# Significance of fabric deformation shape at subgrade in design of reinforced flexible pavements

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C.N.V. Satyanarayana Reddy
Andhra University, Visakhapatnam,India

# TECHNICAL NOTE

# SIGNIFICANCE OF FABRIC DEFORMATION SHAPE AT SUBGRADE IN DESIGN OF REINFORCED FLEXIBLE PAVEMENTS

C.N.V. Satyanarayana Reddy[1] and N.V. Rama Moorthy[2]

**ABSTRACT**: Synthetic geotextiles are being used in construction of flexible pavements over weak soil subgrades. They are in use as separator between layers of pavement, drain, filter and reinforcement at subgrade level. The information on reinforced flexible pavements is still in development stage, particularly with respect to soft soil subgrades. As strengths of geotextile fabrics mobilised are functions of strain induced in them, selection of the deformed shape of fabric at subgrade plays a vital role in design. So, in the present paper, an attempt has been made to stress the importance of fabric deformation shape in design and to finalise appropriate fabric deformed shape through analytical and experimental studies. The effect of consideration of different forms of fabric deformed shapes has been dealt in detail through a proposed reinforced flexible pavement design over clay of high compressibility.

**Keywords:** Flexible pavement, Geotextiles, Road, Analytical study

## INTRODUCTION

All roadways derive their strength and stability from subgrade. The pavements loose designed thickness over a period of time due to intrusion of weak subgrade material into aggregate base and penetration of base material into subgrade. The reduced pavement thickness leads to progressive failure mechanism resulting in need for continual road maintenance. It has been reported that a base contamination of about 10 percent subgrade soil fines can destroy structural strength of base layer (Hicks et al., 1986). The problem of contamination can be solved by placement of geotextiles at subgrade level (Guram et al., 1994; Brorsson et al., 1986; Fannin and Sigurdsson, 1996). Further geotextile as a separator between base course and subgrade soil permits water to drain off quickly through and along the plane of the fabric. As a result the surface remains clear, dry and intact (Srivastava et al., 1995). Due to separation, reinforcement, filtration and drainage multi functions, geotextiles have been tried in unpaved roads (Bender and Barenberg, 1978; Koerner, 1986; Fannin and Sigurdsson, 1996).

The literature on design of reinforced flexible pavements over soft clays is limited. The existing developed design procedures are based on a set of assumptions or adhoc in nature whose validity is to be checked. In the design methodologies, the deformed fabric form has been taken to be parabolic (Giroud and Noiray, 1981) and combination of two inclined straights (Natarajan et al., 1989). The method given by Giroud and Noiray is based on quasi-static approach and it considers that the volume of soil displaced under the wheel results in upward displacement of soil in the form a parabola in between the wheels. Based on analytical analysis, woven and non-woven geotextiles have been recommended for use unhesitatingly as they also offer filtration and drainage functions. The use of geotextiles has been reported to be cost effective when sand or other good quality sub base materials are not available within economic leads or when CBR of subgrade is less than 3 and or when roads are waterlogged (Natarajan & Murthy, 1989).

Based on load deformation characteristics observed from tests conducted in CBR moulds on geotextile reinforced CI and CH group soils, it is reported that woven geotextiles reduce deformations and bring economy in terms of thickness of pavement (Shroff et al., 1989). However the method does not explain the actual behaviour of geotextiles in pavement. Based on design procedure developed using modified CBR test, different soil subgrades using geotextiles have revealed that the reinforcing fabrics significantly reduced pavement thickness over soils of CBR less than 1 and reduction in pavement thickness was insignificant for CBR values of about 15 (Koerner, 1986; Rao et al., 1989). So, in the present paper an attempt has been made to arrive at deformed fabric shape at subgrade, which can be used in design of reinforced flexible pavements. As the existing methods are not accounting for safety of subgrade soils and are developed for high surface settlement (rut) values, a design methodology has been proposed by giving due consideration to safety of subgrade soil in shear failure and also by restricting surface settlement values.

## DETAILS OF STUDY

### High Compressible Soil

The high compressible soil used in the study has been procured from a site near National Institute of Technology, Warangal. The engineering properties of the soil determined from laboratory investigations are given in Table 1.

