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Frictional resistance of geotextiles

Md. Khairul Alam
New Jersey Institute of Technology

ABSTRACT

TITLE OF THESIS: Frictional resistance of Geotextile.

NAME OF CANDIDATE: Md. Khairul Alam.

THESIS SUPERVISED BY: Dr. Raj P. Khera, Professor.

The pullout resistance of geotextiles was examined using pullout tests. A suitable wooden box with large (2 ft x 2 ft x 4 ft) dimensions was used to avoid the effect of boundary and to simulate field conditions. Two types of failure patterns were observed. For shallow embedment (<3 ft), geotextile produced a movement of the surrounding mass of sand in the shape of an inverted cone due to interlocking friction between geotextile and sand particles. The cone angle decreases with increase in depth of embedment. For embedment equal to or greater than 3 ft., no sand cone developed and the failure occurred along the interface of geotextile and sand. For 1 ft. surcharge, the increase in the pullout resistance due to combined horizontal and vertical embedment was about 30 %.

FRICTIONAL RESISTANCE
OF
GEOTEXTILES

By

Md. Khairul Alam

Thesis submitted to the Faculty of the Graduate School of the New Jersey Institute of Technology in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering

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APPROVAL SHEET

TITLE OF THESIS: Frictional Resistance of Geotextiles

NAME OF CANDIDATE: Md. Khairul Alam
Master of Science in
Civil Engineering

THESIS AND ABSTRACT

APPROVED:

Raj P. Khera, P.E.,Ph.D. Professor, Dept. of Civil and Environmental Engineering	Date
Namunu J. Meegoda, Ph. D. Associate Professor, Dept. of Civil and Environmental Engineering	Date

VITA

NAME: **Md. Khairul Alam**

ADDRESS: 351, Broad Street
Apt. # 811
Newark, NJ 07104

DEGREE AND DATE TO BE CONFERRED: Master of Science in Civil Engineering, 1991

DATE OF BIRTH:

PLACE OF BIRTH:

INSTITUTIONS ATTENDED:

Name of Institutions	Date Attended	Degree	Date
Bangladesh University of Engg. and Tech., Dhaka	1981-1986	Bachelor of Science in Civil Engineering	Feb. 1986
New Jersey Institute of Technology, Newark	1990-1991	Master of Science in Civil Engineering	Dec. 1991

MAJOR: Civil Engineering

POSITION HELD: Asst. Engineer
Bangladesh Water
Development Board, Dhaka
1988-1990

Lecturer
Bangladesh Institute of
Technology, Khulna
1987-1988

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CHAPTER 1

INTRODUCTION

The use of geotextile in the geotechnical engineering field has increased tremendously in the last 20 years. Geotextiles offer very good alternative solutions to many soil related problems such as stabilization, drainage, and reinforcement.

The two types of fabrics currently used as geotextiles are 'woven' and 'nonwoven'. Woven geotextiles are the first to be developed from synthetic fibers and are manufactured using weaving techniques. They have regular pattern of spacing between the fibers. On the other hand, nonwoven geotextile are formed from filaments or fibers arranged at random and bonded together into a planar structure. They allow different size of soil particles to be entrapped in their different size of the fabric spacing when embedded in the soil.

Some of the basic functions offered by the geotextile can be summarized as: filtration, separation, drainage and reinforcement.

The reinforcement improves tensile strength of the soil. But basically the tensile strength depends on the interaction between geotextile and soil.

In the landfill systems, both the geotextile and the geonet have been used as drainage media. They are also used in primary and secondary leachate collection and detection systems with many different configurations. In all of the above cases, the soil-geotextile/geomembrane interface friction is of particular importance in the design procedure.

In the landfill, the geotextile/geomembrane liner is covered with certain thickness of soil so as to protect them from physical damage apart from other reasons. A common failure mode of geomembrane lined side slopes of landfills, impoundments, and reservoirs is by slippage of this cover. The problem is much worse in the case of smooth geomembrane due to low interface friction resistance between soil and geomembrane. Moreover, the usual design goal of excavated or build-up impoundments is to build the side slopes as steep as possible. To achieve steep slopes with geomembrane liners and also prevent the slippage of cover materials, it is necessary to place geomembrane between one or two geotextiles. The geotextile will provide higher resistance to downward sliding of soil and also will prevent puncturing of the geomembrane by sharp stones or other objects in the cover or underlying soil.

Generally the geotextile/geomembrane is embedded into the soil beyond the slope in a trench to encounter the pullout force along the liner. Typical layout configuration is shown in Fig 1.1. The pullout resistance depends on the types of fabric, embedment depth, types of soil, unit weight of soil etc.

In this thesis an effort is made to evaluate:

a) The pullout resistance of geotextile for different embedment depths and different orientations.

b) The pattern of the failure surface for different depth and

c) The effect of surcharge on pullout resistance.

The experiment were conducted using woven geotextile ‘Nicolon’ manufactured by Nicolon corporation and the soil consisted of a flint sand.

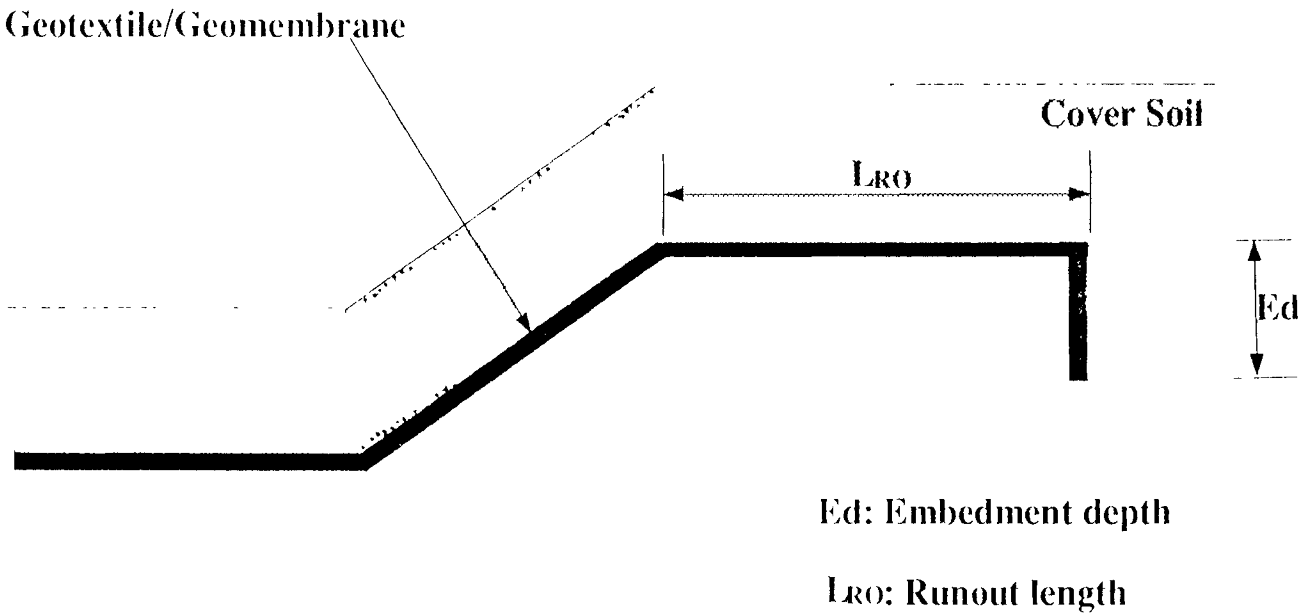


Fig.1.1 Cross section of geotextile/geomembrane runout section with anchor trench

CHAPTER 2

LITERATURE REVIEW

A comprehensive literature survey has been done to review a wide variety of research available on the study of interface friction between soil and reinforcement. When a geotextile is used as a reinforcement, it is necessary to measure the soil-geotextile shear strength characteristics in order to evaluate the ability of the geotextile to act as a reinforcement and to determine whether the geotextile could act as a slip surface inside the earth mass. The literature survey includes several important parameters such as soil characteristics, geotextile properties, types of tests which normally influence the test results.

2.1 INFLUENCE OF SOIL CHARACTERISTICS

It has been generally considered that two main factors influence the value of the soil-geotextile friction: the soil internal friction angle ϕ, and the nature of the surface of reinforcements. Collios et al. (1980) described that the particle angularity has a great effect on the friction value. When two soils have same particles size, the friction value is higher if angularity is higher.

Density also influence the pullout resistance of the reinforcement. Schlosser and Elias (1978) observed that at low density the peak load during pullout is obtained at a small displacement, at high density it is obtained at a greater displacement. The mobilization of friction along the reinforcement is also influenced by the density.

2.2 METHOD OF OBTAINING UNIFORM DENSITY

Bieganousky and Marcuson (1976) describe three devices to obtain homogeneous density throughout the fill. All three devices employ a raining technique. Dry sand in desired quantity is suspended over the specimen and allowed to free fall to the specimen surface. The three raining devices are rotating rainer, circular perforated rainer, and single hose rainer. In the configuration of single hose rainer it consists of a reservoir which feeds a single hose. At the exit of the hose, a series of three 1/4 inches screens are placed to break the fall of sand. Density varied by controlling the height of fall from the screen to the sand surface. The techniques for other two devices are almost the same.

2.3 INFLUENCE OF GEOTEXTILE PROPERTIES

Collios et al. (1980) observed that mesh opening size and deformability of the geotextile play an important role in the shear behavior of a soil-geotextile system. When the size of the mesh opening increases, the friction angle between geotextile and cover material also increases. Contact efficiency is maximum when opening size is slightly larger than soil particles size. Geotextile also provides interlocking of the soil particles when it deforms to the shape of the particles. This interlocking is dependent on the particle size, the flexibility of the geotextile and the magnitude of the normal stress acting on geotextile. The flexibility directly influence the deformation of geotextile around the particles. When the normal stress is high, the geotextile is forced to deform at the shape of the soil particles and the friction angle becomes high.

Martin et al. (1984) observed that non-woven fabric is better than woven fabric to estimate soil-geotextile friction because non-woven types have wide range of fabric opening to allow different graded soil particles. Whereas the woven geotextiles have a more regular pattern and limited opening size range. Hence, while the specific gradation of one soil type may allow considerable fabric penetration, but a slightly coarser soil will not interlock as well. So the size of mesh opening is very important parameter for friction value.

2.4 TESTING METHOD

An internationally accepted method for testing frictional properties of geotextiles has not yet been developed. There are two types of tests, the direct shear test and the pullout test that are used in the evaluation of the soil geotextile interface friction angle. Dembicki and Alenowicz (1987) discussed the problems involved in the two types of test.

The direct shear test would be preferable to the pullout test since the result of the pullout test are difficult to interpret for the following reason:

Shear stress are not uniformly distributed before movement of the sample occurs.

In case of thick and soft non-woven geotextile necking occurs.

The pullout force is partly from the shear force developed in the soil and partly from elongation of the free length between the soil and loading system.

However, pullout tests is still desirable as they are closely related with the failure mechanism happened in the practical case. The placement of the geotextile is also similar to the field condition.

2.5 FRICTIONAL RESISTANCE IN PULLOUT TEST

The friction values obtained from pullout test are always higher than those from direct shear test. Guilloux et al. (1979) suggested that, during pullout, dilatancy occurs in a very small zone in the vicinity of the reinforcement. Due to the arching action that occurs across reinforcement, the ambient back fill suppress the volumetric expansion which is associated with the dilatancy. The suppressed dilatancy results in locally enhanced vertical stress which increase the pullout resistance.

Rao and Pandey (1988) also observed the interface friction value from pullout test to be higher than that of sand.

2.6 EFFECT OF EMBEDMENT DEPTH

Bacot et al. (1978) and Rao and Pandey (1988) observed that the friction value increases with the increase of the embedment depth.

2.7 SAND CONE DEVELOPMENT

Kasturi (1990) observed that during pullout test the failure occurs along a cone that developed around the geotextile. The pullout resistance is proportional to the surface area of the cone. The cone surface decreases as the embedment depth of the geotextile increases. Also the pullout resistance of geotextiles is the sum of the contribution of forces generated on the ends and sides. The end contribution remains constant for a given depth of embedment The sand cone gives a logical explanation of the higher friction value.

2.8 SUMMERY

The sand cone development during pullout test has given a new idea to look at the analysis of the pullout test results. But the cone development has been observed only for the limited embedment depth (< 2.67 ft.).

Therefore, in this thesis, an effort is made to study:

a. The effect of embedment depth in the formation of sand cone.

b. The actual failure mechanism during pullout test for greater embedment.

c. The change in friction values with different embedment depth.

For the purpose of test 'Nicolon' geotextile and Flint sand were used.

CHAPTER 3

MATERIALS

3.1 GEOTEXTILE

Only one Type of geotextile "Nicolon" were used for pullout tests.

3.1.1 NICOLON

The Nicolon Stabilenka 69800 geotextile has a rough surface and is woven type. Its thickness is 1/8 of an inch. The tensile strength given by the manufacturer is 1550 lb per inch width at 5% strain. The soil-geotextile friction angle is also given as 14°.

3.2 SAND

The sand used was a pure silica flint shot blasting sand known as Flint sand. The sand was obtained from, Jersey pulverizing, 1140, Close Avenue. Bronx, NY-10472.

3.2.1 GRAIN SIZE ANALYSIS

ASTM D421 and D422 standard set of sieves were used in the grain size analysis of Flint sand. The results are shown in Table 3.1 and plotted in Fig. 3.1. The sand is poorly graded. The dominant particle size is between 0.84 mm and 0.425 mm. The coefficient of uniformity, $C_u = 1.76$ and the coefficient of concavity, $C_c = 1.10$.

