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(General article)

Stress Distribution on the Kaolinite Layer: A Study

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Abstract

This paper present the technique of ground improvement using geotextile is extensively used in the construction of unpaved roads, fabrication yards, parking spaces, etc. When the underlying soil is soft, having poor consistency and high compressibility, a geotextile layer can be placed over the subgrade followed by a compacted granular fill layer. Although the basic functions of the geotextile are reasonably well understood, there are few data from field trials involving traffic loading that allows the relative improvement in performance of a road section with a geotextile to be quantified. This field test describes the performance of an unpaved- road trafficking trial at Vancouver, British Columbia (B.C.)[1]. The response to traffic loading of four test sections, each stabilized with a different geotextile, is compared with that of an unreinforced test section. Interpretation of the data addresses the development of ruts, subgrade deformations, strain in the geotextile, and the implications of the field observations for current design methods. Geotextiles are also found helpful in reducing settlement and rutting depth. For a given design condition, these improvements lead to a reduced amount of aggregate material and time required for construction and extending of the service life. Geotextile mainly provides separation between base course and subgrade. An analytical approach to the design of geotextile-reinforced unpaved roads was first introduced by Giroud and Noiray (1981)[2].

***Key words**: Stress, Kaolinite, Geotextile*

1. Introduction

Reinforcement mechanisms

For roadway applications, geotextiles have been mostly used for separation, drainage, and filtration and woven geotextiles are sometimes used for reinforcement as a tensioned membrane. Lateral confinement, increased bearing capacity, and the tensioned membrane effect have been identified as the major geosynthetic reinforcement mechanisms (Giroud and Han, 2004). The stabilization of unpaved roads on soft ground with a geotextile is primarily attributed to the basic functions of separation of the base course layer from the subgrade soil, and a reinforcement of the composite system. Although field trafficking studies have consistently shown that the geotextile reduces rutting , there does not seem to be a consistent relationship between improved trafficability and tensile strength of the geotextile. The relationship appears to be good in some trials and poor in others. Analytical models have been proposed for the improved bearing capacity of a geotextile reinforced system that account for contributions from (1) a greater load distribution in the stabilized base course layer; (2) a larger bearing capacity factor due to confinement of the subgrade leading to a plastic, rather than elastic, yield; and (3) a tensioned-membrane effect in the deformed geotextile at large ruts.

From the average pressure on the kaolinite layer for different fill thicknesses, the load dispersion values have been assessed and are presented in Table8. From Table, it is seen that the load dispersion is on the order of 4:1 for fill thicknesses of 40 and 75mm at an average footing pressure of 45 kN/m2.Beyond this footing pressure, it is found that the load dispersion varies between 7:1 to 12:1 (vertical:horizontal). Similarly, for a fill thickness of 110 mm, the load dispersion ranges from 3:1 to 5:1, up to an average footing pressure of 68 kN/m^2. For a fill thickness of 150 mm, the maximum load dispersion within the range of measured pressures is found to be 3:1.

Comparing these observations with the load-carrying capacity of the soil layer for different fill thicknesses at different footing settlements, it can be concluded that the load dispersion angle for the present investigation is on the order of 4:1 up to a maximum settlement of 10 mm. Beyond 10 mm of settlement, it appears to lie in the range of 7:1 to 12:1 (with an average of 10:1)[1-3].

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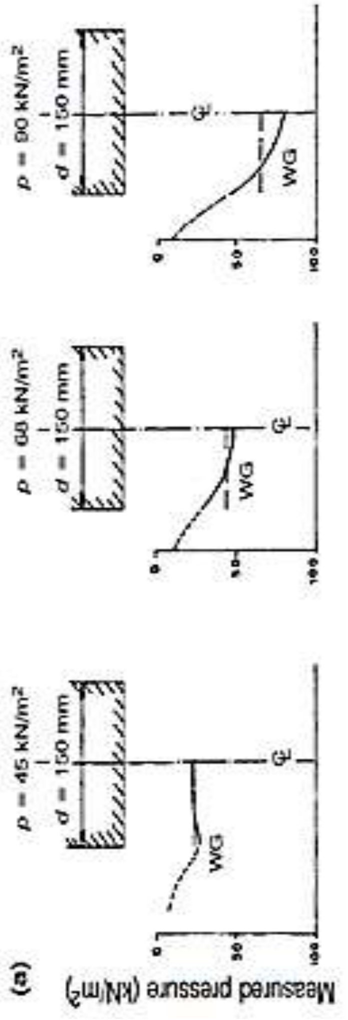
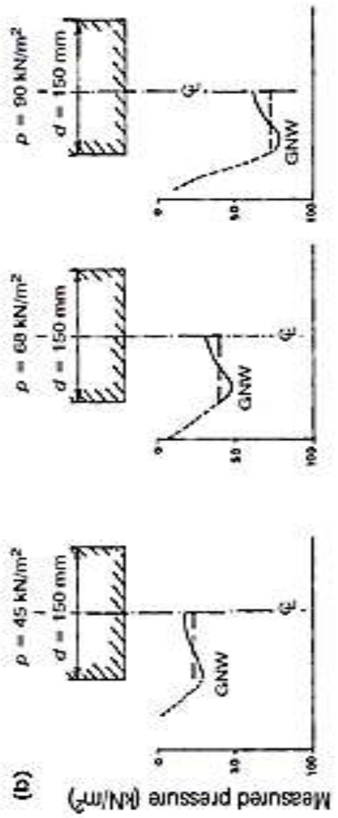
Bearing Capacity Factor, *po* / *cu*