### Design of Reinforced Flexible Pavement over Clayey Soil Subgrade

As conventional CBR method of design is based on load – penetration behaviour of subgrade soils, it will be

[1] Associate Professor, Department of Civil Engineering, Kakatiya Institute of Technology and Science, Warangal – 506015 (A.P) India

[2] Professor and Head, Department of Civil Engineering, National Institute of Technology, Warangal – 506015 (A.P) India

preferable to design pavements over clay subgrades such that they are safe against shear failure, as they are more susceptible to such a failure. Considering the reinforcement to prevent shear failure in subgrade soils, the maximum permissible vertical stress coming on to the reinforcing fabric at subgrade level may be taken equal to ultimate bearing capacity of subgrade soil. As soil begins to deform, the reinforcement comes in to action and reduces stress on subgrade. So minimum pavement thickness required for reinforced flexible pavements over soil under study has been determined by equating vertical stress at subgrade equal to 0.8 times ultimate bearing capacity of soil subgrade using Eq. 1, developed from wheel load dispersion diagram shown in Fig. 1. In developing the equation, it is considered that 2 : 1 load dispersion is valid through pavement section and the bearing capacity of soil gets reduced by 20 percent due to repetitive moving wheel loads of vehicles (Prakash, 1981).

$$\frac{P_e}{(B+h)(L+h)} + \gamma_{av}.h = 0.8q_u \qquad (1)$$

where:

- $P_e$ = equivalent single wheel load based on equal contact pressure
- $q_u$ = ultimate bearing capacity of soil, determined from Vesic's theory (obtained as 117.09 kN/m$^2$)
- $\gamma_{av}$ = average unit weight of pavement material (taken as 22 kN/m$^3$)
- B = width of load dispersion = b + s
- b, L = width and lengths of contact area of tire
- s = spacing of tires (taken as 300mm)

**Table 1 Engineering properties of subgrade soil**

| S. No. | Engineering Property | Value |
|---|---|---|
| 1 | Specific Gravity | 2.69 |
| 2 | Grain Size Analysis | |
| | a) Gravel (%) | 2.0 |
| | b) Sand (%) | 18.6 |
| | c) Fines (%) | 79.4 |
| 3 | Atterberg Limits | |
| | a) Liquid limit (%) | 82.5 |
| | b) Plastic limit (%) | 30.2 |
| | c) Shrinkage limit (%) | 9.8 |
| 4 | Compaction Characteristics (I.S. light compaction test) | |
| | a) Optimum Moisture Content (%) | 19.3 |
| | b) Maximum dry density (Mg/m$^3$) | 1.58 |
| 5 | Undrained Shear Parameters | |
| | a) Cohesion (kN/m$^2$) | 34.0 |
| | b) Angle of internal friction | 5° |
| 6 | Soaked C.B.R. Value (%) | 1.2 |

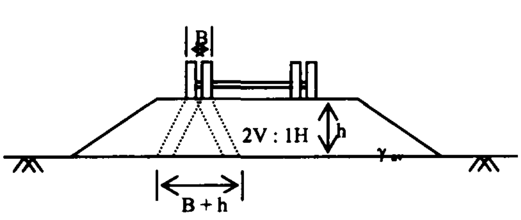


**Fig. 1 Load dispersion through pavement**

The value of minimum thickness for reinforced flexible pavement, $h_{min}$ has been calculated by taking a standard axle load of 10.2 tons with dual wheel assembly. The width and length of contact area of dual wheel have been determined as 477 mm and 295 mm respectively for a tire contact pressure of 551.3 kN/m$^2$ based on contact area shape as combination of a rectangle with two semi circular areas at ends as suggested by Yoder (1975). The value of $h_{min}$ is obtained as 320 mm. However it is not desirable to subject subgrade to ultimate load capacity and so the design pavement thickness in excess of $h_{min}$ should be adopted. After having chosen the value of 'h' in excess of $h_{min}$ so as to avoid shear zones in subgrade soil, the tension in reinforcing fabric is determined based on free body diagram of deformed fabric at subgrade shown in Fig. 2.

