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Behaviour of Shallow Plate Anchors in Reinforced Cohensive Soils

by

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Introduction

Anchors:

Anchor Foundations are those foundations which are designed to resist pullout loads. Ground Anchors/Soil Anchors are the foundations which resist the uplift loads by soil resistance. Depending upon the depth of embedment the plate anchor can be further classified as shallow or deep anchors. The critical depth ratio (λcr), up to which anchors are termed as shallow, depends upon various factors. The λcr value may be taken as 2 for strip shape and 4 for circular/square shapes.

GEOSYNTHETICS & APPLICATIONS

The term Geosynthetics covers various products known as geotextile or geomembranes. Geosynthetics are made from synthetic fibers such as polyester, polypropylene, polyethylene or nylon etc. Natural fibers such as jute or coir are also used as geotextiles. Geosynthetics can be broadly classified into following groups, 1. Nonwovens 2. Wovens 3. Geogrids 4. Membranes 5. Composites 6. Three—dimensional structures:

Uses of geosynthetics for Civil Engineering is constantly expanding. The basic functions of these materials are;

1. Separation 2. Filtration 3. Reinforcement 4. Drainage 5. Erosion control.

Geosynthetics due to their reinforcement property are commonly used for reinforced slope, reinforced soil walls and load bearing beds.

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Brief Review of Literature

A. SOIL ANCHORS

Over past two decades various research workers have developed theoretical solutions for uplift capacity of soil anchors. Nene (1983) critically reviewed the available literature. Saran et al (1986) proposed an analytical solution to predict load displacement characteristics of shallow anchors in c-ϕ soil using a nonlinear constitutive relationship. He also proposed nondimensional break out factors to evaluate break out loads for strip, square and circular anchors.

B. GEOSYNTHETICS AS REINFORCEMENT

Binquet & Lee (1975) proposed 3 modes of failures for footings on reinforced soil and proposed equation for bearing capacity. The Shallow shear failure was predicted if the top reinforcement layer was deep ($s > 0.67$ B). Reinforcement slippage failure occurs when the reinforcement is small and at shallow depth ($s < 0.67$ B). The third mode of failure is reinforcement failure when the geosynthetic is long but placed at a shallow depth ($s < 0.67$ B). Das (1988), based on model tests, concluded that bearing capacity ratio is maximum when the width of geosynthetic layer was four time that of model footing.

C. PLATE ANCHORS IN REINFORCED SOIL

No literature is so far available on plate anchors in reinforced cohesive soil.

Analysis: Shallow Plate Anchors in Reinforced Cohesive Soils

The Break out loads for shallow plate anchors can be computed by limit equilibrium method proposed by Saran et al (1986). The break out load intensity for a square or circular anchor is given by,

$$qo = c.Fc + \gamma H.F\gamma \tag{1}$$

where

c=unit cohesion

γ=unit weight of soil

H=depth of anchor

Fc and $F\gamma$ are nondimensional load factors.

