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LOAD DEFORMATION BEHAVIOUR OF GEOTEXTILE REINFORCED LAYERED SOIL BED — A MODEL STUDY

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ABSTRACT

Behaviour of unpaved roads can be improved by laying a layer of geotextile at the interface of soft subgrade and overlying granular fill. Existing method of design of reinforced unpaved road consider increase in bearing capacity but no quantitative value of footing deformation is given corresponding to these bearing capacity factors. This paper presents a series of model footing tests under monotonic loading. The results of the tests are used to highlight the improvement in load carrying capacity of the reinforced unpaved road with the increase in footing deformation. A set of non-dimensional parameter, p_o/Cu, similar to bearing capacity factor have been proposed for estimation of load carrying capacity of unpaved roads with the increase in footing deformation.

INTRODUCTION

Construction of unpaved roads, fabrication yards, parking space, storage areas and the like is done by laying a layer of coarse granular material over weak and compressible ground. Life of this type of construction is relatively limited with deformations larger than usually accepted. Loading is often localised, variable, repeated, moving or some combinations of all of these. One of the method of improving the performance of this type of construction is use of a layer of geotextile at the interface of soft ground and overlying granular fill. Geotextile improves the load-carrying capacity and settlement characteristics in addition to providing separation and filtration/drainage blanket to underlying soft deposit.

Earlier concept of design of reinforced unpaved road (Giroud and Noiray, 1981) is based on the assumption that inclusion of geotextile increases the bearing capacity of soft subgrade from πCu to (π+2) Cu. Further, geotextile is assumed to be anchored at the road edges to provide membrane action. This gives additional improvement due to the tension mobilized in the geotextile depending on its elongation and deformed shape. The other technique(Milligan et.al.,1989),however, does not consider membrane action. It assumes improvement due to laying of geotextile at the soft subgrade-granular fill interface would be from $(\frac{\pi}{2}+1)$ Cu to $(\pi+2)$ Cu. Thus both the methods assume ultimate load carrying capacity to be based on the failure criteria of soft subgrade. Improvement in load carrying capacity is considered to be the ratio of ultimate load of reinforced and unreinforced soil bed. No emphasis has been given to the deformation of the soil bed with the increase in footing load.

This paper highlights the results of a series of model footing tests under monotonic load comparing the behaviour of unreinforced and reinforced soil bed. Two different types of geotextiles were used at the subgrade-grannular base course interface. The test results were used to study the improvement of reinforced soil bed over unreinforced one with deformation.

EXPERIMENTAL PROGRAMME

The model footing test programme was planned to study the behaviour of reinforced soil bed with the increase in footing settlement. The tests were carried out in a cylindrical steel tank of inner diameter 700mm and height 700mm. A rigid circular plate of diameter 150mm was used as the model footing. (Fig.1)

The model subgrade was prepared by artificially consolidating commercial grade kaolinite slurry (water content 50%) in the test tank. The liquid limit and plastic limit of the kaolinite used were 45% and 25% having silt and clay content 71% and 29% respectively. The final thickness of the subgrade after consolidation was maintained at 450mm. Water content and undrained shear strength of the consolidated kaolinite bed were found to be 32-33% and 0.12kg/sq.cm. respectively.

Thermal power plant waste furnace bottom ash collected from a nearby power plant was used as the model base course (granular fill) over artificially consolidated kaolinite bed. The engineering properties of the material is given in table 1. The thickness of compacted bottom ash was kept 40mm, 75mm, 110mm and 150mm. The compaction of the bottom ash was done in layers manually by using a rigid circular plate weighing 2kg. Thickness of each layer was 35-40mm. Water was maintained at optimum moisture content. Unit weight of compacted bottom ash was 1.20gm/cc corresponding to 80% of dmax.

Table 1 : Porperties of Furnace Bottom Ash

1. Specific Gravity	: 2.10
2. Grain size Distribution	: Medium sand :19% Fine sand :81%
3. Uniformity coefficient, Cu	: 2.08
4. Optimum moisture content	: 29%
5. Maximum dry density, dmax	: 1.16 gm/cc
6. Angle of internal friction	: 46

The test programme consisted of two series of tests. The first series consisted of model footing tests on the compacted bottom ash overlying artificially consolidated kaolinite bed without geotextile at the interface. In the second series geotextile was laid at the interface of subgrade and compacted fill. Diameter of geotextile was 700mm. Before laying it was soaked in water for 24 hours. Two types of geotextile were used. These are needle punched polypropylene nonwoven geotextile and polypropylene multifilament plain woven geotextile. The properties of these geotextiles are presented in table 2.