Reinforcing function of fabrics can be utilised only when they are held in position. In pavements, reinforcing fabrics can be held in position by anchoring them through burial in longitudinal trenches (backfilled by moorum) made in shoulder portions. The mobilised frictional resistance on faces of fabric in burial trenches should be more than tension induced due to wheel loads to prevent pull out failure and maintain fabrics held in position at subgrade. Considering the fabrics to be held in position at subgrade, Tension (T) developed in the reinforcing fabric is calculated using the Eq. 2 developed by considering equilibrium of forces acting on free body diagram of the deformed fabric at subgrade. The fabric requirement is calculated by restricting the vertical stress at subgrade soil to 80 percent of its safe bearing capacity ($q_s$) so as to avoid the risk of shear failure.

$$T = \frac{(q - 0.8q_s)(B+h)}{2Sin\theta} \qquad (2)$$

where:

- q = vertical stress on fabric due to dispersed wheel load and overburden.
- θ = inclination of deformed fabric with horizontal at subgrade.

From Eq. 2, it may be noticed that tension induced in reinforcing fabrics depends on safe bearing capacity of subgrade soil and deformed shape of fabric (represented by θ). As the tension developed in the reinforcing fabric depends on deformed form of fabric at subgrade, the tensions developed in the fabric due to consideration of different forms of deformation are calculated for subgrade soil under study and given below. The values have been calculated against different values of settlements at subgrade and for different design thickness.

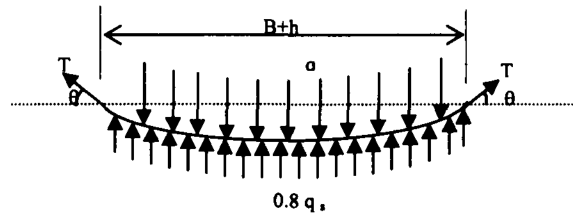


**Fig. 2 Free body diagram of deformed fabric at subgrade**

## Effect of Fabric Deformation Shape on Design

### Parabolic form

The deformed fabric shape has been considered as a parabola having its origin at the point of maximum displacement as shown in Fig. 3. The inclination of deformed fabric with horizontal (θ) at subgrade and strain (∈) induced in the fabric against different settlements have been calculated using the Eqs. 3a and 3b. The values of tensions and corresponding strains developed for different design thickness and permissible settlements at subgrade have been summarised in Tables 2a and 2b respectively.

**Table 2a Details of tensions developed in the fabric with consideration of parabolic deformed form**

| Design Pavement Thickness (mm) | q (kN/m²) | Tension (T) developed in fabric (kN/m) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Settlement at subgrade (mm) | | | | | |
| | | 15 | 20 | 25 | 30 | 40 | 50 |
| 600 | 66.1 | 277.2 | 208.1 | 166.8 | 139.3 | 104.9 | 84.4 |
| 700 | 58.91 | 247.8 | 186.1 | 149.0 | 124.4 | 93.7 | 75.3 |
| 800 | 54.95 | 237.8 | 178.5 | 142.9 | 119.3 | 89.8 | 72.1 |

**Table 2b Strains produced in the fabric with consideration of parabolic deformed form**

| Design Pavement Thickness (mm) | Strain (∈) developed in fabric (%) | | | | | |
|---|---|---|---|---|---|---|
| | Settlement at subgrade (mm) | | | | | |
| | 15 | 20 | 25 | 30 | 40 | 50 |
| 600 | 0.00 | 0.09 | 0.13 | 0.20 | 0.34 | 0.59 |
| 700 | 0.01 | 0.08 | 0.12 | 0.15 | 0.31 | 0.44 |
| 800 | 0.05 | 0.07 | 0.10 | 0.17 | 0.36 | 0.55 |

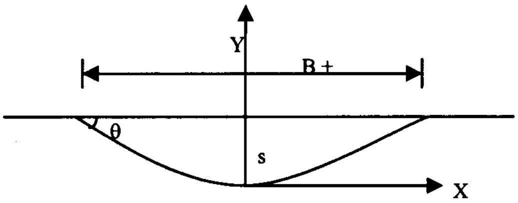


**Fig. 3 Fabric deformation shape as a parabola**

$$\theta = \mathrm{Tan}^{-1}(4s / (B+h)) \quad (3a)$$

$$\in = \left[\frac{L}{(B+h)} - 1\right] \times 100 \quad (3b)$$

where:

$$L = \frac{x}{a}\sqrt{x^2+a^2} + a\ln\frac{\left(x+\sqrt{x^2+a^2}\right)}{a} \quad \text{and}$$

$$a^2 = \frac{(B+h)^4}{64s^2}$$

s = settlement at subgrade below center of wheel load.
B+h is dispersed width of wheel at subgrade level.