$Fc = 4.\lambda\ (1+\lambda\ \tan\ \phi)$

$F\gamma = 1+2\lambda.\tan\phi+4/3.\lambda^2.\ \tan^2\phi$

$\lambda = H/(2.B)$

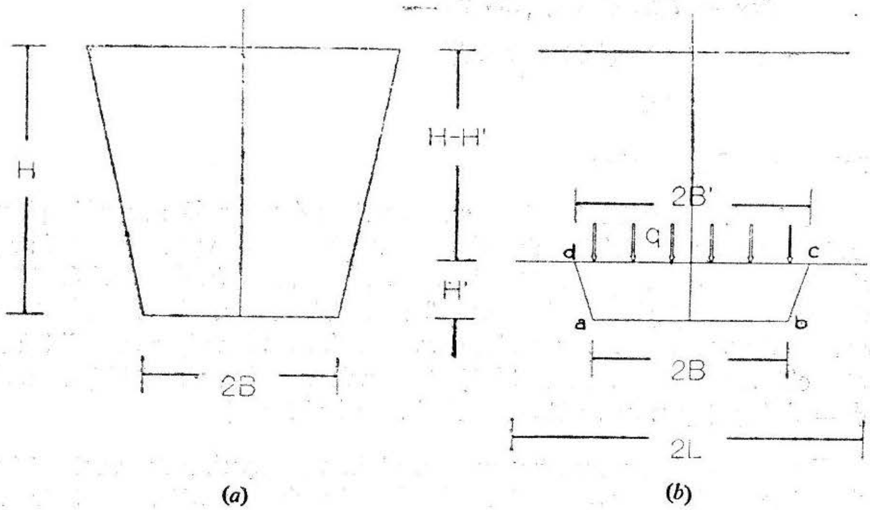

FIGURE 1 Geometrical Symbols for Anchors (a) Without Geosynthetic (b) With Geosynthetic

Using the same method the break out load for shallow anchor in reinforced soil can be evaluated by considering the equilibrium of wedge abcd (Ref. Fig 1 b)

$$qr = c.\text{Frc} + \gamma.\ H'.\ \text{Fr}\gamma + \frac{(B')^2}{(B)^2} q' + 2\cdot \frac{(L^2 - B'^2)}{(B)^2}.\ m.\mu.\ (c + q' \tan \phi) \tag{2}$$

where $Frc = 4\lambda'\ (1 + \lambda' \tan \phi)$

$\lambda' = H'/(2B)$

$Fr\gamma = 1 + 2\ \lambda'.\ \tan \phi + 4/3.\ \lambda'^2.\ \tan^2 \phi$

$B' = B + H' \tan \phi = B.\ (1 + 2.\lambda'.\ \tan \phi)$

$q' = \gamma.\ (H - H') = \gamma.\ H.\ (1 - \lambda'/\lambda)$

$L =$ Half Length of geosynthetic layer

$m =$ Mobilizaton factor $= (H - H')/H = (1 - \lambda'/\lambda)$

$\mu =$ Interface adhesion factor

by substitution and simplification the eq. 2 simplifies as

$$qr = c.\ Frc + \gamma.H.Fr\gamma + \gamma.H.Frq + c.Fgc + \gamma.H.Fg\gamma \tag{3}$$

where $Frq = (1 + 2.\lambda'.\ \tan \phi)^2.\ (1 - \lambda'/\lambda)$

$Fgc = 2.Ar.\ \mu.\ (1 - \lambda'/\lambda)$

$$Fg\gamma = Fgc. (1-\lambda'/\lambda). \tan \phi$$

$$Ar = r^2 - (1+2.\lambda' \tan \phi)^2$$

$$r = L/B$$

Laboratory Investigations

Model Anchors: Model Tests were conducted using 50 mm wide plate anchors of square and circular shapes. Anchor shaft was made of 6 mm size bar of 300 mm length. The depth ratio was maintained 2 and 4. The thickness of steel plate anchors was 5 mm. The soil used for model tests was locally available non expansive clay. The bulk unit weight was 16kN/m^3 at molding water content of 33.7% The unit cohesion was 8 kN/m^2. and ϕ = 5 deg. (By unconsolidated undrained triaxial test)

Two types of geosynthetics were used in the experimental work. The size of geosynthetics was four times the size of anchor i.e. 200 mm.x. 200mm. with 6 mm hole at center for anchor shaft. No literature is available about soil anchors in reinforced soil and also mode of failure in such case was not known. In the case of bearing capacity problems the geosynthetics are placed at a distance of 2/3 the width of foundation. It was therefore decided to place geosynthetics at a distance 25 mm and 50 mm above anchor level.