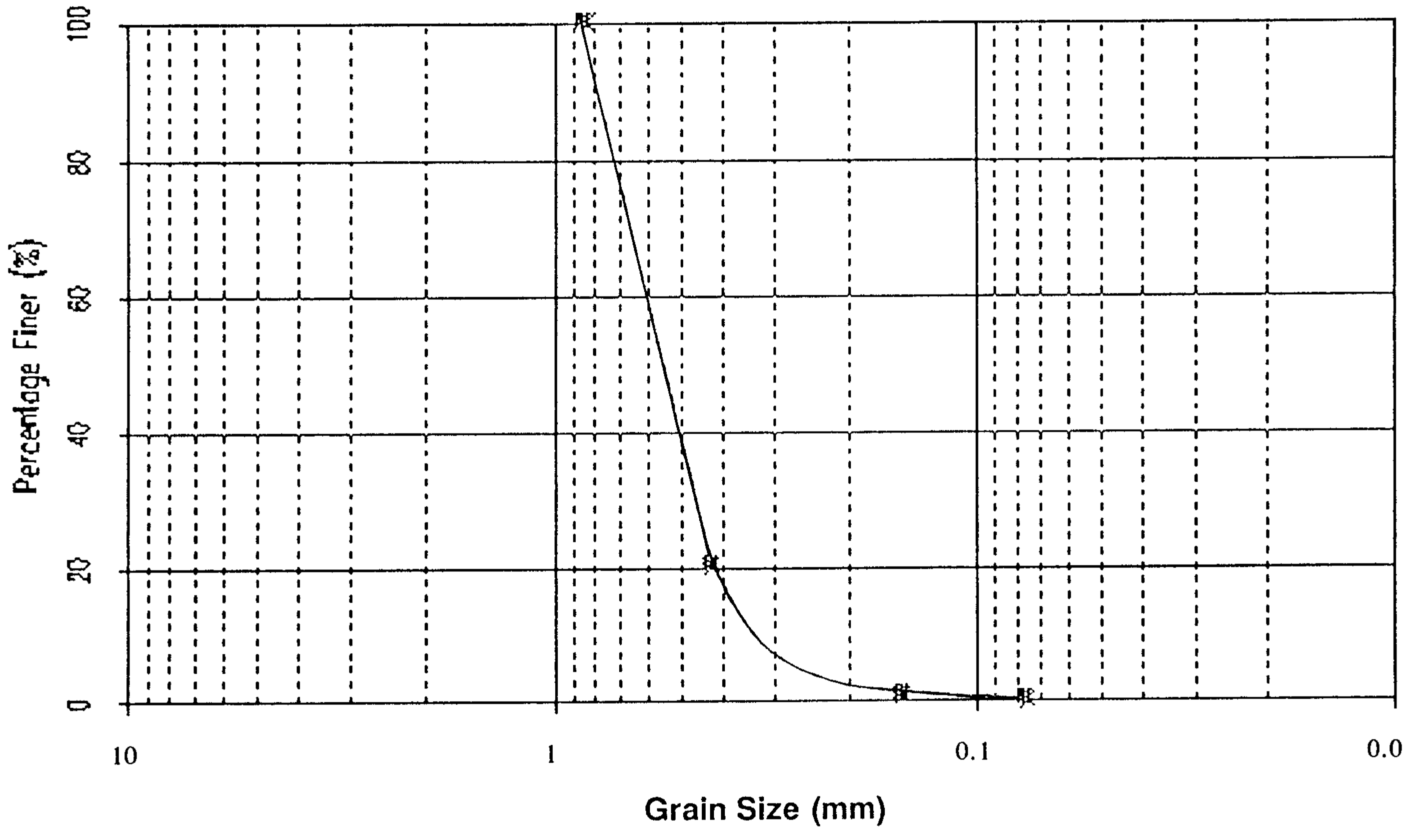
3.2.2 ANGLE OF FRICTION

Direct shear test was used to find the internal frictional angle ϕ of the flint sand. This value has been previously determined (Kasturi, 1990) to be 39.8°. Since same the sand is used in this research ϕ is assumes to be 39.8°.

TABLE 3 1· Grain Size Analysis for Flint Sand

Weight of dry sample 700 gm.							
Sieve No	4	10	20	40	100	200	Pan
Sieve Opening (mm)	4 76	2	0.84	0 425	0 15	0 075	0
Wt of sieve (gm)	475	423	368	344	512	291 5	387 5
Wt of sieve & soil (gm)	475	423	368 25	903	646 75	297	388
Wt of soil retained (gm)	0	0	0.25	559	134 75	5 5	0.5
% of soil retained	0	0	0 035714	79 85714	19 25	0 785714	0 071429
Cumulatative % retained	0	0	0 035714	79 89286	99 14286	99 92857	100
% Finer	100	100	99 96429	20 10714	0 857143	0 071429	0

Fig. 3.1 Grain Size Distribution for Flint Sand



CHAPTER 4

EXPERIMENTAL SETUP

4.1 TYPES OF TESTS

Three types of pullout tests were performed:

a) Vertical pullout tests.

b) Horizontal pullout tests.

c) Combined pullout test.

In the vertical and horizontal tests different embedment length were used but fabric width was constant.

4.1.1 Pullout Test Set Up

The set up is shown in Fig. 4.1 . It consisted of a wooden rectangular box in which the geotextile was embedded. The loading system consisted of a wire, a pulley and a winch to apply the load. In the loading system, the wire goes over a pulley and is attached to a proving ring by a hook. From the lower end of the proving ring two plates of equal size were suspended with one plate having a slit. These two plates were clamped together with screws to hold the geotextile, which ran between the plates and through the slit. Two deflection gauge were fixed at the top of these plates to determine the deflection. The average of the two deflection readings was used in the calculations.

4.2 Preparation of Geotextile

The geotextile was cut to the required width of 12 inches by maintaining two sides straight and parallel throughout the length. To ensure straight edge the loose ends on both sides were scorched. The same piece of geotextile was used repeatedly.

4.3 Geotextile Embedment

The geotextile was suspended from the bottom of proving ring into the box to the desired depth and positioned in the middle of the box. Sand was poured through a tube with a mesh at the end around the geotextile up to the required depth. The mesh ensured the uniform density throughout the fill. This technique is similar to the one described by Bieganousky and Marcuson (1978). To achieve a uniform density of sand a constant height of fall of 1 foot was maintained. The density was calculated directly from the mass of the sand and its volume.

4.4 Rate of Loading

The geotextile was pulled at a rate of about 1.5 cm/min. During the test, the load gauge and deflection gauge readings were taken every 10 to 20 seconds.

4.5 Test Numbering System

The following guidelines were used in numbering the tests. First letter of the test number indicates the orientation, V for vertical and H for horizontal embedment. This is followed by the embedment depth in feet. The surcharge symbol S is indicated after embedment value and followed by its magnitude in feet. If more than one test was done (A), (B), etc. was used. The width of geotextile was 12 inches in all tests.

4.6 Rectangular Sand Box

The dimensions of the rectangular wooden box were 24 in. by 23.1 in. by 48 in. For vertical and combined pullout tests the box was in a vertical position with top open. In a horizontal test the box was in a horizontal position with a horizontal slit at one end.

4.7 Set Up for different Orientations

The vertical pull set up and horizontal pull set up are shown in Fig. 4.2 and Fig. 4.3, respectively. The test results are given in Tables 4.1 and 4.2 .

The set up for combined vertical and horizontal embedment is shown in Fig. 4.4 . The vertical portion of geotextile was embedded first in the box. Then the geotextile was turned into the horizontal position and passed through the slit. After this, the sand was rained on the top to the required surcharge. The geotextile was pulled in the horizontal direction. The result of the test conducted with this set up is given in Table 4.3 .

Set up for vertical pull with surcharge is shown in Fig. 4.5. The geotextile was embedded vertically to the desired depth. Then it passed through a hollow rectangular box made of thin plywood, 13 in. by 12 in. by 0.5 in. in size. Sand was then filled all round the hollow box. Thus the upper portion of the geotextile was not in contact with the sand. The test result is shown in Table 4.4 .

Table 4.1: Vertical pullout test on Nicolon

Test No.	Embedment Depth (ft)	Geotextile width (ft)	Density of Sand (pcf)	Maximum load (lb)
V1	1	1	107.81	94.57
V2	2	1	106.32	224.8
V3	3	1	104.81	310.08
V3.5	3.5	1	109.11	342.63
V4	4	1	106.78	379.85

Table 4.2: Horizontal pullout test on Nicolon

Test No.	Embedment Length (ft)	Embedment Depth (ft)	Geotextile width (ft)	Density of Sand (pcf)	Maximum load (lb)
H1S1	1	1	1	106.11	178.29
H2S1	2	1	1	106.41	333.33

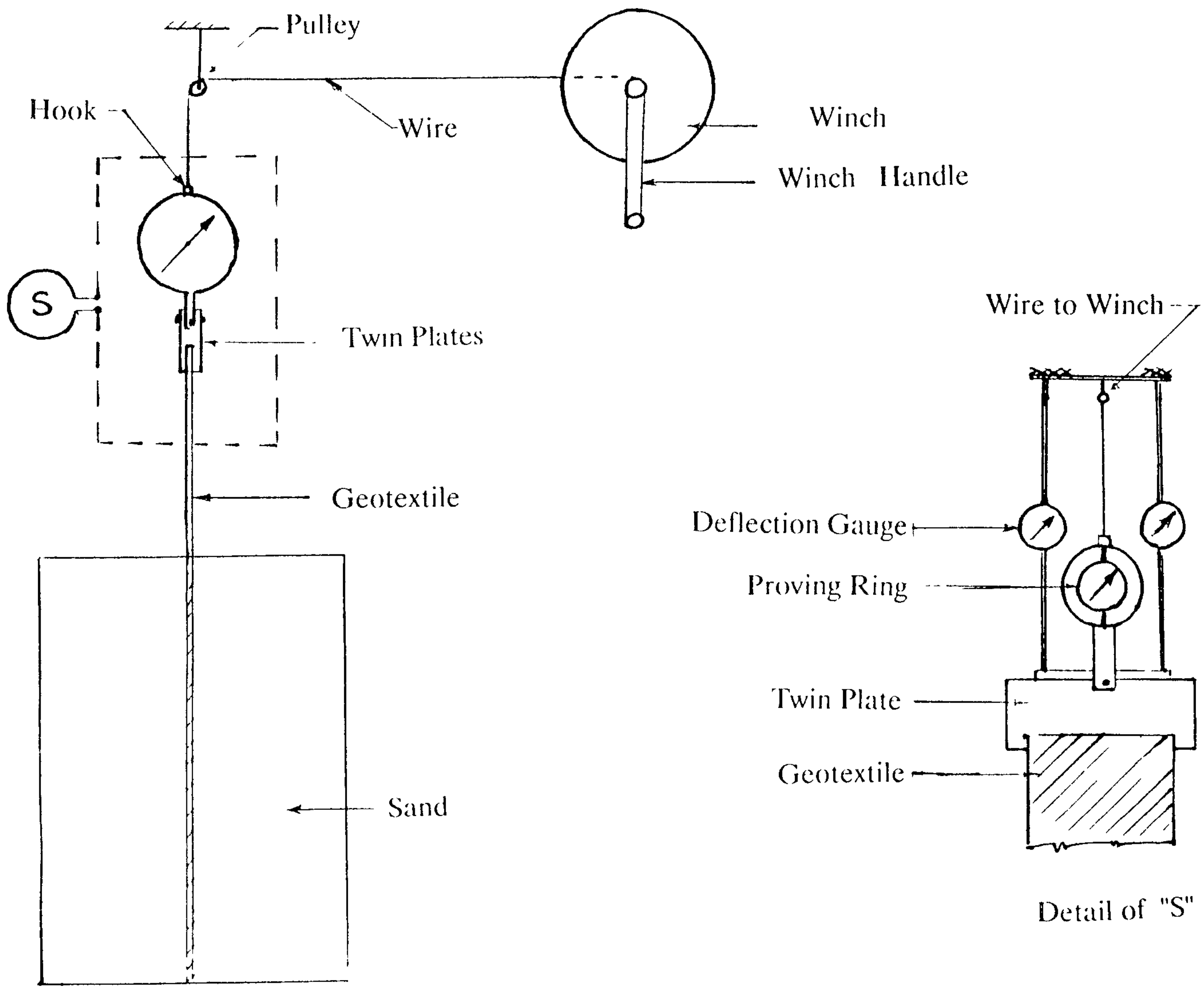


FIGURE 4.1 SETUP FOR PULLOUT TEST

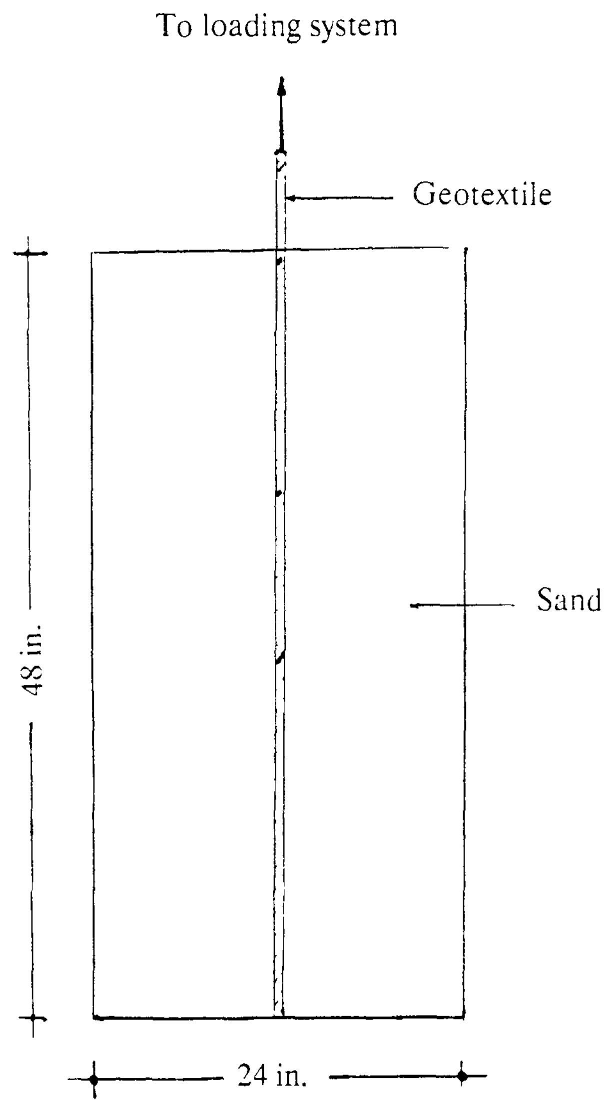


FIGURE 4.2 Cross-Section of the sand box for vertical pull.

Table 4 3 : Combined Vertical and Horizontal Pullout

Test No	Vertical Embed Length (ft)	Horizontal Emb Length (ft)	Surcharge (ft)	Geotextile width (ft)	Density of Sand (pcf)	Maximum Load (lb)
V3H1S1	3	1	1	1	109.23	682.17

Table 4.4: Vertical Pullout With Surcharge

Test No.	Embedment Depth (ft)	Surcharge (ft)	Geotextile Width (ft)	Density of Sand (pcf)	Maximum Load (lb)
V3S1	3	1	1	109.52	341.09

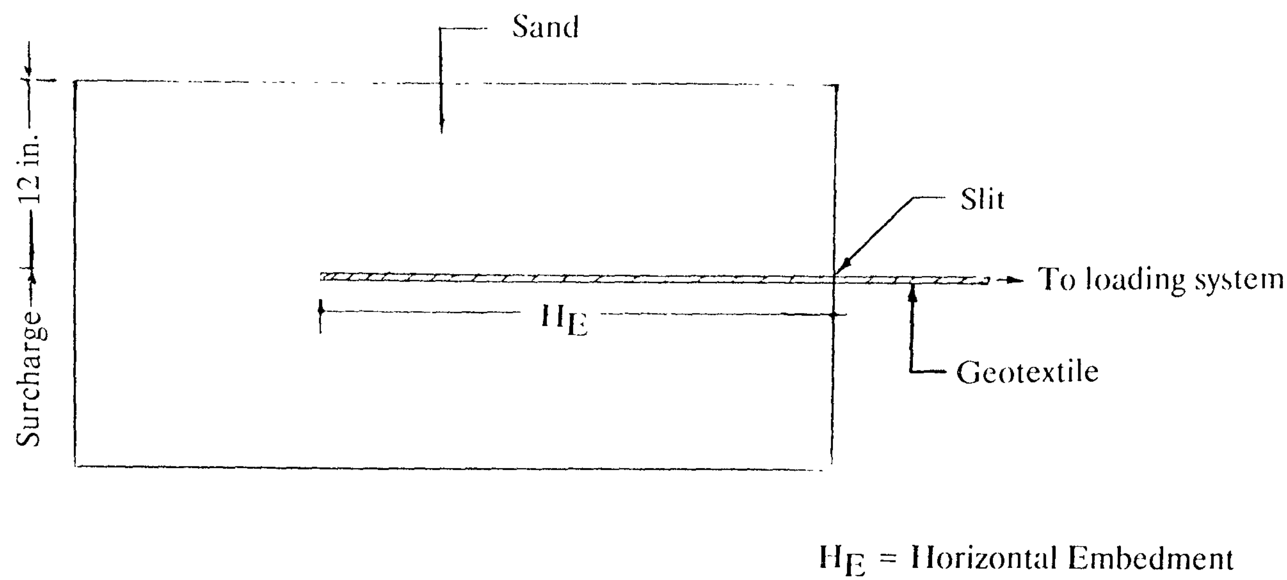


FIGURE 4.3 Cross-Section of the sand box for horizontal pull.