Table 2 : Properties of Geotextile

Properties		Nonwoven	Woven
Mass per unit area (gm/sq.m.)		203	214
Thickness(mm) under .02kg/sq.cm.		3.40	0.65
Wide width tensile strength	MD	3160	4120
(Kg/m)	CD	1370	2270
Extension at maximum	MD	60.6	17.6
Load(%)	CD	75.0	17.8
Secant Modulus at	MD	4000	32000
10% elongation (Kg/m)	CD	4000	16000
Elongation at 50% peak	MD	29.0	5.6
Strength (%)	CD	41.0	6.4

MD : Machine direction
CD : Cross machine direction

After preparing the soil bed footing was placed centrally over it. Load was applied on the footing in increments by lever arrangement. For each increment the settlement readings were recorded. Then the next load increment was applied and the process continued till failure.

TEST RESULTS AND DISCUSSION

Load-Settlement Behaviour

Average footing pressure vs. settlement curves for fill thickness 75mm and 150mm are presented in fig 2. From the curves it is seen that below 10mm(0.067D) footing deformation there is little change in load settlement behaviour with the inclusion of geotextile at fill-subgrade interface. Beyond this settlement rate of deformation of unreinforced bed is much higher in comparison with reinforced bed.

Further, it may be observed that both the geotextiles, nonwoven and woven, give similar load settlement response. Average footing pressure is found to increase continously with the increase in footing settlement giving no definite failure point. It is, therefore, felt appropiate to express the average footing pressure in relation to the footing settlement. These are ploted in figure 3 to show the change in average footing pressure with the increase in fill thickness for different footing settlement. The curves presented are the average lines drawn through the measured values. 5mm and 10mm curves are the average of unreinforced and reinforced tests, while, 15, 20, 30 and 45mm curves are only for reinforced tests.