TABLE 1

Properties of Geosynthetics

Property	Type:	Nonwoven	Woven
Weight (kN/sq. m.)		4	1.85
Thickness (mm.)		3.2	0.5
Tensile Strength (N/50 mm.)		700	1800
Puncture Strength (kN/sq. cm.)		30	30
U.V. Resistance		Excellent	

MODEL TESTING

Model tests were conducted to investigate the effect of geosynthetics on load displacement behavior of square and circular plate anchors. The dry soil was mixed with requisite amount of water in two stages and kept covered for 24 hours prior to filling into test tank. All the tests were conducted in a circular tank of size 300 mm and 500 mm in height. The

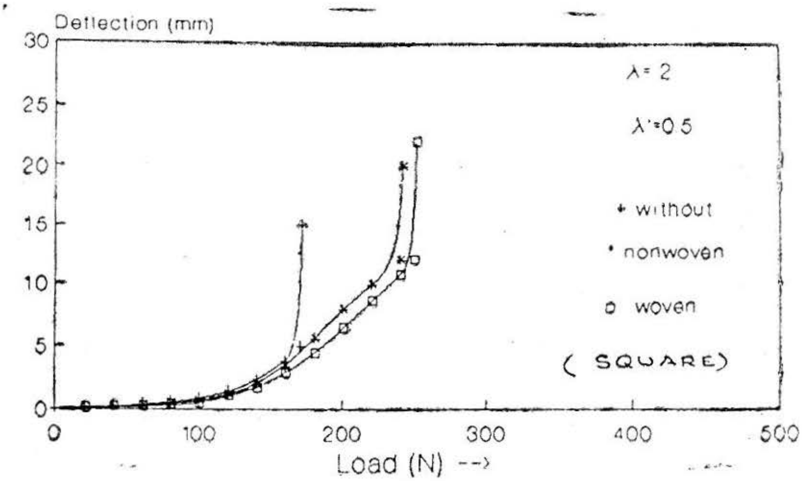

FIGURE 2 Load Displacement Curve

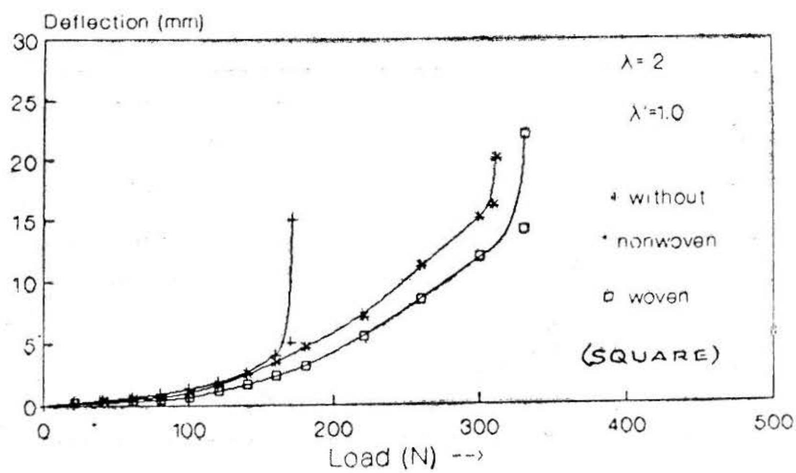

FIGURE 3 Load Displacement Curve

Prepared soil was filled using kneading compaction. The model anchor was positioned and then soil was placed above till the proper embedment is achieved. The minimum thickness of soil layer below anchor was 300 mm. To eliminate the soil adhesion, a filter paper of anchor size was placed below the model. The anchor shaft was connected to a cable which passed over two friction less pulleys and end of the cable was attached a hanger for applying pullout loads. Two dial gauges of 0.01 mm least count were used to measure the upward displacement. For model tests with geosynthetics, the geosynthetic layer was laid horizontally above the top surface of anchor at a distance of 25 mm or 50 mm. The anchors were subjected