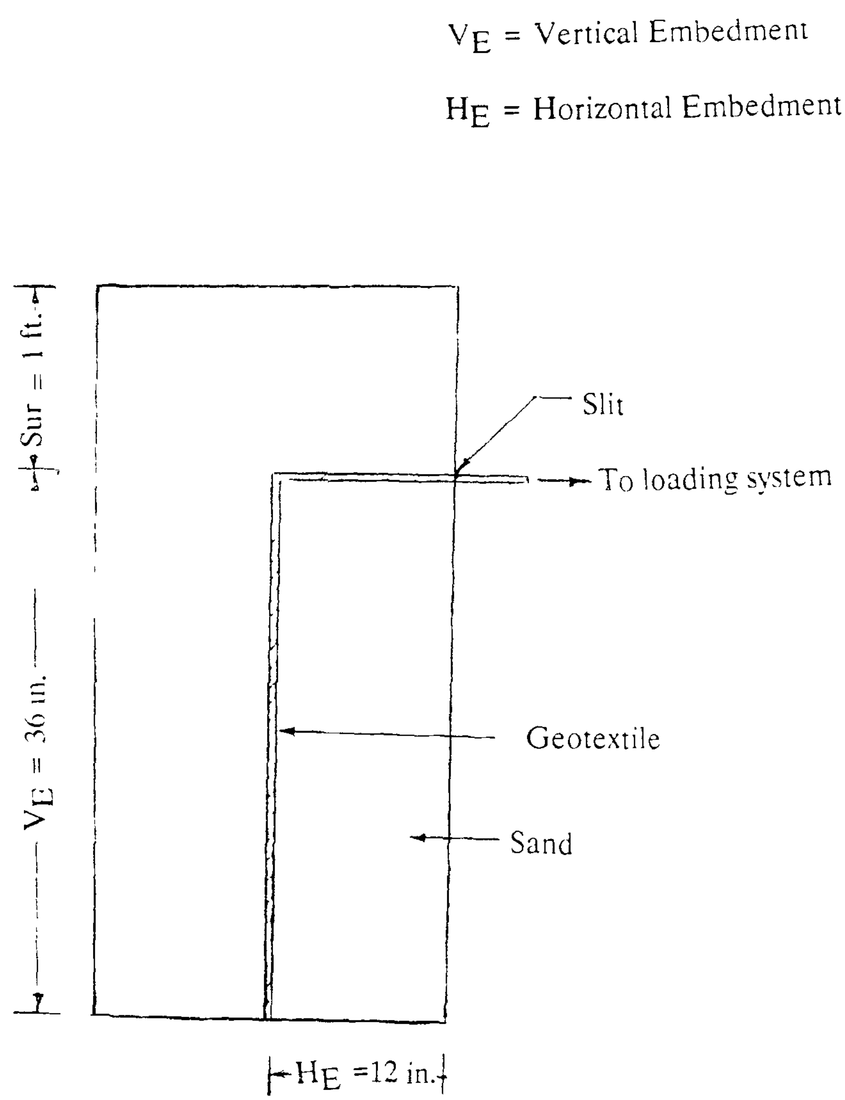


FIGURE 4.4 Cross-Section of the sand box for combined pullout test.

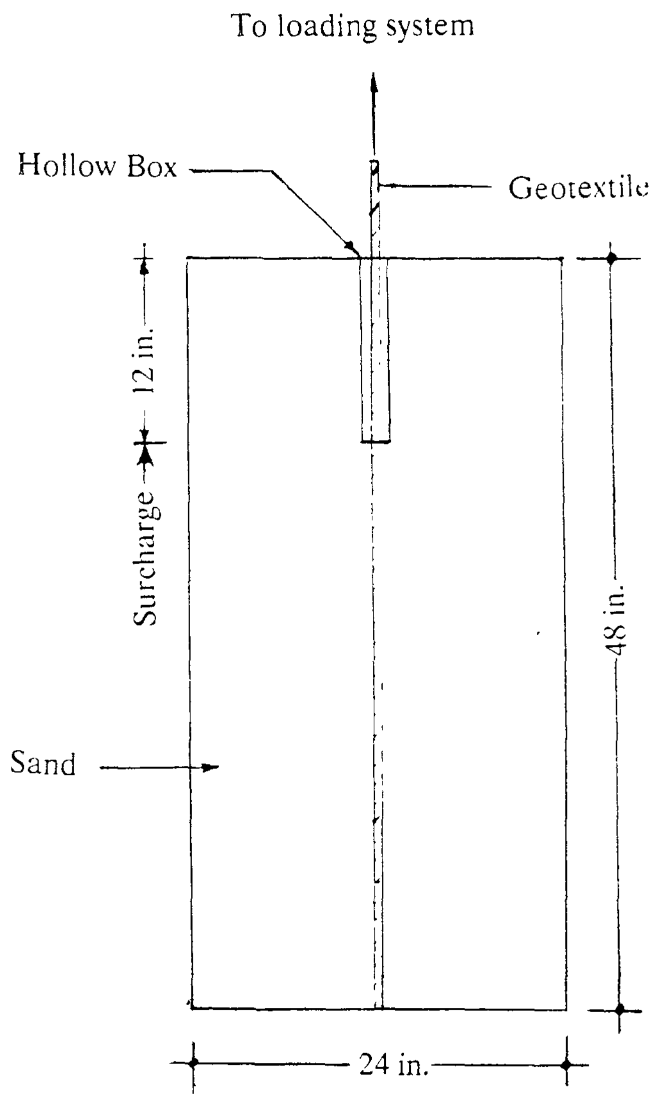


FIGURE 4.5 Cross-Section of the sand box for vertical pull with surcharge.

CHAPTER 5

ANALYSIS OF RESULTS AND DISCUSSION

The results of all the tests are presented in Table 5.1 . The following sections will discuss the mechanism involved in the failure pattern for different embedments and analyze the result obtained from the tests.

5.1 FAILURE SURFACE PATTERN FOR SHALLOW EMBEDMENT

Generally it is assumed that a geotextile embedded in earth simply slips along the interface as it is pulled out. Kasturi (1990) found that the failure occurs away from the interface of sand and geotextile in the form of a sand cone. The same type of failure surface was observed in the present research. Fig 5.1 shows the sand cone development at surface for 1 ft. embedment.

Baker and Kondner (1966) described the possible pattern of failure zone development for an anchor with wide circular base. Although the geotextile did not have a wide base like an anchor, the movement observed for sand was similar to that of an anchor. The pullout resistance depends on the shape of the failure zone, i.e. the surface area of the sand mass that moves with the geotextile.

The reason for formation of conical surface can be justified as follows. As the sand was poured around the geotextile, sand particles got into the openings of geotextiles. These sand particles developed an interlocking friction with the geotextile during pullout test and due to arching action, it mobilized large quantity of sand lying over it. Through this process, at the sand surface an increasing amount of sand moved up creating a heave around geotextile. Fig 5.2 (a) shows the possible failure shape in geotextile pullout for shallow embedment. As the surcharge along the geotextile decreases with decreasing depth, there is a decreasing resistance to the movement of sand. This results in a bell shaped cone formation. The cone formed with smooth geotextile is smaller than that for a rough geotextile due to little or low interlocking friction between sand and geotextiles (Kasturi, 1990).

5.2 ANALYSIS BASED ON CONE SHAPED FAILURE SURFACE

A cone was observed to form up to 2 ft. embedment. There was no cone in the case of 3 ft. embedment. Kasturi (1990) observed a small cone with 2.67 ft. embedment. For the given sand and density within the range 104.81 to 110.75 pcf, an embedment depth less than 3 ft. is treated as shallow embedment and a depth of 3 ft. or more as deep embedment.

For shallow embedment, the analysis is based on the surface area of cone. The extent of movement at the surface of sand was clearly visible. The shape and dimensions of the heave were used for the analysis. The heave at the edge of geotextile was of circular shape. Along the width of geotextile the heave was slightly curved. Fig 5.2 (b) shows the actual shape of the heave. In the field the width of geotextile is very large compared to the test width 12 inch. For the analysis of the heave is assumed along a surface parallel to the width of the geotextile. Fig. 5.3 shows the dimensions which are used in calculations. Equilibrium of all the forces acting on the cone are considered in the analysis. The sample calculations are given in appendix-A.

5.3 EFFECT OF INCREASING DEPTH FOR SHALLOW EMBEDMENT

The prism angle in case of 1 ft. embedment is worked out as 11.86° and corresponding cone angle 9.09°. For 2 ft. embedment the prism angle is 4.57° and cone angle is 2.29°. That is the prism and the cone angles decrease with increase of embedment. The same pattern was also observed by Kasturi (1990).

5.4 FAILURE PATTERN FOR DEEP EMBEDMENT

As mentioned earlier, with the increase in embedment the prism and the cone angles decrease, finally after a certain depth the sand cone does not develop at all on the surface. Fig 5.4 shows the failure surface for deep embedment. For tests with the embedment depth of 3 ft. or more, no heave was apparent at the surface. A small amount of sand that was entrapped in the opening of the geotextile came out with the geotextile during pullout.

5.5 ANALYSIS OF TEST RESULT FOR DEEP EMBEDMENT

For deep embedment the failure occurs at the interface of sand and geotextile. Fig. 5.5 shows the forces acting on geotextile. Equilibrium of all the forces is used in the analysis. The sample calculations are shown in appendix - A.

5.6 EFFECT OF INCREASING DEPTH FOR DEEP EMBEDMENT

From Fig 5.6 it is apparent that the pullout resistance increases linearly with the increase in depth of embedment. The horizontal force due to overburden pressure is acting normal to the geotextile surface. The frictional component of this force is the resisting force against pullout. Table 5.2 shows the stresses acting on the geotextile for different embedment

5.7 ANALYSIS OF TEST FOR HORIZONTAL EMBEDMENT

The horizontal pullout tests were conducted for 1 ft and 2 ft embedment with the surcharge of 1 ft. The coefficient of interface friction between sand and geotextile was computed from normal stress due to surcharge and shear stress due to pullout. The result are shown in Table 5.1. Details of calculations are given in appendix - A. From the results it appears that the value of interface frictional resistance decreases with increase in length of embedment which is in agreement with studies conducted by Rao and Pandey (1988).

5.8 ANALYSIS OF TEST WITH SURCHARGE

The vertical pullout test (Fig. 4.5) with surcharge was conducted for 3 ft embedment with 1 ft surcharge. The result is shown in Table 5.1. The pullout resistance of V3S1 is computed 10 % higher than that from V3 test. This is due to greater depth at which geotextile in test V3S1 was embedded.

Again (Table 5.1) the pullout resistance for test V4 and V1 were computed as 380 lbs and 95 lbs respectively. Therefore, the net resistance for 3 ft embedment (380 - 95) = 285 lbs.

For the same embedment depth the pullout resistance for V3S1 = 341 lbs

Hence, the increase in pullout resistance = 100 x (341 - 285) / 285 = 19.65 %

This increase in pullout resistance is due to the formation of sand cone for V1 test which contributed a greater resistance than the upper 1 ft in V4 .

5.9 THE DEFLECTION CORRESPONDING MAXIMUM LOAD

The deflection corresponding to maximum load with different embedment is given in Fig. 5.7. The deflection increases with increase in vertical embedment. The increase is higher for deep embedment than for shallow embedment.

5.10 COMBINED PULLOUT RESISTANCE

In practice geotextile is placed horizontally and then extended vertically down into the trench. The pull on geotextile is exerted along the slope or in a horizontal direction. The pull is resisted partly by the vertical run out and partly by the horizontal runout. In order to interpret these results, tests were performed on geotextile embedded horizontally and geotextile embedded in a vertical position with a surcharge. Both types of tests were conducted with 1 ft surcharge. The total resistance from these two tests are then compared with the test results for combined horizontal and vertical embedment.

5.11 ANALYSIS OF THE COMBINED TEST RESULT

From Table 5.1 the pullout resistance for the horizontal test H1 with 1 ft. surcharge = 178 lbs.

The pullout resistance for the vertical test V3S1 = 341 lbs.

Total pullout resistance of the two tests = 178 +341 = 519 lbs.

For the combined horizontal and vertical test V3H1S1, the pullout resistance = 682 lbs.

Therefore, increase or efficiency in the pullout resistance due to the run out of 1 ft width geotextile from vertical to horizontal can be computed as:

$$[(682 - 519) / 519] \times 100 = 31.4 \%$$

Similar calculation for the test results performed by Kasturi (1990) shows that for test V1H1.37S1 with 3 inchs width the efficiency is 26% and for V1.67H1.37S1 with 3 inchs width the efficiency is 29 %. Thus for a given surcharge (1 ft.) the efficiency is found to be very close although their widths and depths are different.

The efficience is similar to the mechanical advantage in the case of a pulley. The soil portion marked 'P' in Fig. 4.4 can be considered as a soil drum acting as a pulley over which the geotextile runs.

The efficiency equation can be written as follows:

$$T_2 = T_1 \times e^{(\mu \quad \pi/2)}$$

Where, $\mu = \tan \varnothing$, T_1 = maximum load for vertical pull for the given surcharge and T_2 = maximum load for the combined pullout test.

From V3S1 test T_1 = 341 lbs., and $\mu = \tan 39.8^\circ$

Hence $T_2 = 341 \times e^{(\tan 39.8 \quad \pi/2)}$

= 1262 lbs.

The experiment value is 682 lbs. from V3H1S1 test.

The experimental value is much less than that of computed using efficiency equation. So the above efficiency equation does not hold good. The equation is to be modified for the friction coefficient ø. Because at the fabric-soil interface ø will be different.

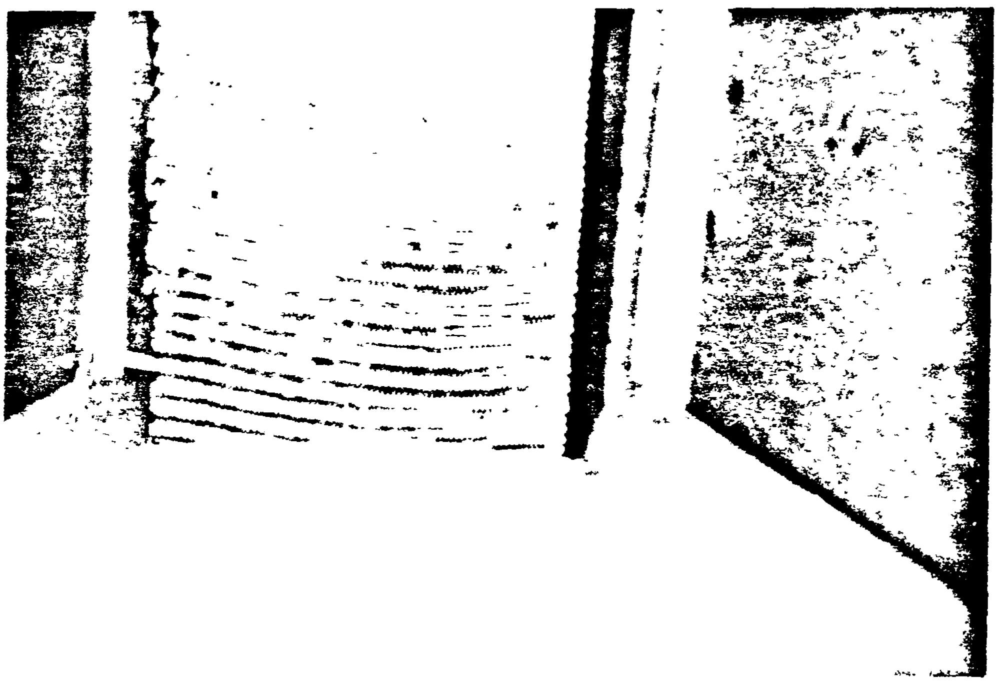


Fig. 5.1 Shape of cone for Test V1 at the sand surface.

