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Bearing capacity of inclined loaded footing on geotextile reinforced two-layer soil system

V. R. Manjunath
Department of Civil Engineering, AIT, Chikmagalur, India
D. M. Dewaikar
Department of Civil Engineering, IIT Mumbai, India

ABSTRACT: Experimental investigations were carried out with model square footings placed on the surface of a dense sand layer overlying a soft clay subgrade with geotextile reinforcement at the interface in order to study the load-settlement behaviour and tilt of the footing subjected to centric inclined loads. The test results indicate that, the introduction of the geotextile element at the sand-clay interface results in a substantial increase in the load carrying capacity and reduction of tilt/rotation of the footing.

1 INTRODUCTION

Reinforced soil technique is one of the latest and fast growing ground improvement techniques, which has gained wide spread application in improving the properties of soils behind retaining walls, inside embankments and below roads. One of the areas where this technique can be used very effectively is in the improvement of bearing capacity. There are a number of situations in practice, where the foundations are often subjected to loads which are not purely vertical. Structures such as gantry cranes, rail roads and paved roads are subjected to inclined loads. This load inclination results in a reduced allowable bearing capacity associated with tilt/rotation of the footing. The present investigations were aimed at investigation the effectiveness of soil reinforcement technique for footings resting on a two-layer system<a cohesionless base over a soft clay subgrade), subjected to inclined loads.

2 EXPERIMENTAL PROGRAM

The experimental program essentially involved model footing tests on a square footing of size 304.8 mm placed on the surface of a dense sand overlying a soft clay subgrade with a geotextile layer at the sand clay interface and subjected to centric inclined loads. The geometry of the model test is shown in Fig. 1. Tests were also conducted for unreinforced system in order to compare the results. The details of experimental set-up and testing equipment is shown in Fig. 2.

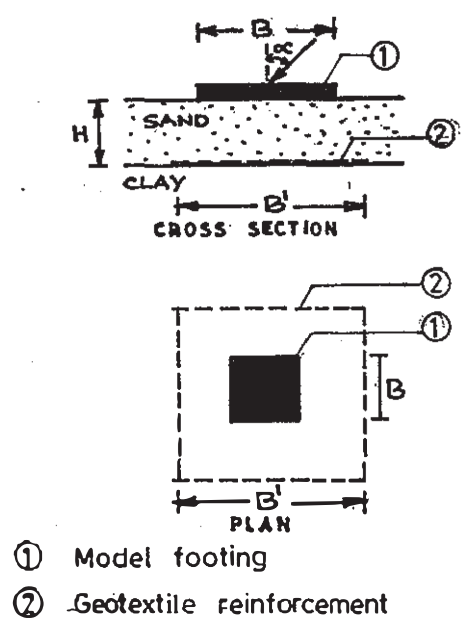

Fig. 1 GEOMETRIC DETAILS OF MODEL TESTS

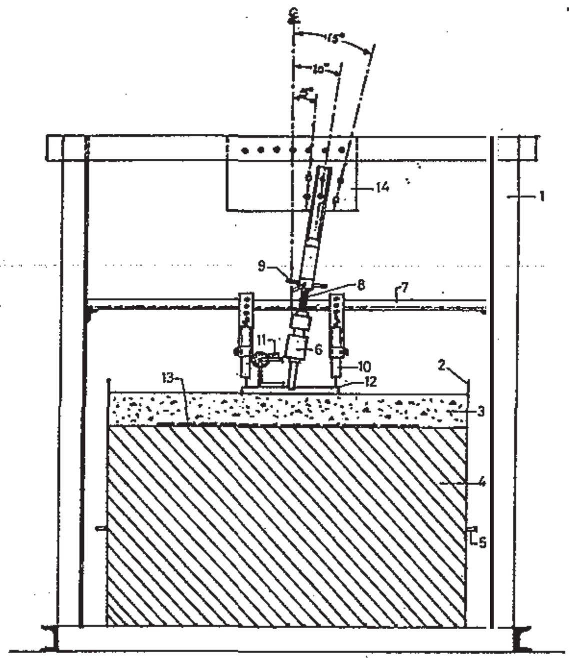

Fig. 2 : EXPERIMENTAL SET UP FOR INCLINED LOADING TESTS.
1)Anglesection 2)Steel tank 3)Sand 4)Clay subgrade 5)Out let 6)Load cell 7)Slotted angle 8)Screw jack 9)Handle for applying load 10)LVDT 11)Tilt meter 12)Model footing 13)Reinforcement 14)M.S.Plate