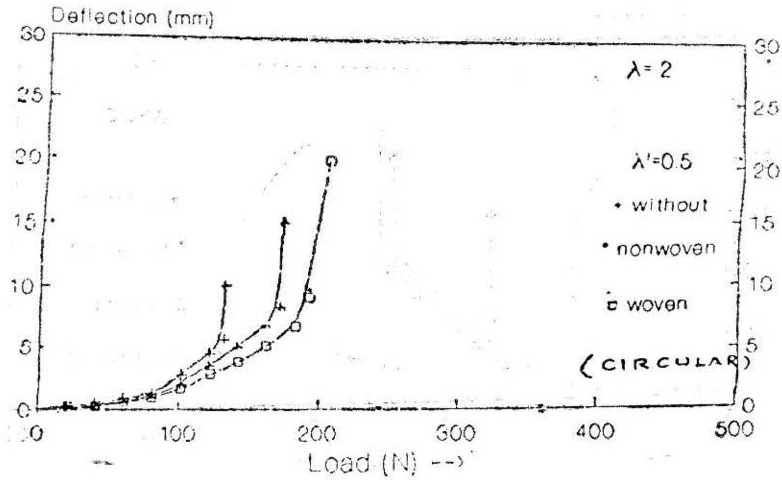

FIGURE 4 Load Displacement Curve

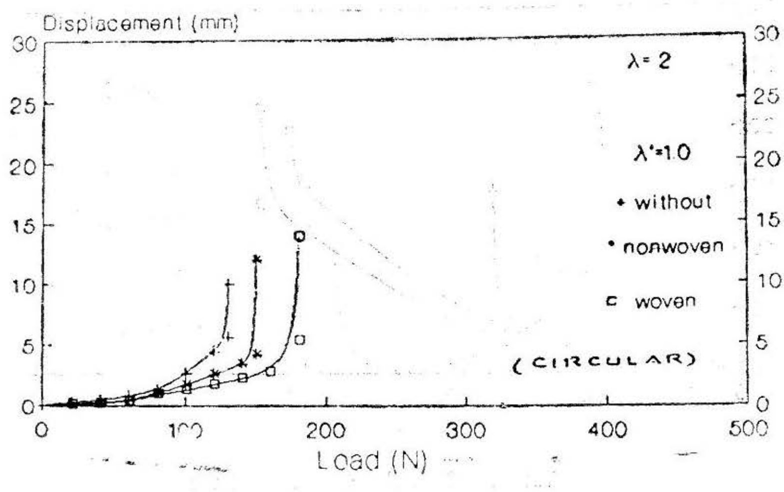

FIGURE 5 Load Displacement curve

to sustained incremental loading with a load increment of 20 N or 40 N. The higher loads were applied when the rate of displacement reduced to 0.05 mm/hour or less. Load—Displacement data is presented in figures 2 to 9. Break out loads were taken as load at which load-displacement-curve becomes vertical.