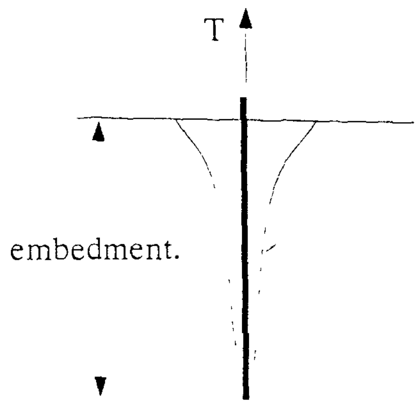


Fig 5.2 (a) Possible failure shape in geotextile pullout for shallow embedment.

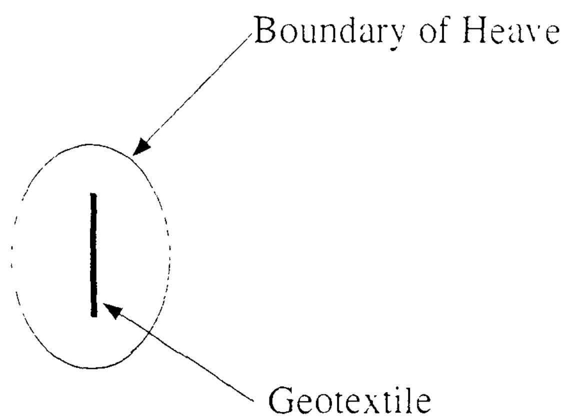
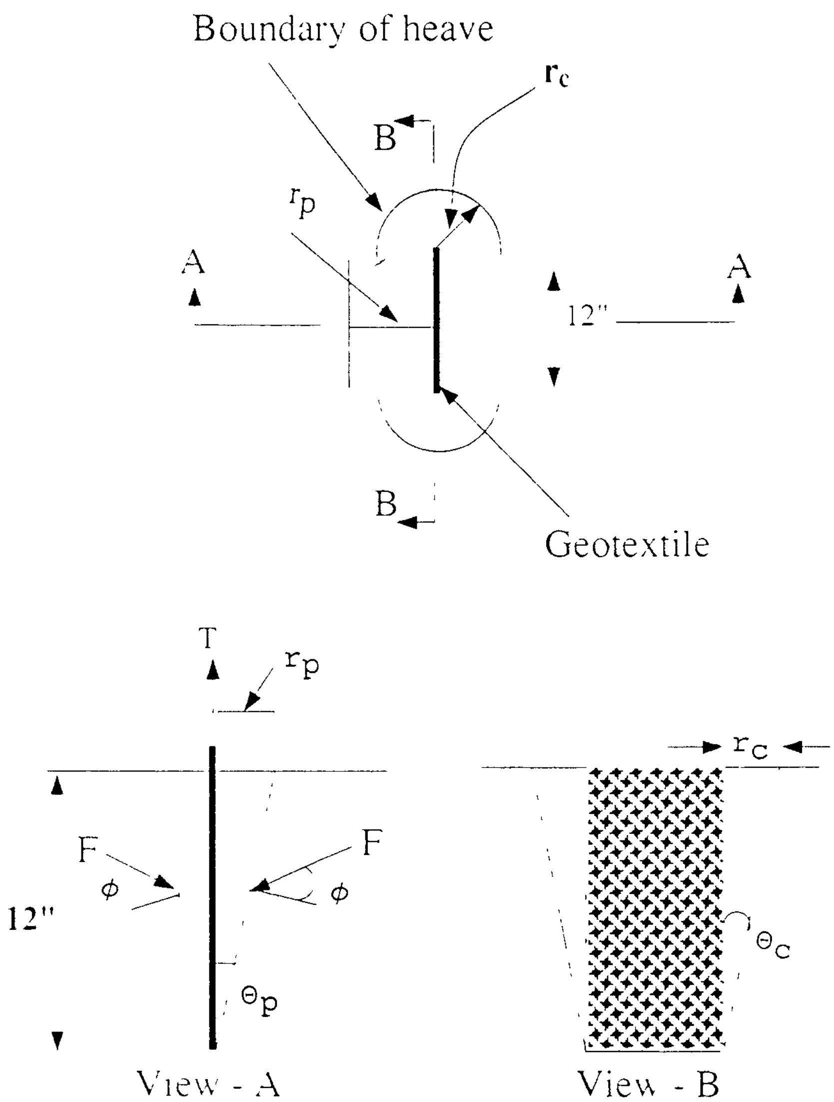


Fig. 5.2 (b) Actual shape of heave observed at sand surface.



ϕ = friction angle
Θ_p = prism angle
Θ_c = cone angle

r_c = avg. cone radius
r_p = avg. heave distance

Fig. 5.3 Forces acting on sand cone for shallow embedment

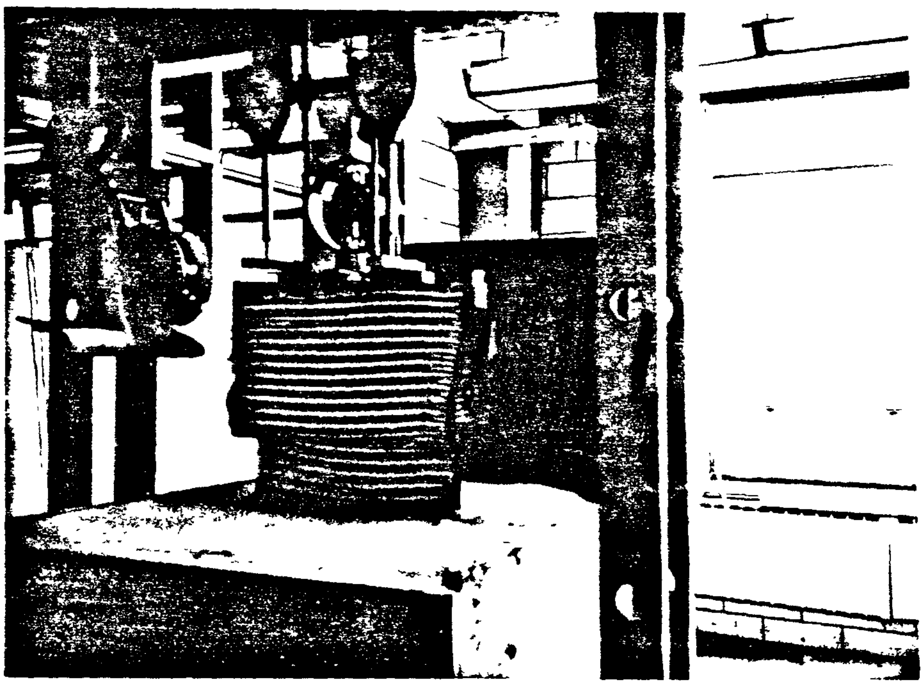


Fig. 5.4 Test V4 after vertical pullout

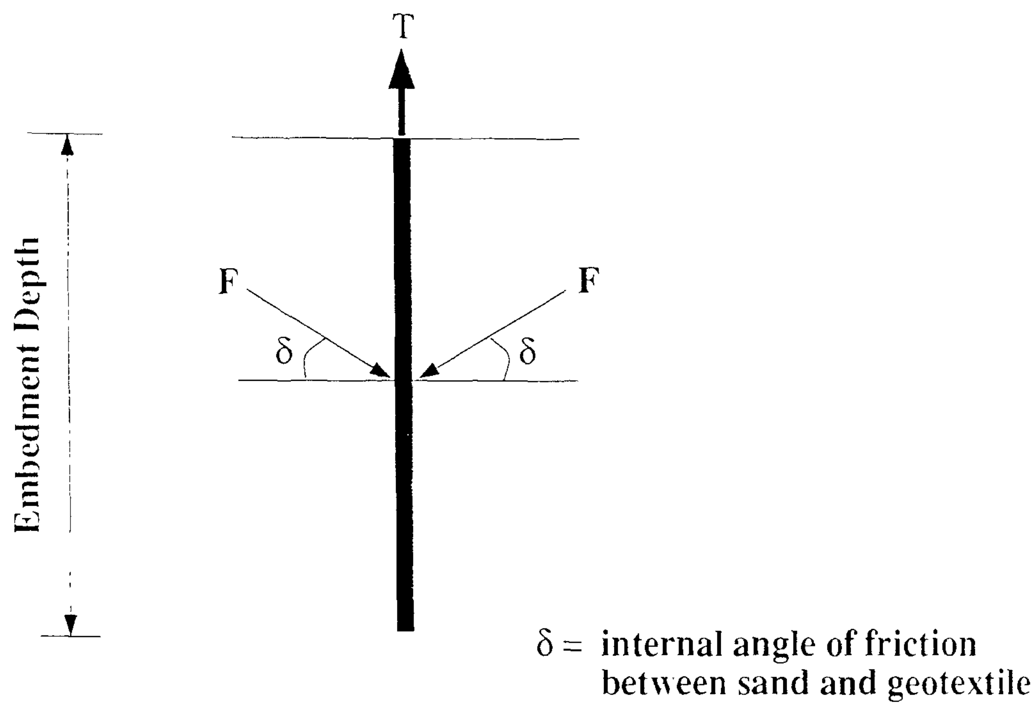


Fig. 5.2 Forces Acting on the Geotextile for Deep Embedment (>3 ft)

Fig. 5.6: RELATIONSHIP FOR MAXIMUM LOAD WITH DIFFERENT DEPTH

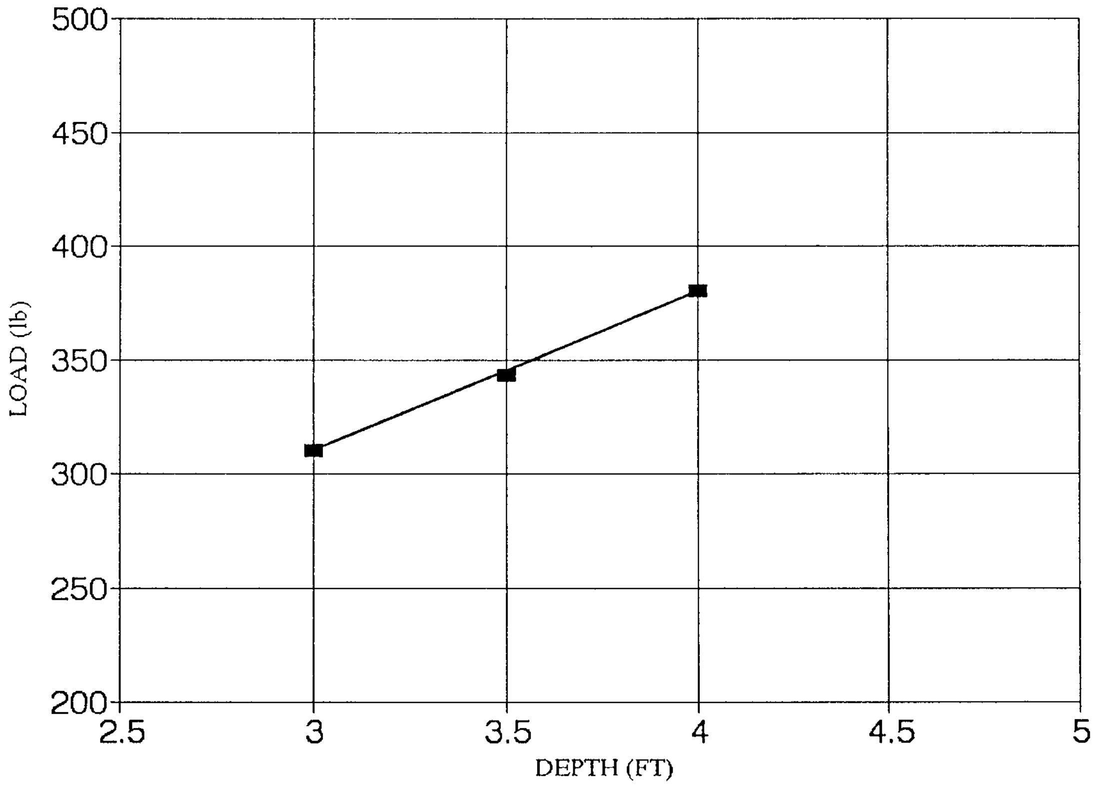


Fig. 5.7 RELATIONSHIP OF DEFLECTION AT FAILURE WITH EMBEDMENT

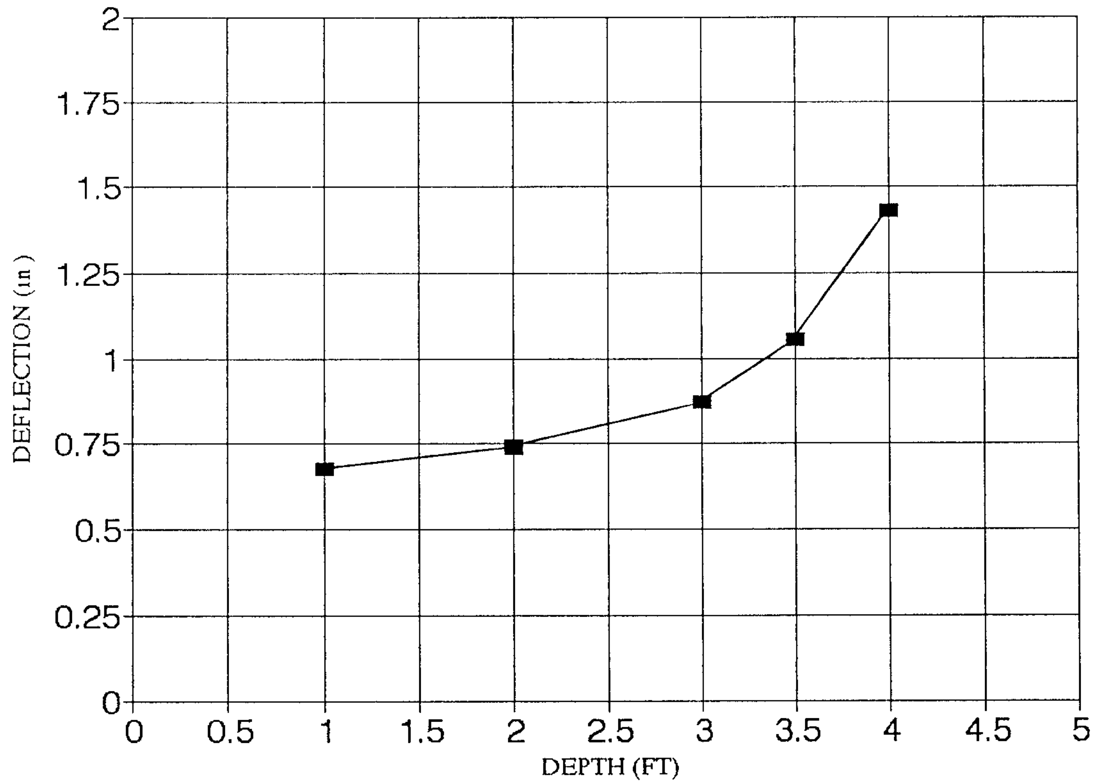


TABLE 5 1 SUMMERY OF ALL TEST RESULTS

Test No	Type of Geotextile	Embedment Length (ft)	Surcharge (ft)	Density (pcf)	Avg Heave Distance rp (ft)	Avg Cone Radius rc (ft)	Maximum Load (lb)
V1	Nicolon	1	0	107.81	0.21	0 15	95
V2 (A)	Nicolon	2	0	106 32	0.16	0 08	225
V2 (B)	Nicolon	2	0	110.75	0.16	0.08	229
V3	Nicolon	3	0	104 81	0	0	310
V3 5	Nicolon	3.5	0	109 11	0	0	343
V4	Nicolon	4	0	106 78	0	0	380
V3S1	Nicolon	3	1	109 52	0	0	341
H1S1	Nicolon	1	1	106 11	0	0	178
H2S1	Nicolon	2	1	106 41	0	0	333
V3H1S1	Nicolon	Ver 3 Hor 1	1	109.23	0	0	682