Bearing capacity factors are available in the literature for estimation of the load-carrying capacity of unreinforced and reinforced unpaved roads, i.e. for soil layers with a granular fill overlying soft soil. These bearing capacity factors multiplied by the cohesion of the soft subgrade, along with the dispersion effect, give the maximum load on the fill layer. No recommendation has been given for the behaviour of a soft soil layer at different levels of deformation. An attempt has, therefore, been made to estimate the soil layer bearing capacity factors, i.e. *po* / *cu* , where *po* is the pressure on the kaolinite layer after dispersion and *cu* is the cohesion of the kaolinite layer, for different footing settlements. The load dispersion angle, was taken as 4:1 for settlements of 5 and 10 mm, and 10:1 for settlements of 15 mm and greater. The bearing capacity factor values, *po* / *cu* , calculated for different fill thicknesses and footing settlements are given in Table 7. The values presented for 5 and 10mmof settlement are the average values for the unreinforced and reinforced soil layers. For a settlement equal to or greater than 15 mm, the values for reinforced soil layers are given. Comparing the values presented in Table 9with the load-carrying capacity proposed by Giroud and Noiray (1981) andMilligan et al. (1989), it is seen that the average value of *po* / *cu* for a settlement of 10 mmis comparable with the bearing capacity factor π and (π/2 + 1) for unreinforced soil layers, while the same bearing capacity factor value for 15 mm of settlement is close to (π + 2) for reinforced layers. Higher values of *po* / *cu* , observed at greater amounts of settlement, are probably due to the lateral restraint mobilized through interface friction at the geotextile-soft soil (i.e. kaolinite) interface and tension induced in the geotextile.

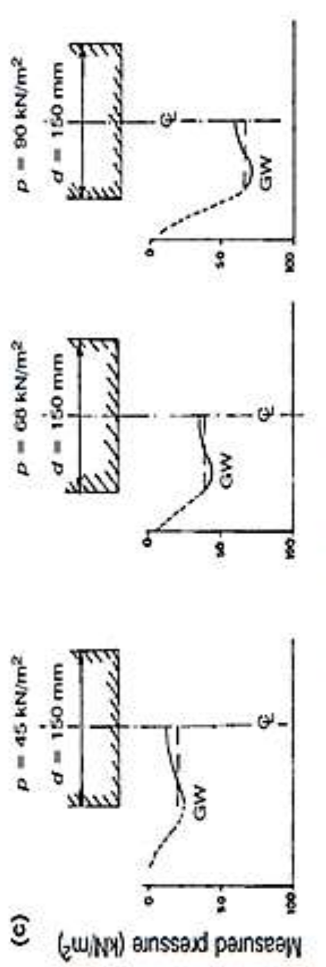


geotextile-soft soil (i.e. kaolinite) interface and tension induced in the geotextile.

- The empirical design of geosynthetic-reinforced unpaved roads began with the incorporation of geotextiles at the base–subgrade interface for separation, filtration, and reinforcement. The first notable design procedure for geotextile-reinforced unpaved roads was proposed by Barenberg et al. on the basis of the limit equilibrium bearing capacity theory. The limit equilibrium bearing capacity theory is based on selecting an aggregate base thickness such that the vertical stress applied to the subgrade is below the theoretical limits for subgrade shear failure. This design procedure is based on the bearing capacity theory of a footing under static load, a granular fill, and a soft cohesive subgrade. An additional assumption is that the failure mode of the unreinforced system is characterized by local shear, while the failure mode of a geotextile-reinforced system is characterized by a general shear failure due to additional distribution of the load. Barenberg et al. proposed bearing capacity factors of 3.3 and 6.0 for unreinforced and reinforced systems, respectively. These factors were suggested for roads designed for very low traffic volumes and large deformations[2]. The limit equilibrium bearing capacity theory was modified by Steward et al. by proposing lower bearing capacity factors to account for increased traffic requirements. Steward et al. suggested an unreinforced bearing capacity factor of 2.8 and a geotextile reinforced bearing capacity factor of 5.0 for unpaved roads designed for 1,000 equivalent single-axle loads (ESALs) and 2-in. of rutting. Steward et al. used a Boussinesq solution for calculating the vertical stress beneath a uniform circularly loaded area and the modified bearing capacity factors to construct design curves for single, dual, and dual tandem axle loadings.