### Circular form

The deformed shape of the fabric has been considered to be an arc of circle with its center located on a vertical axis bisecting the loaded width as shown in Fig. 4. The inclination of deformed fabric with horizontal (θ) at subgrade and strain (∈) induced in the fabric against different settlements have been calculated using the Eqs. 4a and 4b.

$$\theta = 2\tan^{-1}\{2s/(B+h)\} \quad (4a)$$

$$\in = \left[\frac{\theta}{\sin\theta} - 1\right] \times 100 \quad (4b)$$

The tensions and corresponding strains induced in the reinforcing fabric based on the consideration of the circular deformation at subgrade are given in Tables 3a and 3b.

### Deformed form as combination of two inclined straights

The deformed fabric shape has been replaced by two inclined straights emanating from the boundaries of load dispersed width and intersecting at the point of maximum settlement as shown in Fig. 5.

The design tensions and strains developed in the fabric at different subgrade settlements due to the considered form of deformation are given in Tables 4a and 4b. The inclination of deformed fabric with horizontal (θ) at subgrade and strain (∈) induced in the fabric against different settlements have been calculated using the Eqs. 5a and 5b.

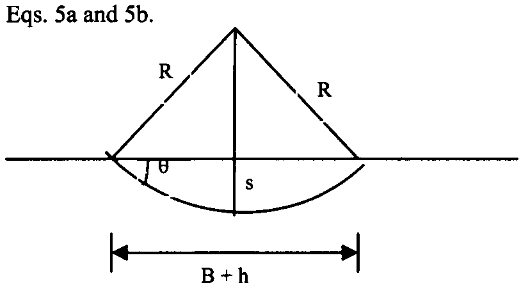


**Fig. 4 Fabric deformation shape as a circular arc**

**Table 3a Details of tensions developed in the fabric with consideration of circular deformed form**

| Design Pavement Thickness (mm) | q (kN/m²) | Tension (T) Developed in Fabric (kN/m) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Settlement at Subgrade (mm) | | | | | |
| | | 15 | 20 | 25 | 30 | 40 | 50 |
| 600 | 66.1 | 277.0 | 207.8 | 166.4 | 138.8 | 104.3 | 83.7 |
| 700 | 58.91 | 247.7 | 185.8 | 148.8 | 124.1 | 93.3 | 74.8 |
| 800 | 54.95 | 237.7 | 178.3 | 142.7 | 119.0 | 89.4 | 71.7 |

**Table 3b Strains produced in the fabric with consideration of circular deformed form**

| Design pavement thickness (mm) | Strain (∈) developed in fabric (%) | | | | | |
|---|---|---|---|---|---|---|
| | Settlement at subgrade (mm) | | | | | |
| | 15 | 20 | 25 | 30 | 40 | 50 |
| 600 | 0.05 | 0.092 | 0.144 | 0.21 | 0.37 | 0.574 |
| 700 | 0.04 | 0.08 | 0.12 | 0.17 | 0.37 | 0.48 |
| 800 | 0.036 | 0.06 | 0.102 | 0.15 | 0.26 | 0.41 |

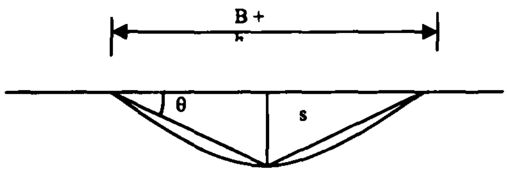


**Fig. 5 Fabric deformation shape as combination of inclined straights**

**Table 4a Details of tensions developed in the fabric with consideration of deformed form as combination of two inclined straights**

| Design Pavement Thickness (mm) | q ($kN/m^2$) | Tension (T) Developed in Fabric (kN/m) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Settlement at Subgrade (mm) | | | | | |
| | | 15 | 20 | 25 | 30 | 40 | 50 |
| 600 | 66.1 | 553.7 | 415.4 | 332.4 | 277.2 | 208.1 | 166.8 |
| 700 | 58.91 | 495.2 | 371.5 | 297.3 | 247.8 | 186.1 | 149.0 |
| 800 | 54.95 | 475.2 | 356.5 | 285.3 | 237.8 | 178.5 | 143.0 |