TABLE 5 2 ANALYSIS OF THE TEST RESULTS

Test No	Prism Angle(deg)	Cone Angle(deg)	side area sq ft	End area sq ft	Maximum Load (lb)	Sand cone Weight (lb)	Interface Fric Angle δ	* Ks /Kd / Kh	Avg Stress psf
V1	11 86	8 53	2 0436	0 4765	95	25 18	39 8	Ks = 1 08	58 22
V2 (A)	4 574	2 29	4 0128	0 50306	225	35 448	39 8	Ks = 0 69	73 36
V2 (B)	4 574	2 29	4 0128	0 50306	229	36 925	39 8	Ks = 0 67	74 2
V3	0	0	6	0	310	0	39 8	Kd = 0 51	80 18
V3 5	0	0	7	0	343	0	39 8	Kd = 0 40	76 38
V4	0	0	8	0	380	0	39 8	Kd = 0 35	74 21
V3S1	0	0	6	0	341	0	39 8	Kd = 0 32	87 62
H1S1	0	0	2	0	178	0	40	Kh = 0 84	89
H2S1	0	0	4	0	333	0	37 95	Kh = 0 78	83 25
V3H1S1	0	0	8	0	682	0	39 8	Effi =1 31	85 25

*

Ks = Earth pressure coefficient for shallow embedment

Kd = earth pressure coefficient for deep embedment assuming $\delta = \phi$

Kh = interface friction coefficient for sand & geotextile

CHAPTER 6

SUMMARY

Pullout tests on vertically embeded geotextiles showed two types of failure patterns:

(a) For embedment of less than 3 ft pullout of the geotextile resulted in the movement of a sand mass with a shape of an inverted prism with conical ends.

(b) For deep embedment (≥ 3 ft), no lifting of sand mass was observed.

(c) The prism angle for 1 ft. embedment was 11.86° and for 2 ft. embedment it was 4.57° .

(d) In the horizontal pullout the friction resistance decreases with the increase in the embedment length of geotextile.

(e) The increase in the pullout resistance from the combined horizontal and vertical embedment over sum of the individual resistance of horizontal and vertical embedments was about 30 % for 1 ft surcharge and it remains almost the same for different embedment depths with the same surcharge.

SCOPE OF FUTURE RESEARCH

The effect of increase in surcharge for different depths and width of embedment can be studied. The effect of surcharge on the horizontal embedment is also to be studied. The pullout resistance for various types of geotextiles are also need to be further studied.

Since clay is used as cover material in most of the cases, so tests with geotextile and clay can be carried out to study the failure pattern It would be very useful if different saturation conditions of the soils are studied to find its effect on the frictional properties of the geotextile.

APPENDIX - A

A. 1 CALCULATION OF TEST RESULTS FOR SHALLOW EMBEDMENT

In case of shallow depth (<3 ft), sand cone was developed. Fig. A1 shows the forces acting on the sand cone during pullout for V1 test. Using equilibrium of forces acting on the sand cone, the following expression is used for the calculations:

$$T = W + 1/2 \times K_S \times \tau \times H \times [A_p \times \sin(\phi - \Theta_p) + A_C \times \sin(\phi - \Theta_c)] \qquad \text{-----(1)}$$

Where,

T = Pullout resistance.

W = Weight of the sand cone.

K_S = Constant.

τ = Unit weight of sand.

H = Vertical embedment of the geotextile.

A_p = Surface area of the prism.

A_c = Surface area of the end cone.

ϕ = Internal angle of friction of the sand.

Θ_p = Prism angle of the sand cone.

Θ_c = Cone angle of the end portion of sand cone

A. 1. 1 Sample calculation for 1 ft embedment

T = 95 lbs.

H = 1 ft

τ = 107.81 lbs/cu. ft

w = width = 1 ft

$\phi = 39.8^\circ$

$\Theta_p = \tan^{-1}(r_p / H) = \tan^{-1}(.21 / 1) = 11.86^\circ$

$\Theta_c = \tan^{-1}(r_c / H) = \tan^{-1}(.15 / 1) = 8.53^\circ$

$A_p = (H / \cos \Theta_p) \times w \times 2 = 1.0218 \times 1 \times 2 = 2.0436$ sq. ft.

$A_c = \pi \times r_c \times (H / \cos \Theta_c) = 22/7 \times 0.15 \times 1.011 = 0.4765$ sq.ft.

Total volume of sand cone (V):

$= [2 \times 1/2 \times r_p \times H \times w] + [\, 1/3 \times \pi \times (r_c)^2 \times H]$

$= [2 \times 1/2 \times 0.21 \times 1 \times 1] + [1/3 \times 22/7 \times (.15)^2 \times 1]$

$= 0.2335$ cu. ft.

Weight of sand cone,

$W = \tau \times V = 107.81 \times 0.2335 = 25.18$ lbs.

Putting all the values in the equation (1),

$K_S = 1.08$

Average Stress on the geotextile

$= 1/2 \times K_S \;\; \times \;\; \tau \times H$

$= 1/2 \times 1.08 \times 107.81 \times 1$

$= 58.22$ lbs/sq ft.

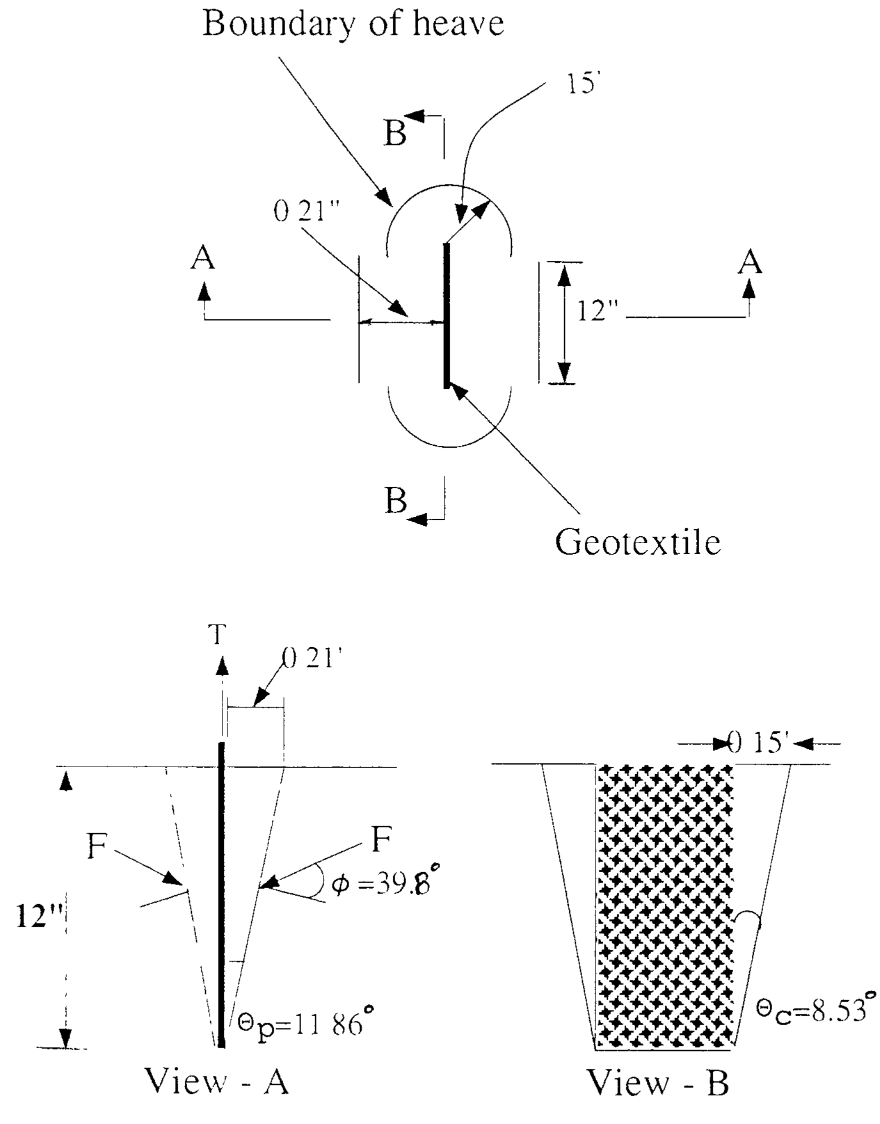


Fig A.1 Forces acting on sand cone for test V1

A. 2 CALCULATION OF TEST RESULTS FOR DEEP EMBEDMENT

For depth of embedment $\geq$ 3 ft no sand cone was observed i.e. the failure occurs along the interface of sand and geotextile. Fig. A2 shows the forces acting on the geotextile for 3 ft vertical embedment.

Using equilibrium of all the forces acting on the geotextile the following expression is used for the calculation:

$$T = 1/2 \times \tau \times H \times A \times Kd \times \sin \delta \qquad \text{------ (2)}$$

Where,

T = Total pullout resistance.

τ = Unit weight of sand.

H = embedment depth

A = Total surface area of the geotextile inside sand

Kd = Earth pressure coefficient

δ = Interface angle of friction between sand and geotextile

= ϕ (If failure is assumed to occur in sand adjacent to geotextile)

A. 2. 1 Sample Calculation for 3 ft Embedment

From the test results,

T = 310 lbs.

H = 3.0 ft.

w = width = 1 ft

τ = 104.81 lbs./cu. ft.

$A = 2 \times w \times H = 2 \times 1 \times 3.0 = 6.0$ sq. ft.

Putting all the values in equation (2),

$310 = 1/2 \times 104.81 \times 3.0 \times 6.0 \times Kd \times \sin 39.8^{\circ}$

$K_d = 0.51$

Average stress on the geotextile

$= 1/2 \times Kd \times \tau \times H$

$= 1/2 \times 0.51 \times 104.81 \times 3$

$= 80.18$ psf.

A. 2. 2 Sample calculation for V3S1 test

From the test result

T = 341 lbs.

H = 3 ft

w = 1 ft

τ = 109.52 lbs./cu. ft

$A = 2 \times w \times H = 2 \times 1 \times 3 = 6$ sft.

S = surcharge = 1 ft

Hence, $T = T = 1/2 \times \tau \times (H + S) \times A \times Kd \times \sin \delta$

$341 = 1/2 \times 109.52 \times (3 + 1) \times 6 \times Kd \times \sin 39.8^{\circ}$

Kd = 0 32

Average stress on geotextile

$= 1/2 \times 0.32 \times 109.52 \times (4 + 1)$

$= 87.62$ psf

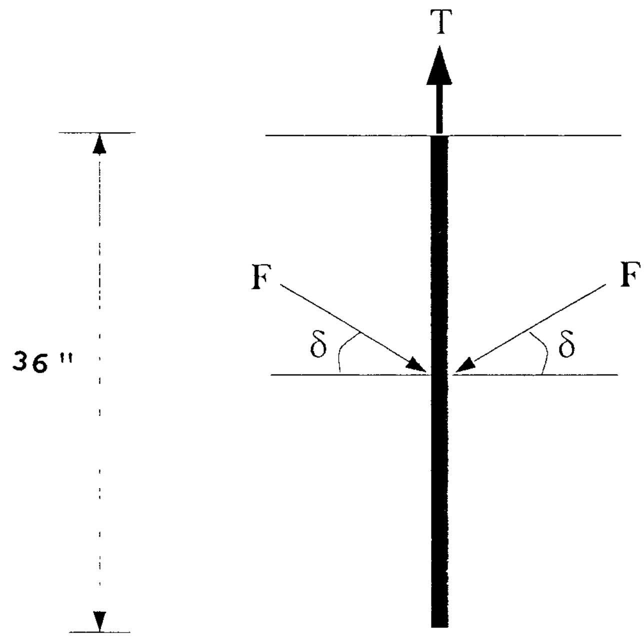


Fig. A 2 Forces Acting on the Geotxtile for Test V4.0

A 3: CALCULATION OF TEST RESULTS FOR HORIZONTAL EMBEDMENT

For horizontal embedment normal stress due to surcharge and shear stress due to pullout is consider in the computations. The following equation is used:

$$\tau = \sigma \times \tan \delta \qquad \text{---- (3)}$$

Where,

τ = shear stress

σ = normal stress

δ = Sand - geotextile friction angle

A 3.1 Sample calculations for 1 ft horizontal embedment

From test results,

τ = 106.11 lbs./ cft

H = 1 ft

T = 178 lbs.

w = 1 ft

Total area contributing resistance,

A = 2 x H x w

= 2 x 1 x 1 = 2 sq ft

Shear stress, τ = T / A

= 178 / 2 = 89.0 lb / sq ft

Normal stress, σ = τ x H

= 106.11 x 1 = 106.11 lb / sq ft

Putting all the values in the equation (3):

$$89 = 106.11 \times \tan \delta$$

$$Kh = \tan \delta = 0.84$$

Hence, $\delta = 39.99^{\circ}$

APPEDDIX - B

LIST OF GRAPHS

FIG. B1: LOAD DISPLACEMENT RELATIONSHIP
FOR TEST V1

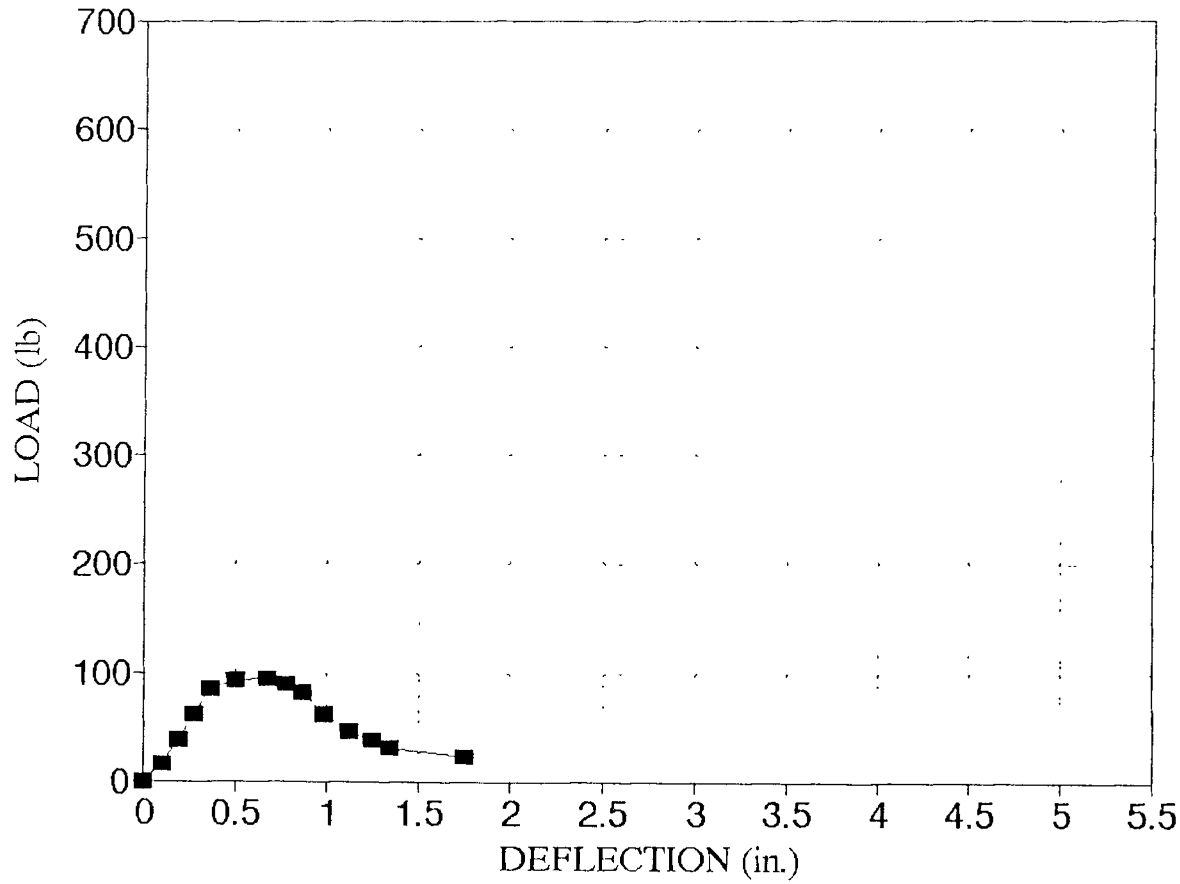


FIG. B2: LOAD DISPLACEMENT RELATIONSHIP
FOR TEST V2 (A)