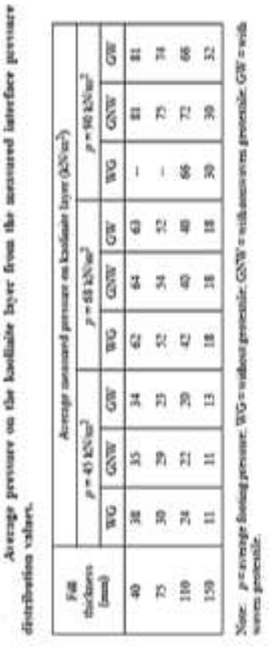
- An alternative approach in the design of geosynthetic-reinforced unpaved roads was based on the widespread acceptance of the tensioned membrane effect as the primary reinforcement mechanism responsible for changing shear failure modes from localized shear for unreinforced systems to generalized shear for geotextile-reinforced systems. New design procedures were developed on the basis of the use of large-deformation membrane analysis equations. The most popular design procedure was produced by Giroud and Noiray and was also based on limit equilibrium bearing capacity theory with modifications to include benefits of the tensioned membrane effect.
- More recently Giroud and Han modified the Giroud and Noiray method to consider the stress distribution, base course strength properties, geosynthetic–base interlock, and geosynthetic in-plane stiffness. These additions are combined with previously considered factors: traffic volume, wheel load, tire pressure, subgrade strength, rut depth, and influence of the type of geosynthetic on the failure mode of the system[3].

Giroud and Han's design method is based on determining the stresses at the base–subgrade interface and determining the rut depth as a function of those stresses and the subgrade bearing capacity. The influence of the number of vehicle passes and the properties of the geogrid are accounted for through modificationsof the stress distribution angle of the aggregate base. Table : shows the critical assumptions for the three design:



Pressure distribution on the kaolinite layer for a fill thickness of 110 mm: (a) without a geotextile, WG; (b) with a nonwoven geotextile, GNW; (c) with a woven geotextile, GW.

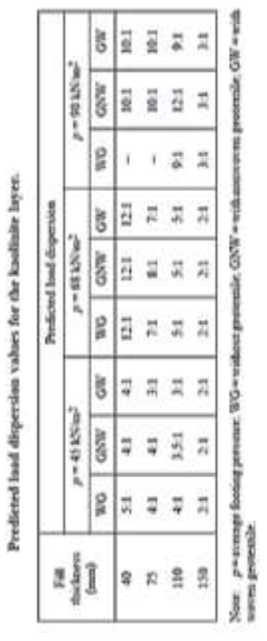
Tables



Average pressure on the kaolinite layer from the measured interface pressure distribution values.

Fill thickness (mm)	Average measured pressure on kaolinite layer (kN/m²)								
	$p = 45$ kN/m²			$p = 68$ kN/m²			$p = 90$ kN/m²		
	WG	GNW	GW	WG	GNW	GW	WG	GNW	GW
40	38	35	34	62	64	63	–	81	81
75	30	29	23	52	54	52	–	75	74
110	24	22	20	42	40	48	66	72	66
150	11	11	13	18	18	18	30	30	32

Note: p = average footing pressure; WG = without geotextile; GNW = with nonwoven geotextile; GW = with woven geotextile.



Predicted load dispersion values for the kaolinite layer.

Fill thickness (mm)	Predicted load dispersion								
	$p = 45$ kN/m²			$p = 68$ kN/m²			$p = 90$ kN/m²		
	WG	GNW	GW	WG	GNW	GW	WG	GNW	GW
40	5:1	4:1	4:1	12:1	12:1	12:1	–	10:1	10:1
75	4:1	4:1	3:1	7:1	8:1	7:1	–	10:1	10:1
110	4:1	3.5:1	3:1	5:1	5:1	5:1	9:1	12:1	9:1
150	2:1	2:1	2:1	2:1	2:1	2:1	3:1	3:1	3:1

Note: p = average footing pressure; WG = without geotextile; GNW = with nonwoven geotextile; GW = with woven geotextile.