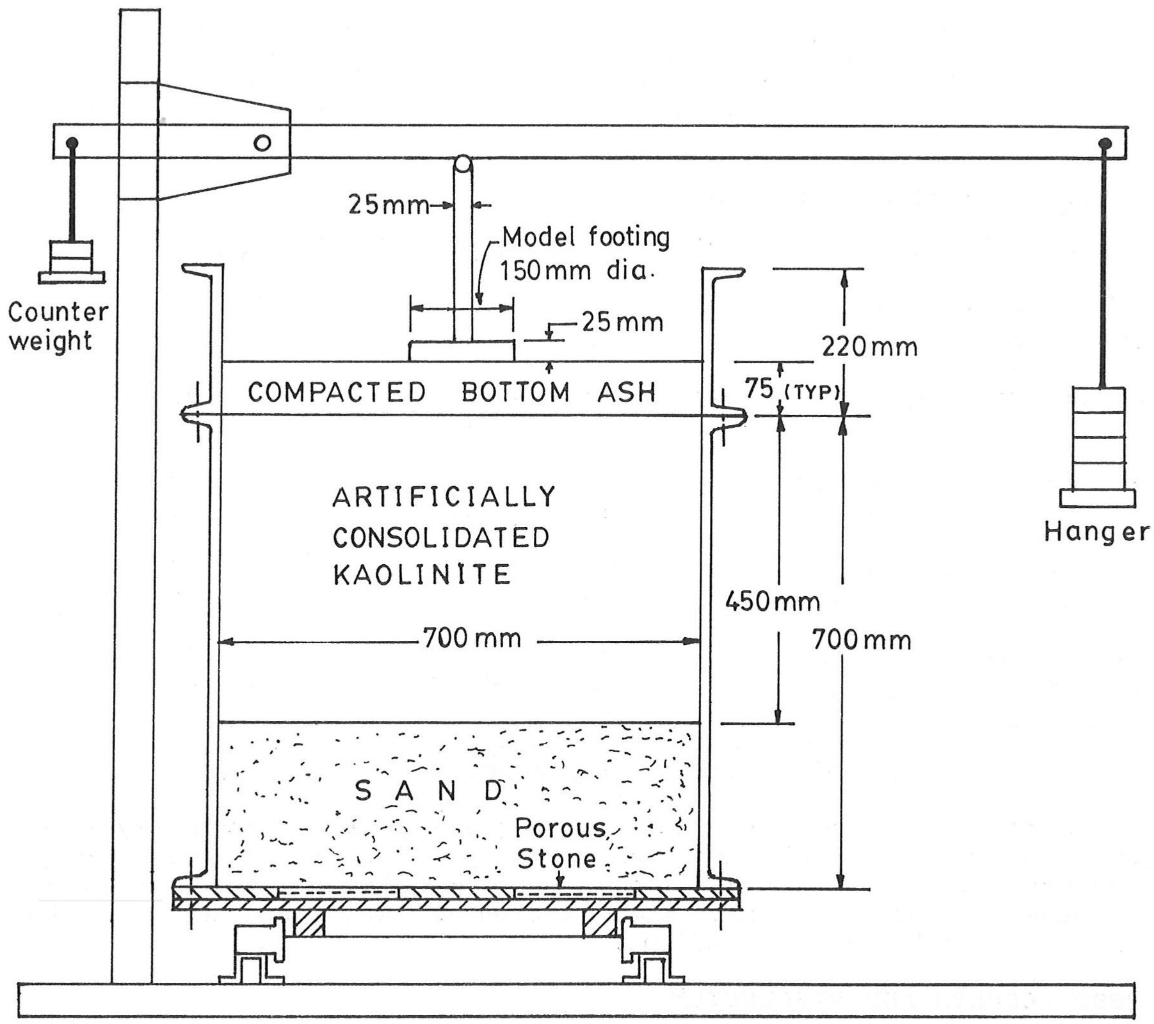

Fig. 1: Test Set-up for Model Footing Test

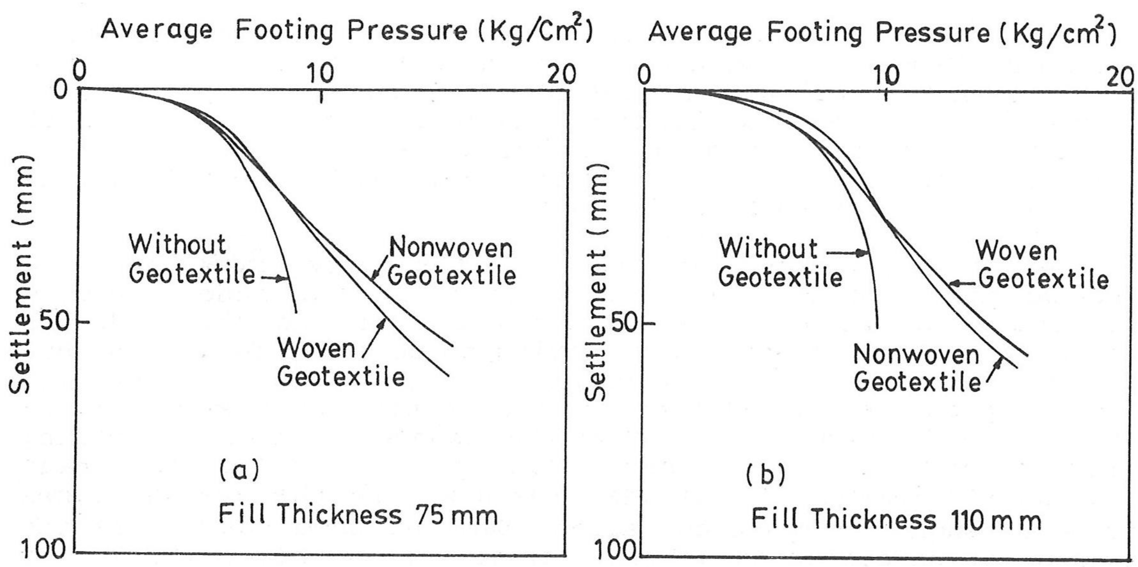

Fig. 2: Pressure Vs. Settlement Relationship

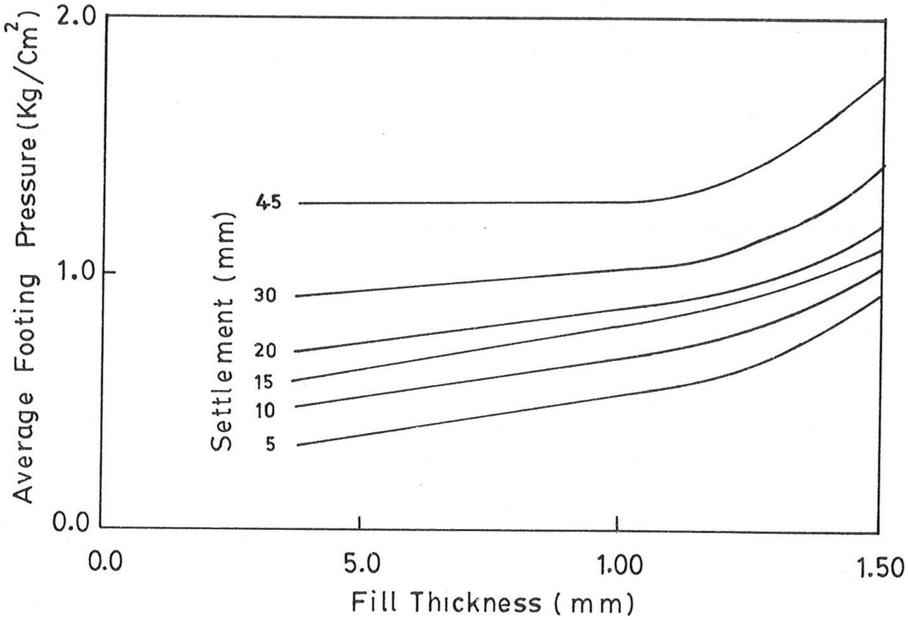

Fig. 3 : Variation of Average Footing Pressure with (a) Fill Thickness (b) Footing Settlement