**Table 4b Strains produced in the fabric with consideration of deformed form as combination of two inclined straights**

| Design Pavement Thickness (mm) | Strain (∈) Developed in Fabric (%) | | | | | |
|---|---|---|---|---|---|---|
| | Settlement at Subgrade (mm) | | | | | |
| | 15 | 20 | 25 | 30 | 40 | 50 |
| 600 | 0.039 | 0.07 | 0.11 | 0.16 | 0.28 | 0.43 |
| 700 | 0.032 | 0.058 | 0.09 | 0.13 | 0.23 | 0.36 |
| 800 | 0.028 | 0.05 | 0.08 | 0.11 | 0.20 | 0.31 |

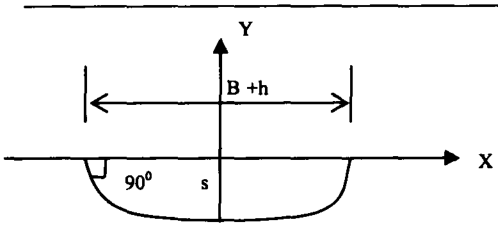


**Fig. 6 Fabric deformation shape as elliptical**

$$\theta = \mathrm{Tan}^{-1}\{2s/(B+h)\} \qquad (5a)$$

$$\in = \left[\sqrt{\frac{4s^2}{(B+h)^2}+1}-1\right]\times 100 \qquad (5b)$$

where:

s = settlement at subgrade below center of wheel load.
B+h = dispersed width of wheel at subgrade level.

### Elliptical Form

Based on the concept of reinforced beds over soft ground, it appears reasonable to consider the shape of deformation at subgrade as the one, which meets the original ground surface normally. So, elliptical deformed shape has been considered as it satisfies the requirement. The analysis for developed tensions and strains has been done by treating the deformed fabric shape to be elliptical as shown in Fig. 6. The tensions and the strains produced in the fabric with different pavement thickness and permissible settlements at subgrade are presented in Table 5. Strains produced in the fabric have been calculated using the Eq. 6.

$$\in = \{\frac{\pi}{2}\left[1-\frac{e^2}{4}-\frac{3e^4}{64}-\frac{5e^6}{256}\right]-1\} \times 100 \qquad (6)$$

where:

e = the eccentricity of ellipse = $\frac{\sqrt{a^2-s^2}}{a}$

a = half the width of load spread at subgrade = $\frac{B+h}{2}$

s = settlement at subgrade level.

It can be seen from Tables 2a and 3a that the tensions developed in the fabrics based on the considerations of parabolic and circular arc shapes are nearly same. The strain values presented in Tables 2b and 3b also give nearly same values. There is no significant difference of fabric design requirements based on these geometric forms. It may be noticed from the results presented in Tables 4a and 4b that the circular form consideration leads to high tensile force developments in the reinforcing fabric at relatively smaller strains. The elliptical form consideration yields lesser values of tensions in the reinforcing fabric placed at subgrade as shown in Table 5 because in that form, the deformed fabric meets the subgrade at right angles. The strains developed are considerable and thus the design data based on elliptical shape indicate that geotextile fabric reinforcement suits well to such requirement. The other considerations of deformed shapes lead to requirement of high stiffness reinforcement because the resulting tensions in the fabrics are not only high, but also they need to be mobilised at very low strain values. As punching of pavement layers in the form of truncated frustum takes place into soft subgrades initially under load and thereafter stops when fabric reinforcement mobilises strength, it may result in elliptical fabric deformed shape at subgrade. Parabolic or circular shaped fabric deformations are likely to occur only when supporting strength of subgrade soil is moderate to high. Further, it can be seen from the Tables that the settlement at subgrade decreases as stiffness of fabric increases.