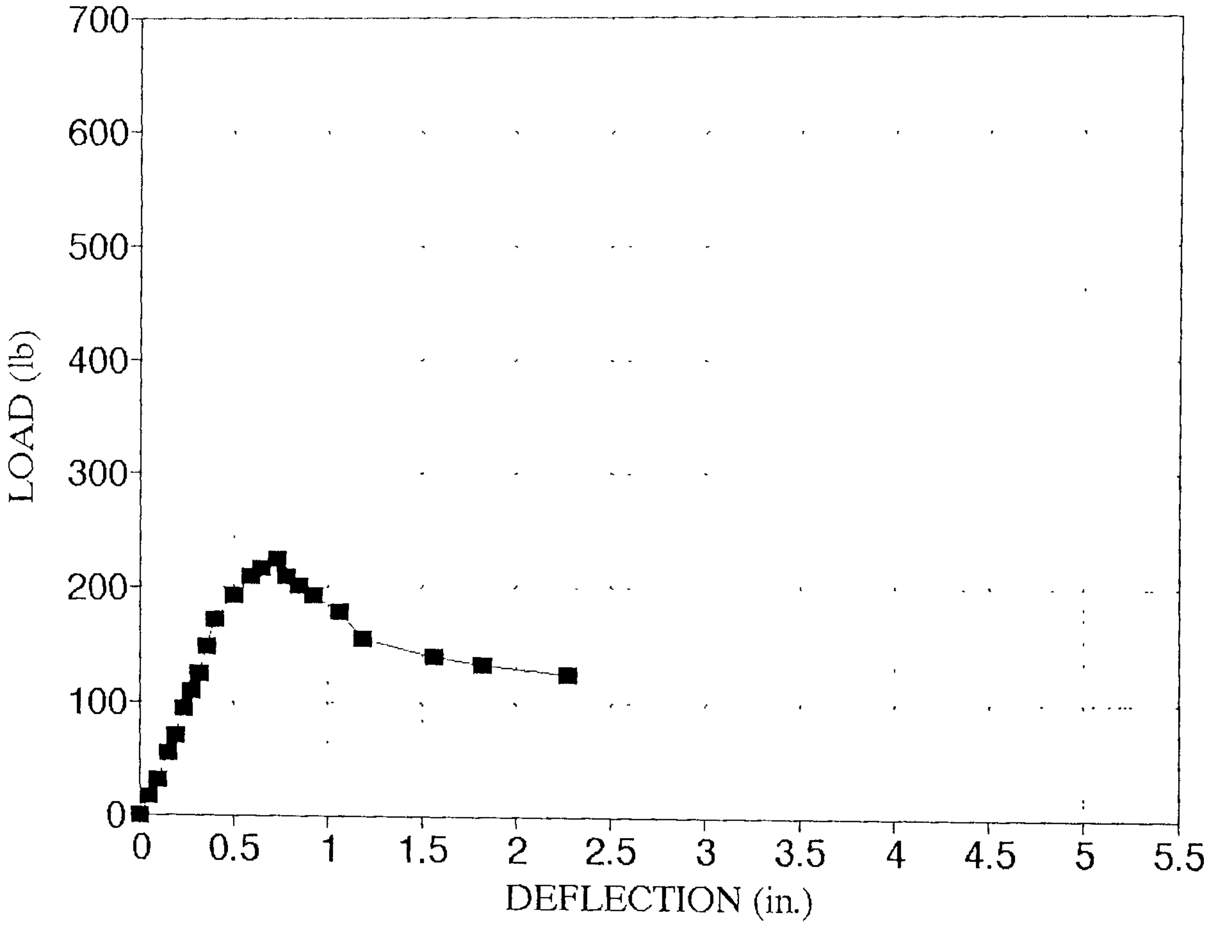


FIG. B3: LOAD DISPLACEMENT RELATIONSHIP
FOR TEST V2 (B)