From the figure it is seen that rate of increase of average footing pressure with the increase in fill thickness is comparatively smaller upto a depth of 110mm which, again, decreases with the increase in footing settlement. Beyond 110mm fill thickness the rate of increase of average footing pressure is much higher. Thus it indicates that at higher settlement the load carrying capacity of reinforced soil bed is independent of fill thickness upto a value of 110mm(0.073D) beyond which improvement is due to the increase in fill depth.

p_o/Cu Ratio

Load carrying capacity of unreinforced and reinforced unpaved roads as suggested by various investigators (Giroud & Noiray, 1981; Milligan et. al., 1989) are based on the concept of small deformation of the soil bed. Corresponding bearing capacity of subgrade is πCu or $(\frac{\pi}{2}+1)$ Cu. For reinforced soil bed, however, it is considered to be equal to ultimate load carrying capacity of subgrade [$(\pi+2)$ Cu] assuming considerable deformation of the soil bed.Angle of load dispersion through the fill is assumed to be 25°-45° (2:1 to 1:1).

An attempt has been made to evaluate a non-dimensional parameter similar to the bearing capacity factor of the subgrade required to estimate load carrying capacity of the unreinforced and reinforced soil bed with the increase in footing deformation. The observed data of the model footing tests (Fig. 3) have been used to develop the parameter, p_o/Cu, for different footing settlement, where, p_o is the pressure on the subgrade after dispersion through granular fill. 4:1 (4 vertical: 1 horizontal) load dispersion has been found to fit the observed data more closely to the earlier proposed bearing capacity factor. The deviation in load dispersion angle from conventional 2:1 to 4:1

may be due to the fact that overlying granular fill is not sufficiently stiff and, therefore, might have caused punching shear failure instead of general shear failure. The resulting non-dimensional parameter, p_o /Cu, for different footing settlement corresponding to different fill thickness has been presented in table 3.

Table 3 : Non-dimensional parameter, p_o /Cu

Fill thickness (mm)	Footing Deformation (mm) 5 (0.033D)	10 (0.067D)	15 (0.1D)	20 (0.133D)	30 (0.2D)	45 (0.3D)
40 (0.27D)	2.14	3.11	3.76	4.54	6.03	8.23
75 (0.5D)	2.35	3.09	3.79	4.27	5.23	6.83
110 (0.73D)	2.45	3.12	3.74	3.97	4.64	5.80
150 (1.0D)	3.33	3.70	4.0	4.37	5.18	6.41
Average	2.57 (2.31)	3.26 (3.11)	3.82	4.29	5.27 (5.02)	6.82 (6.35)

For footing deformation 5mm and 10mm the values presented in the parenthesis are the average for fill thickness 40mm, 75mm and 110mm, while for 30mm and 45mm settlement these are for 75mm, 110mm and 150mm fill thickness.

From the table it is clear that the non-dimensional parameter increases with the increase in footing deformation for different fill thickness. The average value for settlement 10mm(0.067D) is comparable with the bearing capacity factor, π or $(\frac{\pi}{2}+1)$, for unreinforced unpaved roads. The same for settlement 30mm (0.2D) is found to be close to the factor, $(\pi+2)$, for reinforced unpaved roads. Beyond this the improvement in load carrying capacity is probably due to the tension mobilized in the geotextile.

CONCLUSION

From the present investigation the following conclusion may be drawn :

i. Little improvement in load settlement behaviour is obtained with the inclusion of geotextile at the fill- soft subgrade interface till a footing settlement of 10mm(0.067D). Beyond this the rate of increase of settlement for unreinforced soil bed is much higher in comparison with reinforced bed.

ii. For reinforced soil bed rate of increase of average footing pressure decreases with the increase in fill thickness of upto a depth of 110mm(0.73D).

iii. A non-dimensional parameter, p_o /Cu, factor similar to the bearing capacity factor has been suggested to indicate the increase in load carrying capacity for the soft subgrade. The average value of the parameter at footing settlement of 10mm (0.067D) and 30mm(0.20D) are found to be comparable with the bearing capacity factor of subgrade for unreinforced and reinforced unpaved roads.

REFERENCES

Giroud & Noiray (1981), "Geotextile Reinforced Unpaved Road Design", J. Geotech. Eng. Div., ASCE, 107.

Milligan, et.al. (1989), "A New Approach to the Design of Unpaved Roads - Part I", Ground Engineering, Vol.22, No.3.