneath a Footing", Report by M.I.T., Department of Civil Engineering, U.S. Army Engineer, Waterways Experiment Station, 1966.

[5]Steward J. and Mahoney J., 1982, "Construction And Evaluation Of Roads Over Low Strength Soils Using Textiles" Idaho Soil and Geological Symposium.

Eigentlich: Tragfähigkeitserhöhung durch Geotextil (Abschnitt 2C)