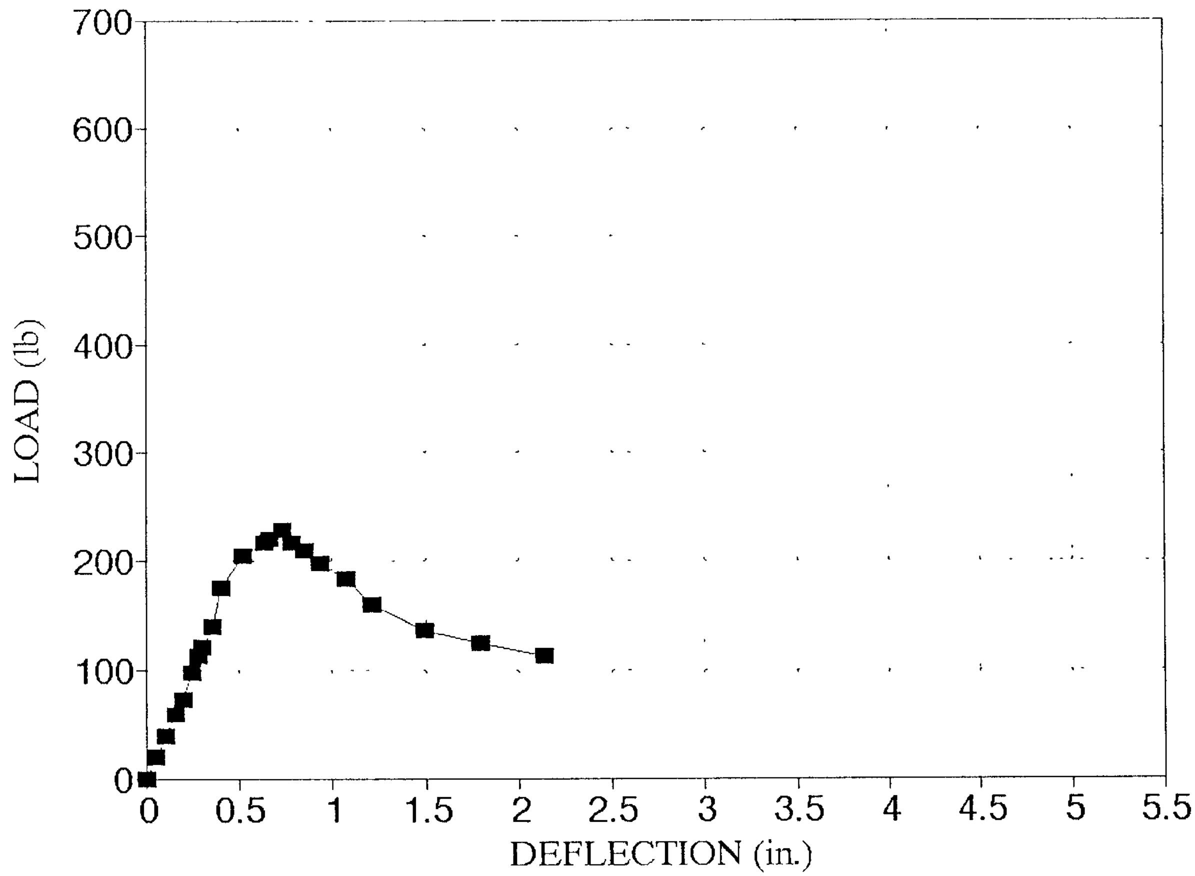


FIG. B4: LOAD DISPLACEMENT RELATIONSHIP
FOR TEST V3

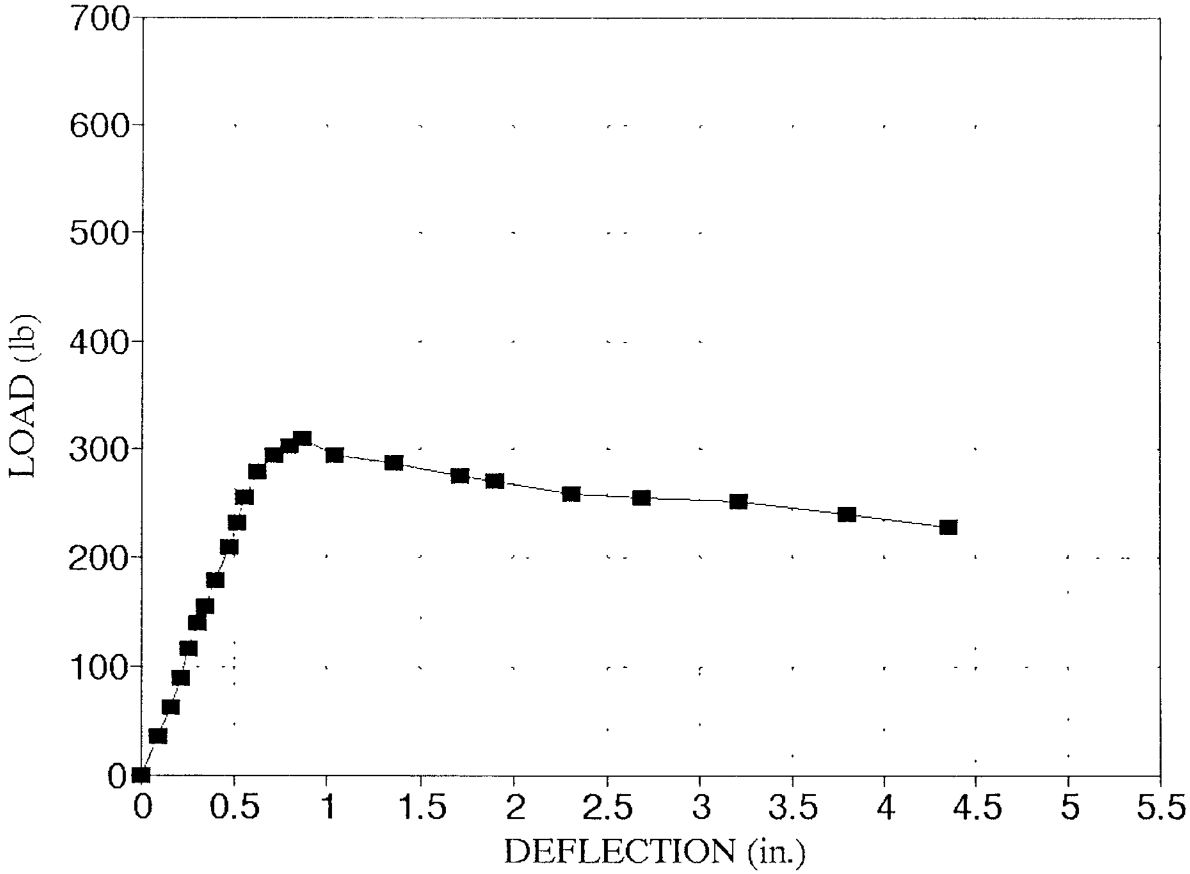


FIG. B5: LOAD DISPLACEMENT RELATIONSHIP
FOR TEST V3.5

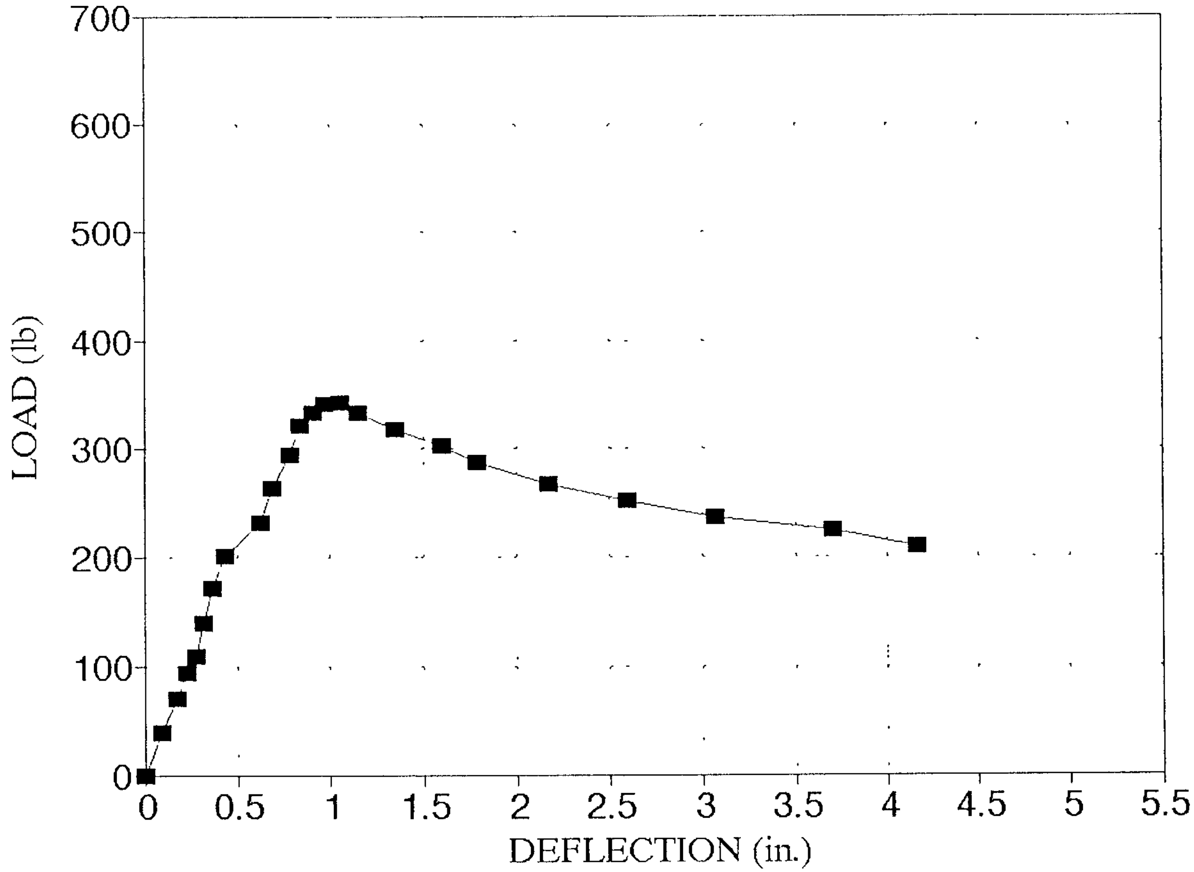


FIG. B6: LOAD DISPLACEMENT RELATIONSHIP
FOR TEST V4

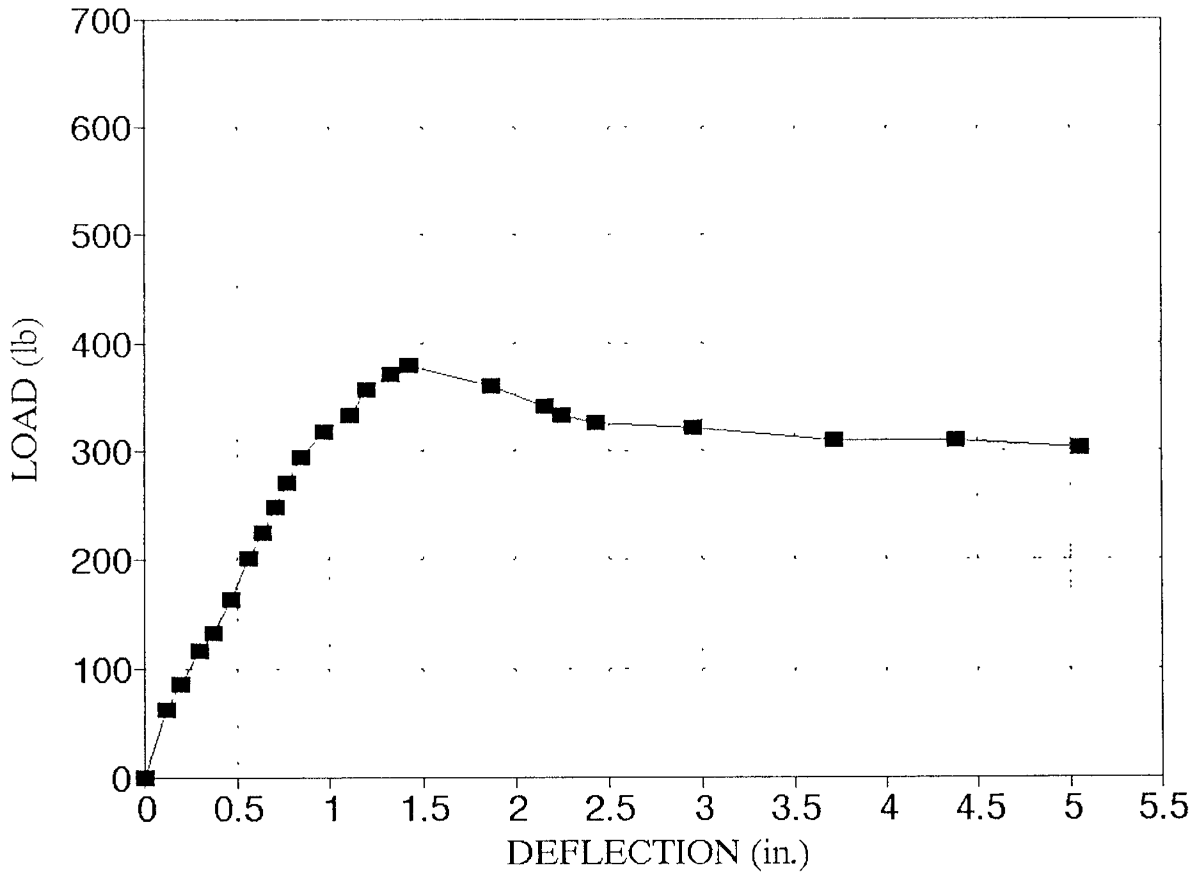


FIG. B7: LOAD DISPLACEMENT RELATIONSHIP
FOR TEST V3S1

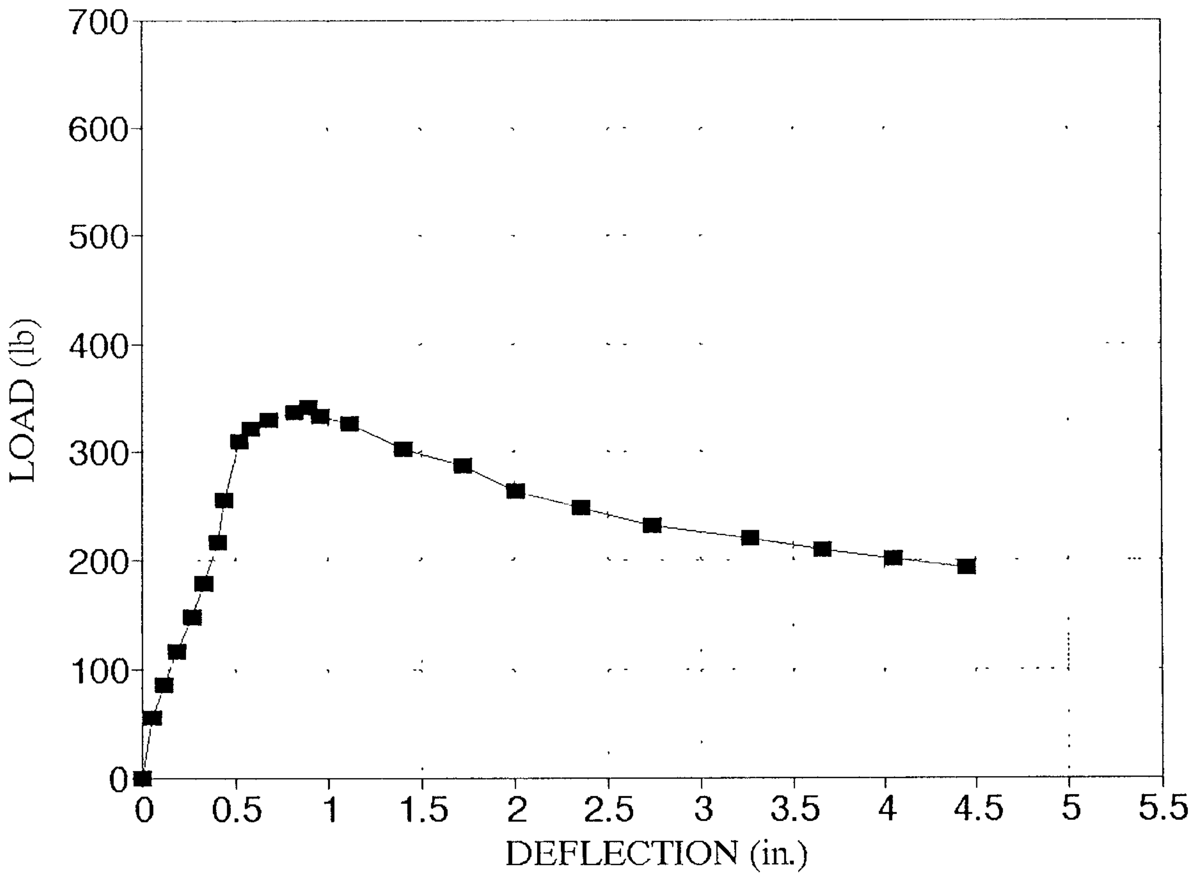


FIG. B8: LOAD DISPLACEMENT RELATIONSHIP
FOR TEST H1S1

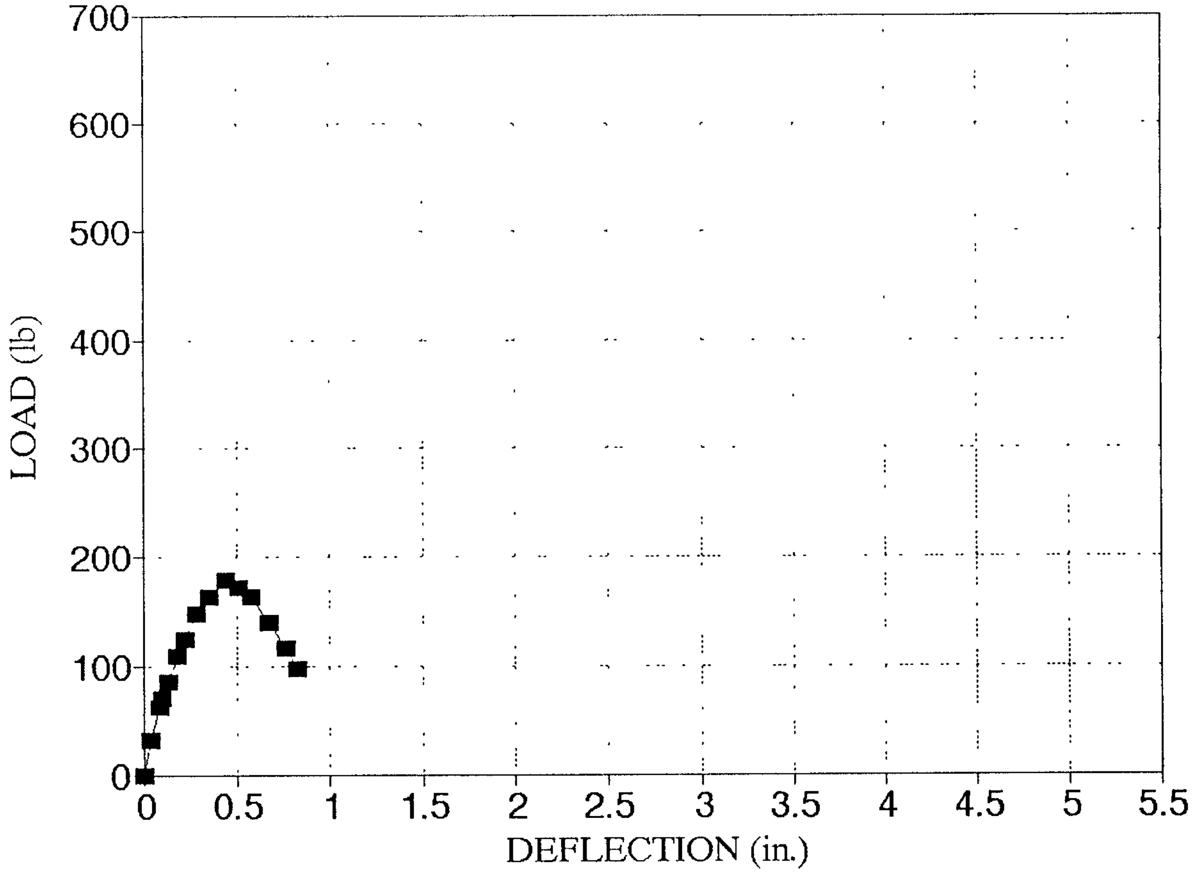


FIG. B9: LOAD DISPLACEMENT RELATIONSHIP
FOR TEST H2S1

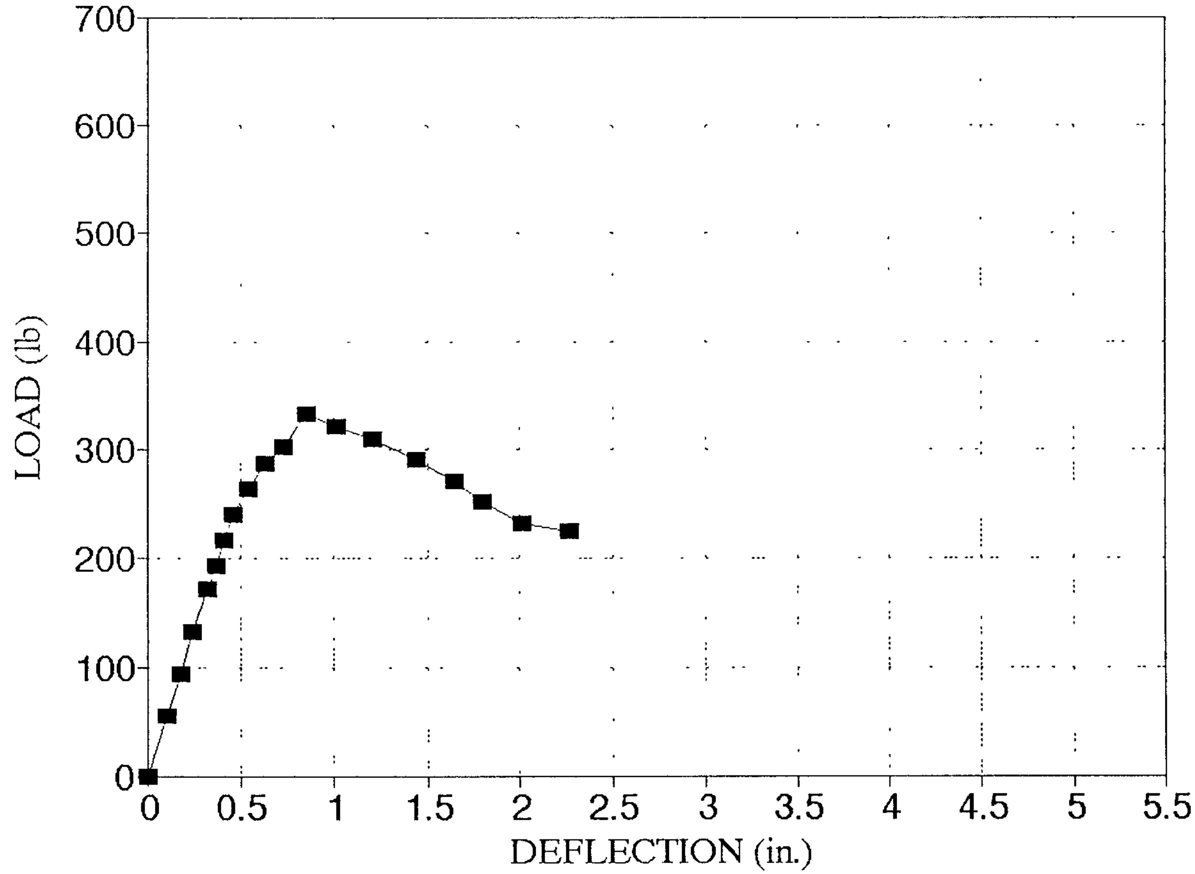
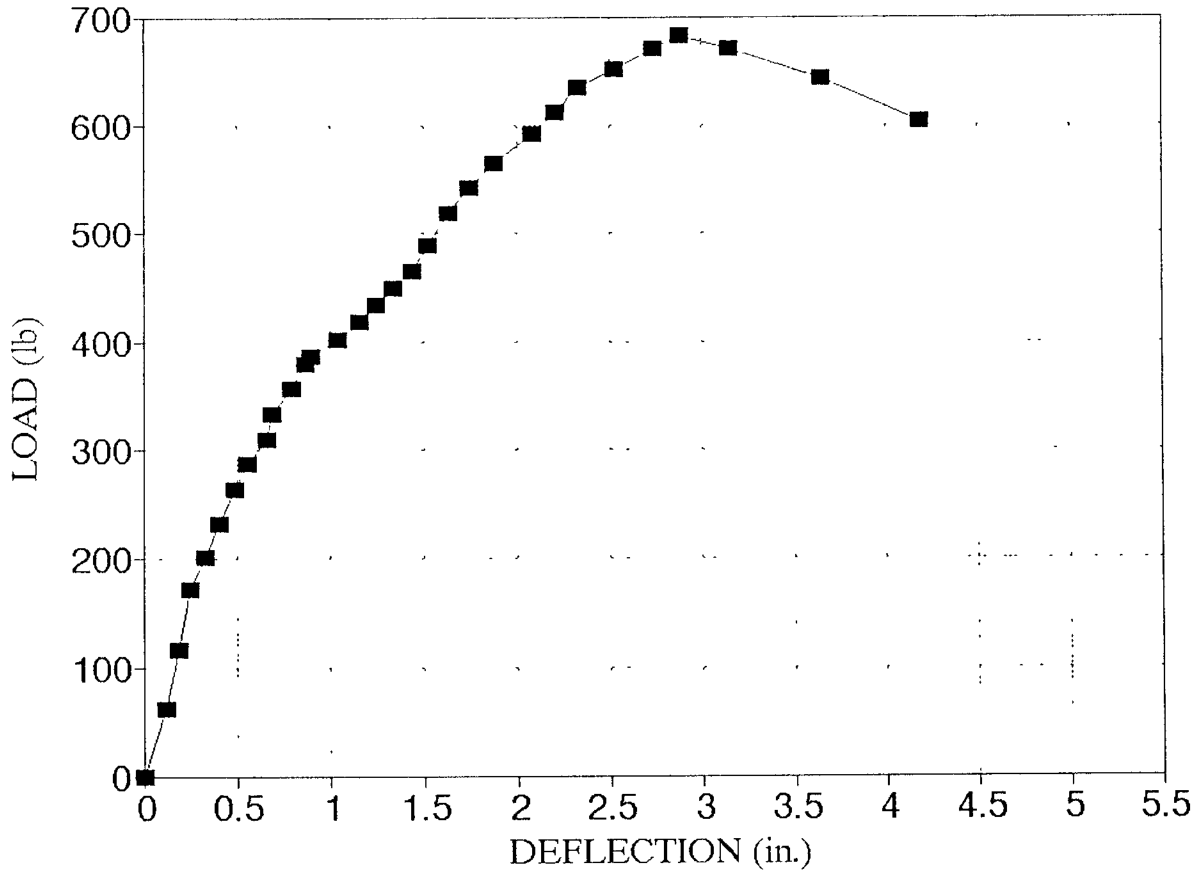