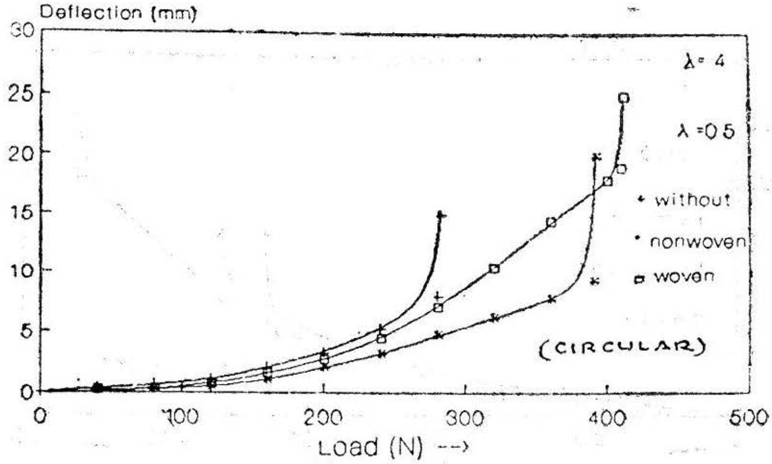

FIGURE 6 Load Displacement curve

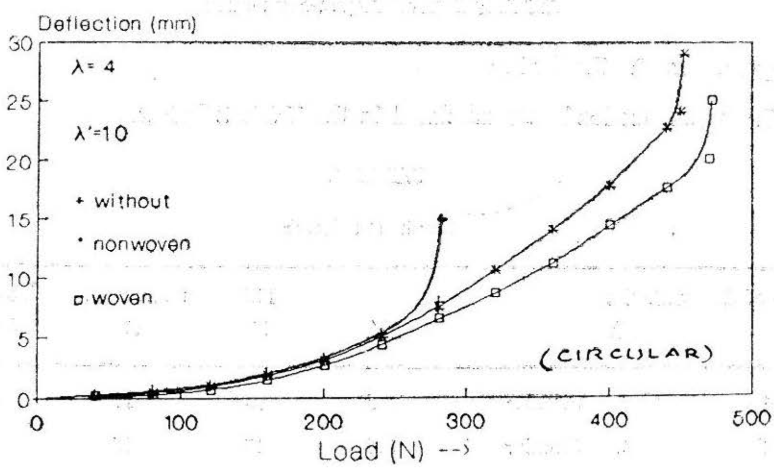

FIGURE 7 Load Displacement curve

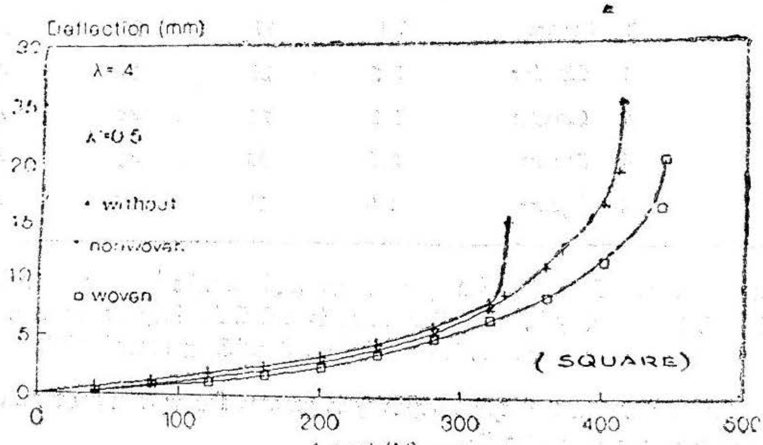

FIGURE 8 Load Displacement curve

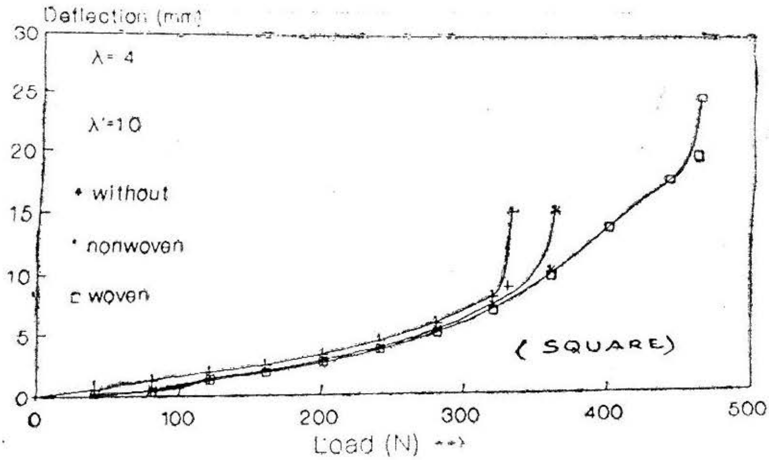

FIGURE 9 Load Displacement curve

Interpretations & Conclusions

The break out loads are tabulated in the Table 2 below.

TABLE 2

Break out Loads

Type of Geosynthetics	λ		λ'	Nil N	Nonwoven N	Woven N
Fig. 4	2	Circular	0.5	13	17	19
Fig. 5	2	Circular	1.0	13	15	18
Fig. 2	2	Square	0.5	17	24	25
Fig. 3	2	Square	1.0	17	31	33
Fig. 6	4	Circular	0.5	28	39	41
Fig. 7	4	Circular	1.0	28	45	47
Fig. 8	4	Square	0.5	33	41	44
Fig. 9	4	Square	1.0	33	36	46

Based on above following interpretations and conclusions are made, 1. The Fig. 2 to 9 clearly indicate that there is a definite improvement in uplift capacity of shallow plate anchors reinforced with geosynthetics.