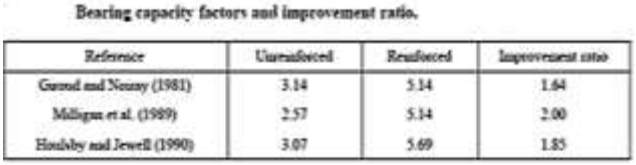
Engineering Technical Letter 1110-1-189	Failure in subgrade Fine-grained subgrade soils with undrained loading conditions 2-in. rut failure criterion 1,000-pass failure criterion with linear extrapolations to higher traffic levels Geotextile primary function: separation rather than reinforcement Minimum aggregate thickness of 6 in. (0.15 m)
Giroud and Han (2004)	Uniform base course thickness Channelized traffic for nontraffic areas Minimum base course thickness of 4 in. (0.1 m) for constructability and anchorage purposes Fine-grained subgrade soils with undrained loading conditions Reinforcement allowing loads in the elastic zone while acting as though the subgrade is in the plastic zone Reorientation of shear stress at the subgrade interface Resilient moduli of base course and subgrade used Upper bound of base to subgrade modulus ratio: 5 Limited to less than 10,000 vehicle passes Minimum aggregate thickness of 4 in. (0.10 m)
Giroud and Noiray (1981)	Fine-grained subgrade soils with undrained loading conditions Limited to less than 10,000 vehicle passes Elliptical contact area from wheel replaced with rectangular area associated with dual tire Geotextile roughness preventing failure of the aggregate layer by sliding along the geotextile Pyramidal distribution of load in aggregate layer Assumed angle of load distribution pyramid Reinforcement allowing loads in the elastic zone while acting as though the subgrade is in the plastic zone Induced settlement under load assumed to be parabolic No minimum aggregate depth

Load Capacity Ratio (LCR)

Improvement in the load-carrying capacity of a reinforced soil layer with the inclusion of a geotextile is typically expressed as the ratio of the ultimate load on the reinforced soil to that of the unreinforced soil. The improvement parameter is denoted by the load capacity ratio, *LCR*, and is defined as:

$$LCR = \frac{\text{Footing pressure for reinforced soil bed at a specified settlement}}{\text{Footing pressure for unreinforced soil bed at the same settlement}}$$

Table



Bearing capacity factors and improvement ratio.

Reference	Unreinforced	Reinforced	Improvement ratio
Giroud and Noiray (1981)	3.14	5.14	1.64
Milligan et al. (1989)	2.57	5.14	2.00
Houlsby and Jewell (1990)	3.07	5.69	1.85

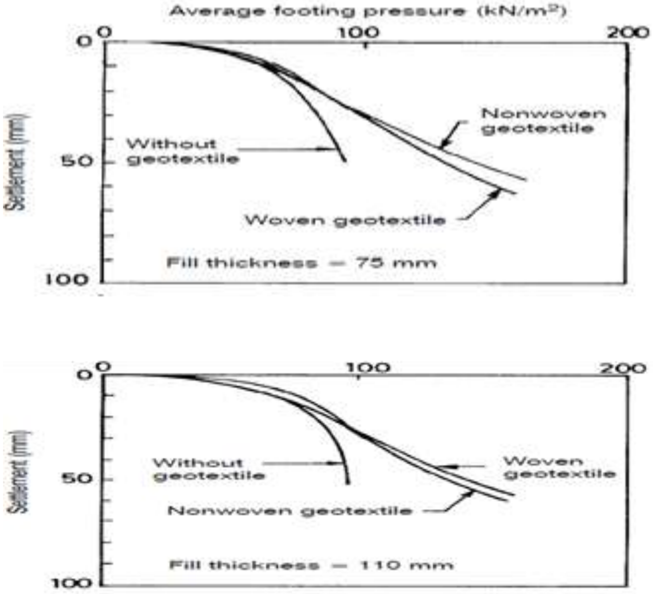


Fig. Settlement V/s pressure relationship

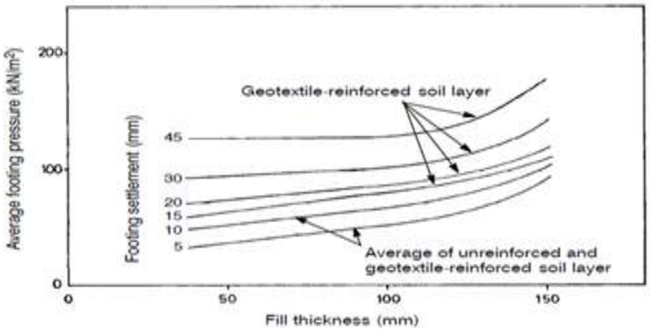


Fig. Variation of Avg. footing pressure

Conclusion

This paper focuses that the Geotextile have been used for sub grade stabilization and base course reinforcement for construction of unpaved structures (roads and areas) since the 1970s. Placed between the subgrade and base course, or within the base course, the geotextile improves the performance of unpaved roads carrying channelized traffic and unpaved areas subjected to random traffic. Improved performance consists of increases to the volume of traffic that can be carried by a given thickness of base course, decreases to the base course thickness required to carry a given volume of traffic, or combinations of both increased traffic and thickness reduction.

References

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