Inclined loads were applied to the footing by means of a screw jack and they were transmitted through a rod with rounded tip, which was placed inside the semi circular groove made on the footing at its centroid. An electronic load cell was used to measure the applied loads and the settlements of the footing were monitored by four LVDT's(Linear Voltage Displacement Transducers) placed at the corners of the footing. The tilt/rotation of the footing was measured by a specially designed and fabricated tilt meter, the geometrical details of which are shown in Fig. 3. The tilt meter was mounted on the model footing.

The soft subgrade was prepared using marine clay and locally available mumbra sand was used as a base material. The geotechnical properties of these soils are reported in Table-1. The reinforcement material used in the investigations was non-woven, needle punched geotextile manufactured by Tata Mills. The description and properties of the reinforcement are given in Table-2.

The parameters varied were as follows:

i) Inclination of applied load, α=0.0, 5^{o}, 10^{o} and 15^{o}.

ii) Thickness of sand layer, where, B = Width of the footing.

The width of the square sheet of geotextile reinforcement, B' was maintained constant at B'= 3.0B.

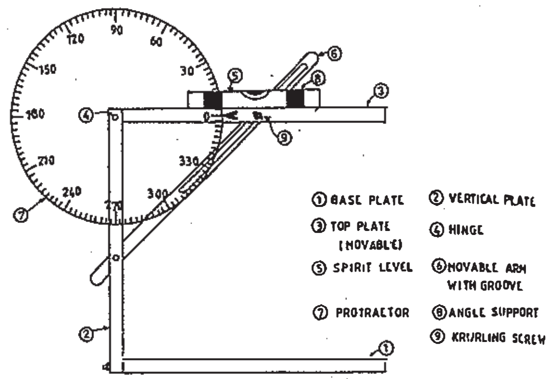

FIG.3 TILT METER

Table 1. Properties of Soil.

SUBGRADE (MARINE CLAY):	
PHYSICAL PROPERTIES	
Liquid Limit(%)	72.0
Plastic Limit(%)	41.0
Plasticity Index	31.0
Shrinkage Limit(%)	17.0
Specific Gravity	2.70
I. S. Classification	OH/MH
Modified Proctor density	13.15 KN/m^3
Optimum moisture content	31.0%
BACKFILL(MUMBRA SAND):	
Density of sand	17.30 KN/m^3
Maximum dry density	18.20 KN/m^3
Minimum dry density	16.00 KN/m^3
Relative density	85%
Average grain size (D_{50})	0.42
Effective grain size (D_{50})	0.165
Uniformity coefficient (C_u)	2.94

3 RESULTS AND DISCUSSION

The variation of ultimate bearing capacity with H/B ratio, for different load inclinations is shown in Fig. 4.

It can be seen that for all the load inclinations, in both reinforced and unreinforced cases, the ultimate bearing capacity increases with increasing thickness of sand layer, upto a certain value, beyond which any further increase in thickness of sand layer does not result in any increase in the ultimate bearing capacity of the footing. The H/B ratio at which maximum bearing capacity is achieved is designated as $(H/B)_{cr}$. It can be further noted that, at all load inclinations, the $(H/B)_{cr}$ for reinforced system is considerably lesser and the corresponding ultimate bearing capacity is substantially higher as compared to the unreinforced system.

Fig. 5 shows the variation of ultimate bearing capacity, q_u, with load inclination, α for both reinforced and unreinforced cases. It is clearly seen there is a rapid decrease in the ultimate bearing capacity with increasing load inclination. However, the bearing capacity ratio, BCR ($BCR = (q_u)_{reinforced}/(q_u)_{unreinforced}$) shows an increasing trend with increase in load inclination. The BCR increases from a value of 30% for α=0 to 36%, 42% and 52% respectively for $\alpha = 5°$, 10° and 15°.

The variation of tilt/rotation of the footing at ultimate load for different load inclinations is shown in Fig. 6. Clearly, there is an increase in the angle of tilt of footing with greater load inclinations. However, for any given load inclination, the angle of tilt for a reinforced soil system is considerably less, as compared to unreinforced system.

4 CONCLUSIONS

1) The investigations clearly indicate that the introduction of a geotextile element at the sand clay interface results in a substantial increase in bearing capacity and reduction of tilt/rotation of a footing subjected to inclined loads.