2. The increase in the uplift capacity is greater for woven geotextile than that for nonwoven geotextile.

3. The interface adhesion factor μ varies with the the type of geosynthetic material and also depends upon depth ratio. The μ value were assumed as follows,

Nonwoven : $\mu = 0.4$ and 0.8 for $\lambda = 2$ & 4 respectively

Woven : $\mu = 0.425$ and 0.85 for $\lambda = 2$ & 4 respectively

4. The validity of the proposed analysis is verified by plotting Q (Theoretical) Vs Q (Experimental) as shown in Fig. 10 & 11.

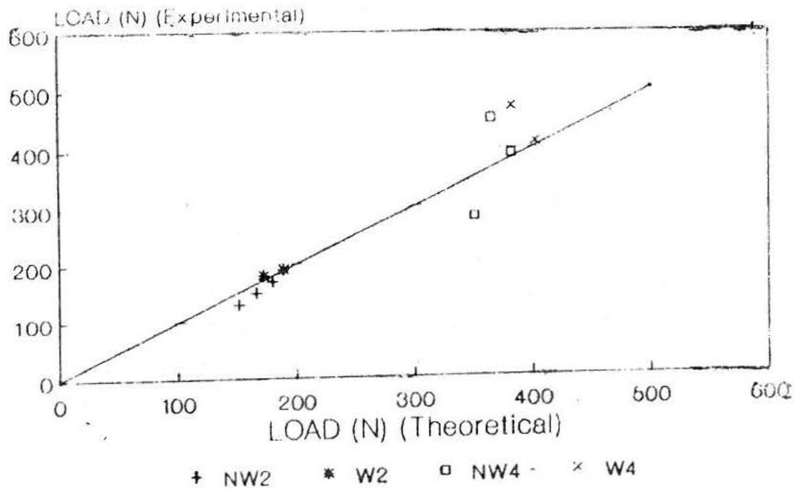

FIGURE 10 Comparison of Results for Circular Anchor

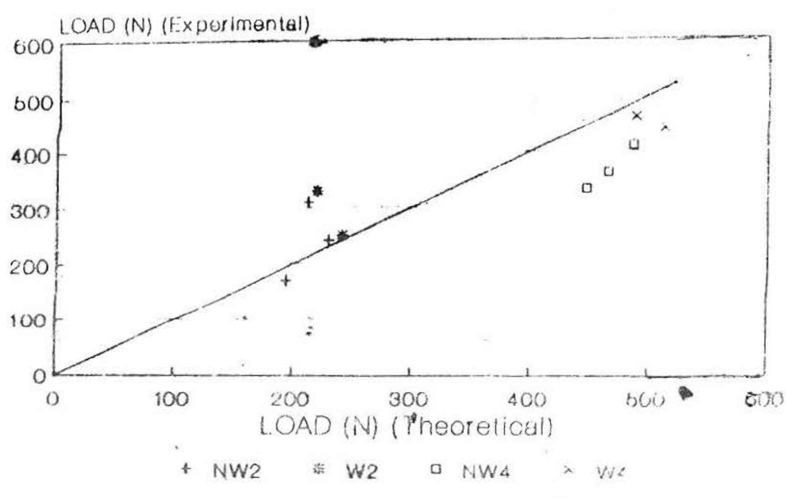

FIGURE 11 Comparision of Results for Square Anchor

5. There is a fairly good agreement between the theoretical and experimental values.

The above interpretations are based on limited model tests. The other influencing parameters are being investigated.

Acknowledgement

The woven and nonwoven geosynthetics with their properties were supplied by M/s Dinesh Mills Ltd. Baroda.

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