FIG. C10:LOAD DISPLACEMENT RELATIONSHIP
FOR TEST V3H1S1



APPENDIX - C

LIST OF TABLES

TABLE : C1 TEST NO. V1

DATE: SEPTEMBER 11, 1991
WIDTH: 12 in., DEPTH: 1 ft.
DENSITY: 106.11 pcf
PROVINR RING FACTOR· 1.29 lb/div.

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: VERTICAL
MAXIMUM CAPACITY: 775.19 lbs.

SL. NO.	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION (inch)
1	0	0	0	0	0
2	20	15.503876	99	105	0.102
3	50	38.75969	195	190	0.1925
4	80	62.015504	285	270	0.2775
5	110	85.271318	375	360	0.3675
6	120	93 023256	495	510	0.5025
7	122	94.573643	680	670	0.675
8	116	89.922481	760	790	0.775
9	105	81.395349	840	900	0.87
10	80	62.015504	960	1020	0.99
11	60	46.511628	1120	1130	1.125
12	50	38.75969	1230	1260	1.245
13	40	31.007752	1330	1350	1.34
14	30	23.255814	1740	1770	1.755

TABLE C2: TEST NO. V2 (A)

DATE: SEPTEMBER 16, 1991
WIDTH: 12 inchs, DEPTH: 2 ft.
DENSITY: 108.05 pcf.
PROVING RING FACTOR: 1.29 lb/div.

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: VERTICAL
MAXIMUM CAPACITY: 775.19 lbs.

SL. NO.	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION (inch)
1	0	0	0	0	0
2	20	15.503876	49	50	0.0495
3	40	31 007752	98	100	0.099
4	70	54.263566	157	160	0.1585
5	90	69.767442	188	200	0.194
6	120	93.023256	230	240	0.235
7	140	108.52713	270	280	0.275
8	160	124.03101	310	320	0.315
9	190	147.28682	355	355	0.355
10	220	170.54264	410	390	0.4
11	250	193.79845	530	480	0.505
12	270	209.30233	610	580	0.595
13	280	217.05426	650	640	0.645
14	290	224 8062	740	730	0.735
15	270	209.30233	770	780	0.775
16	260	201.55039	850	855	0.8525
17	250	193.79845	910	930	0.92
18	230	178.29457	1045	1070	1.0575
19	200	155.03876	1160	1210	1.185
20	180	139.53488	1540	1590	1.565
21	170	131.78295	1800	1840	1.82
22	160	124 03101	2260	2285	2.2725

TEST C3: TEST NO. V2 (B)

DATE: MAY 27, 1991
WIDTH: 12 inchs, DEPTH: 2 ft.
DENSITY: 110.75 pcf.
PROVING RING FACTOR 1 29 lb/div.

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: VERTICAL
MAXIMUM CAPACITY: 775.19 lb

SL. NO.	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION (inch)
1	0	0	0	0	0
2	25	19.379845	45	50	0.0475
3	50	38.75969	100	105	0.1025
4	75	58 139535	160	170	0.165
5	93	72.093023	190	210	0.2
6	125	96 899225	240	255	0.2475
7	145	112.4031	280	295	0.2875
8	155	120.15504	300	320	0.31
9	180	139.53488	360	355	0.3575
10	225	174.4186	420	400	0.41
11	265	205 42636	540	510	0.525
12	280	217 05426	620	660	0.64
13	285	220.93023	660	670	0.665
14	295	228.68217	755	730	0.7425
15	280	217.05426	780	795	0.7875
16	270	209.30233	850	868	0.859
17	255	197 67442	925	945	0.935
18	235	182.17054	1080	1060	1.07
19	205	158.91473	1185	1230	1.2075
20	175	135 65891	1470	1510	1.49
21	160	124.03101	1760	1820	1.79
22	145	112 4031	2090	2180	2.135

TABLE C4: TEST NO. V3

DATE: MAY 21, 1991
WIDTH: 12 inchs, DEPTH: 3 ft.
DENSITY: 104.81 pcf.
PROVING RING FACTOR: 1.29 lb/div.

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: VERTICAL
MAXIMUM CAPACITY: 775.19 lbs

SL. NO.	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION (inch)
1	0	0	0	0	0
2	44	34.108527	87	95	0.091
3	80	62.015504	150	170	0.16
4	115	89.147287	200	230	0.215
5	150	116.27907	245	265	0.255
6	180	139.53488	300	320	0.31
7	200	155.03876	335	345	0.34
8	230	178.29457	390	410	0.4
9	270	209.30233	460	485	0.4725
10	300	232.55814	500	535	0.5175
11	330	255.81395	555	570	0.5625
12	360	279.06977	612	640	0.626
13	380	294.57364	700	740	0.72
14	390	302.32558	770	830	0.8
15	400	310.07752	840	900	0.87
16	380	294.57364	1020	1060	1.04
17	370	286.82171	1330	1385	1.3575
18	355	275.1938	1690	1725	1.7075
19	350	271.31783	1870	1920	1.895
20	335	259.68992	2290	2330	2.31
21	330	255.81395	2660	2710	2.685
23	325	251.93798	3190	3235	3.2125
24	310	240.31008	3785	3810	3.7975
25	295	228.68217	4330	4380	4.355

TABLE C5: TEST NO. V3.5

DATE: SEPTEMBER 13, 1991
WIDTH: 12 inchs, DEPTH: 3.5 ft.
DENSITY: 109.11 pcf.
PROVING RING FACTOR: 1.29 lb/div.

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: VERTICAL
MAXIMUM CAPACITY: 775.19 lbs

SL. NO.	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION (inch)
1	0	0	0	0	0
2	50	38.75969	90	95	0.0925
3	90	69.767442	160	175	0.1675
4	120	93.023256	220	235	0.2275
5	140	108.52713	270	280	0.275
6	180	139.53488	310	320	0.315
7	220	170.54264	360	365	0.3625
8	260	201.55039	430	440	0.435
9	300	232.55814	620	630	0.625
10	340	263.56589	680	700	0.69
11	380	294 57364	770	795	0.7825
12	415	321.70543	830	850	0.84
13	430	333.33333	900	915	0.9075
14	440	341.08527	960	980	0.97
15	442	342.63566	1040	1070	1.055
16	430	333 33333	1150	1160	1.155
17	410	317.82946	1340	1360	1.35
18	390	302.32558	1590	1610	1.6
19	370	286.82171	1770	1790	1.78
20	345	267.44186	2160	2180	2.17
21	325	251.93798	2590	2610	2.6
23	305	236.43411	3040	3100	3.07
24	290	224.8062	3680	3730	3.705
25	270	209.30233	4140	4200	4.17

TABLE C6: TEST NO. V4

DATE: AUGUST 24, 1991
WIDTH: 12 inchs, DEPTH: 4 ft.
DENSITY: 106.78 pcf
PROVING RING FACTOR: 1.29 lb/div.

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: VERTICAL
MAXIMUM CAPACITY: 775.19 lbs

SL. NO.	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION (inch)
1	0	0	0	0	0
2	80	62.0155	120	125	0.1225
3	110	85.271318	180	210	0.195
4	150	116.27907	280	315	0.2975
5	170	131.78295	350	390	0.37
6	210	162.7907	440	498	0.469
7	260	201.55039	500	628	0.564
8	290	224 8062	590	690	0.64
9	320	248.06202	670	750	0.71
10	350	271.31783	730	810	0.77
11	380	294.57364	820	885	0.8525
12	410	317.82946	990	960	0.975
13	430	333.33333	1050	1165	1.1075
14	460	356.58915	1100	1298	1.199
15	480	372.09302	1200	1450	1.325
16	490	379.84496	1330	1530	1.43
17	465	360.46512	1840	1890	1.865
18	440	341.08527	2120	2190	2.155
19	430	333.33333	2200	2295	2.2475
20	420	325.5814	2410	2450	2.43
21	415	321.70543	2910	2990	2.95
22	400	310.07752	3690	3740	3.715
23	400	310 07752	4340	4410	4.375
24	390	302.32558	4990	5120	5.055

TABLE C7. TEST NO. V3S1

DATE: MAY 28, 1991
WIDTH: 12 inchs, DEPTH: 3 ft.
DENSITY: 109.52 pcf.
PROVING RING FACTOR: 1.29 lb/div.
SURCHARGE: 1 ft

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: VERTICAL
MAXIMUM CAPACITY: 775.19 lbs

SL. NO.	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION (inch)
1	0	0	0	0	0
2	70	54.263566	50	55	0.0525
3	110	85.271318	110	125	0.1175
4	150	116.27907	180	195	0.1875
5	190	147.28682	260	275	0.2675
6	230	178.29457	325	335	0.33
7	280	217 05426	400	410	0.405
8	330	255.81395	440	445	0.4425
9	400	310.07752	520	530	0.525
10	415	321.70543	580	600	0.59
11	425	329 45736	670	690	0.68
12	435	337.2093	810	830	0.82
13	440	341.08527	880	900	0.89
14	430	333.33333	950	970	0.96
15	420	325.5814	1110	1130	1.12
16	390	302.32558	1390	1415	1.4025
17	370	286 82171	1710	1735	1.7225
18	340	263 56589	1990	2025	2.0075
19	320	248.06202	2340	2365	2.3525
20	300	232.55814	2730	2760	2.745
21	285	220.93023	3250	3285	3.2675
23	270	209.30233	3640	3680	3.66
24	260	201.55039	4030	4065	4.0475
25	250	193.79845	4425	4465	4.445

TABLE C8: TEST NO. H1S1

DATE: MAY 30, 1991
WIDTH: 12 in.,DEPTH: HOR. 1 ft.
DENSITY: 106.11 pcf.
PROVING RING FACTOR: 1.29 lb/div.

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: HORIZONTAL
MAXIMUM CAPACITY: 775.19 lbs

SL. NO	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION DEFL.(inch)
1	0	0	0	0	0
2	40	31.007752	40	29	0.0345
3	80	62.015504	85	88	0.0865
4	90	69 767442	94	95	0.0945
5	110	85.271318	145	128	0.1365
6	140	108.52713	175	179	0.177
7	160	124.03101	218	223	0.2205
8	190	147.28682	285	291	0.288
9	210	162.7907	342	355	0.3485
10	230	178.29457	435	448	0.4415
11	220	170.54264	503	510	0.5065
12	210	162.7907	580	585	0.5825
13	180	139.53488	680	675	0.6775
14	150	116 27907	770	760	0.765
15	125	96.899225	830	820	0.825

TABLE C9: TEST NO. H2S1

DATE· JUNE 3, 1991
WIDTH: 12 in., DEPTH: HOR. 2 ft.
DENSITY: 106.41 pcf.
PROVING RING FACTOR: 1.29 lb/div.

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: HORIZONTAL
MAXIMUM CAPACITY: 775.19 lbs

SL. NO.	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION DEFL.(inch)
1	0	0	0	0	0
2	70	54.263566	95	111	0.103
3	120	93.023256	175	183	0.179
4	170	131.78295	245	241	0.243
5	220	170.54264	322	315	0.3185
6	250	193.79845	360	378	0.369
7	280	217.05426	400	425	0.4125
8	310	240.31008	450	470	0.46
9	340	263.56589	550	535	0.5425
10	370	286.82171	640	630	0.635
11	390	302.32558	730	740	0.735
12	430	333.33333	860	850	0.855
13	415	321 70543	980	1050	1.015
14	400	310 07752	1210	1190	1.2
15	375	290.69767	1450	1430	1.44
16	350	271.31783	1660	1635	1.6475
17	325	251.93798	1810	1785	1.7975
18	300	232.55814	2030	1990	2.01
19	290	224.8062	2280	2245	2.2625

TABLE C10: TEST NO. V3H1S1

DATE: OCTOBER 17, 1991
WIDTH: 12 inchs
DENSITY: 109.23 pcf
PROVING RING FACTOR: 1.29 lb/div.

GEOTEXTILE: NICOLON
SOIL USED: FLINT SAND
PULL: VER. 3' & HOR. 1'
MAXIMUM CAPACITY: 775.19 lbs

SL. NO.	LOAD		DEFLECTION		
	DIAL READING	LOAD (lb)	LEFT DIAL(.001 in.)	RIGHT DIAL(.001 in.)	DEFLECTION DEFL.(inch)
1	0	0	0	0	0
2	50	62.0155	72	60	0.1225
3	150	116.27907	200	165	0.1825
4	220	170.54264	285	210	0.2475
5	260	201.55039	351	300	0.3255
6	300	232.55814	430	380	0.405
7	340	263.56589	500	470	0.485
8	370	286.82171	570	550	0.56
9	400	310.07752	670	650	0.66
10	430	333.33333	700	685	0.6925
11	460	356.58915	800	780	0.79
12	490	379.84496	880	860	0.87
13	500	387.5969	900	880	0.89
14	520	403.10078	1050	1030	1.04
15	540	418.60465	1170	1145	1.1575
16	560	434 10853	1260	1240	1.25
17	580	449.6124	1340	1330	1.335
18	600	465.11628	1450	1435	1.4425
19	630	488.37209	1530	1510	1.52
20	670	519.37984	1640	1620	1.63
21	700	542.63566	1760	1730	1.745
22	730	565.89147	1880	1865	1.8725
23	765	593.02326	2090	2060	2.075
24	790	612 4031	2210	2185	2.1975
25	820	635.65891	2340	2315	2.3275
26	840	651.16279	2540	2510	2.525
27	865	670.54264	2760	2725	2.7425
28	880	682.17054	2910	2870	2.89
29	865	670 54264	3175	3130	3.1525
30	830	643.41085	3680	3610	3.645
31	780	604.65116	4210	4160	4.185

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