2) The percentage increase in the bearing capacity (BCR) and reduction of tilt show an increasing trend, with increasing load inclinations.

3) The inclination of a geotextile layer leads to a considerable reduction in fill thickness with a subsequent higher ultimate bearing capacity of the footing.

Table 2. Properties of Reinforcement

GEOTEXTILE (TATA MILLS Q.425A):		
1.	PHYSICAL PROPERTIES:	
	Form	Non-woven sheet
	Mean pore size	130 microns
	Thickness (± 10%)	2.5 mm
	Structural weight (± 10%)	300 g/m^2
	Specific gravity	0.907
2.	CHEMICAL PROPERTY:	
	Fibre	Polypropylene
3.	MECHANICAL PROPERTIES:	
	Tensile strength	8.4 KN/m
	Elongation at break	70%
	Bursting strength	78 KPa

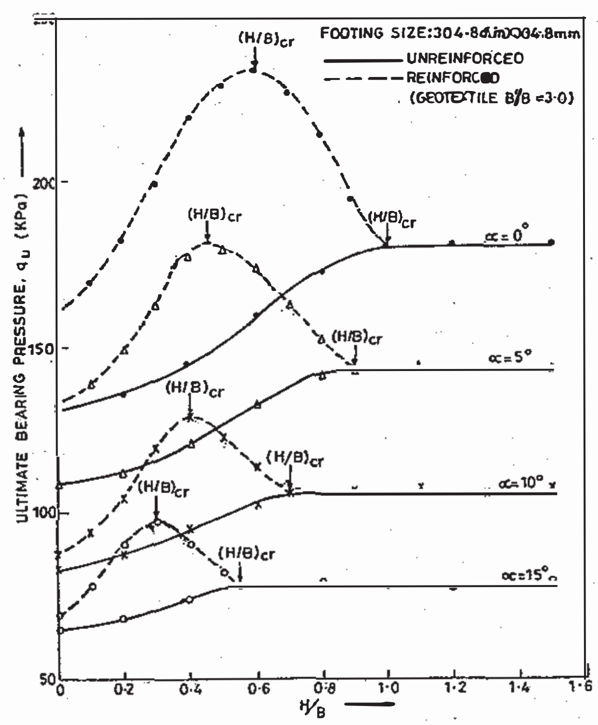

FIG.4: VARIATION OF ULTIMATE BEARING PRESSURE WITH H/B FOR DIFFERENT LOAD INCLINATIONS.

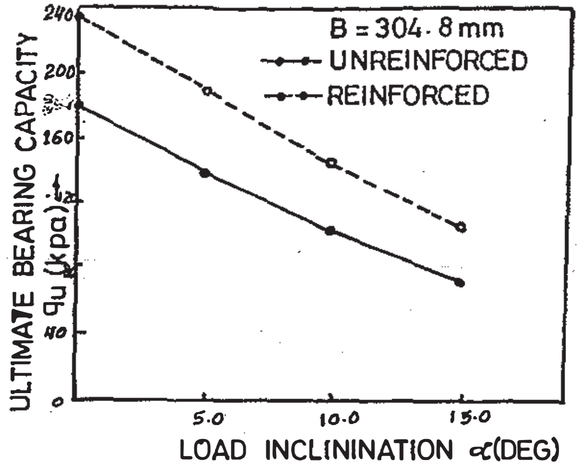

FIG. 5. q_u VS α FOR INCLINED LOADED SQUARE FOOTING

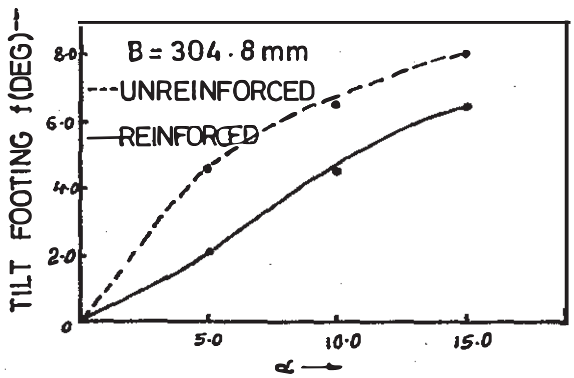

FIG. 6 TILT VS α FOR SQUARE FOOTING

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