## SELECTION OF DEFORMED FABRIC SHAPE FOR DESIGN

As the design requirements of the reinforcing fabrics are observed to change with the shape of the deformation and also with the amount of deformation, the wheel tracking tests have been conducted on reinforced model pavement layers taken in a small tank. Based on the usage of available fabrics and data generated, the appropriate fabric deformed shape selection is made.

### Details of Tests on Reinforcing Ability of Fabrics

Wheel Tracking Test apparatus developed by British National Rail Road Research Institute (Originally developed for measuring resistance to plastic deformation of bituminous mixtures) has been used to assess the adequacy of fabric tensile strength to support the contact pressure from the considerations of elliptical deformation shape of fabric at subgrade. The wheel tracking test set up used in the tests is shown in Fig. 7. The wheel tracking test apparatus simulates the field condition of moving wheels with provision for varying contact pressures.

**Table 5 Tensions and strains developed in the fabric with consideration of elliptical deformed form**

| Design Pavement Thickness (mm) | T (kN/m) | Strain (∈) Developed in Fabric (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Settlement (S) at Subgrade in mm. | | | | | |
| | | 15 | 20 | 25 | 30 | 40 | 50 |
| 600 | 15.0 | 7.43 | 7.46 | 7.51 | 7.57 | 7.73 | 7.95 |
| 700 | 12.6 | 7.42 | 7.45 | 7.49 | 7.55 | 7.68 | 7.84 |
| 800 | 11.2 | 7.41 | 7.43 | 7.48 | 7.52 | 7.63 | 7.76 |
| 900 | 9.2 | 7.41 | 7.45 | 7.46 | 7.50 | 7.60 | 7.71 |

The apparatus consists of:

1. **Loading Wheel**: Total maximum Load of 540N, wheel diameter 200 mm, width 50 mm made of solid rubber.
2. **Test Table**: It is fitted with a fabricated mild steel tank of size 300 mm x 300 mm x 400 mm made of 5 mm gauge sheet. The test table is made to reciprocate 42 passes a minute, controlled by autocounter reciprocation of about 230 mm.
3. **Motor**: 75 kW, 400V(200V), Three Phase.

To enable loading onto model pavement layers taken in the tank the height of the loading lever has been raised by changing the angle sections controlling the elevation. A mild steel tank of size 300 mm x 300 mm x 400 mm has been used for preparing model pavement layer systems. For preparation of model pavement layers in the mild steel tank CH group soil has been used as subgrade, moorum conforming to Ministry of Road Transport and Highways (Morth, 2001), Government of India specifications in terms of plasticity and strength has been used as sub base course material and Water Bound Macadam (WBM) layer as base course. Polypropylene-based woven and non-woven geotextiles have been used for assessing the reinforcing ability when used at the interface of sub grade soil and sub base moorum. The stiffness of fabrics is shown in Figs. 8 and 9, generated from grab tension tests. The Engineering properties of moorum used in the investigations are presented in Table 6. The properties of geotextiles and aggregate used in WBM layer are given in Tables 7 and 8.

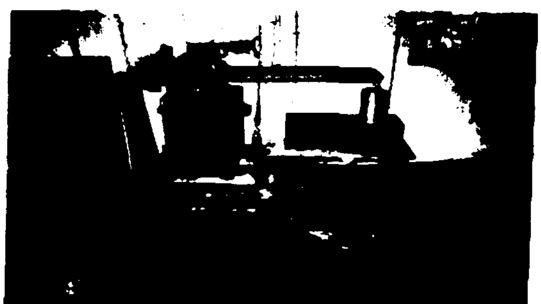

**Fig. 7 Wheel tracking test set up**

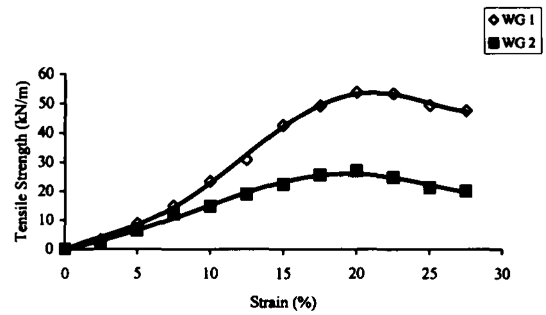


**Fig. 8 Tension test results of woven geotextiles**

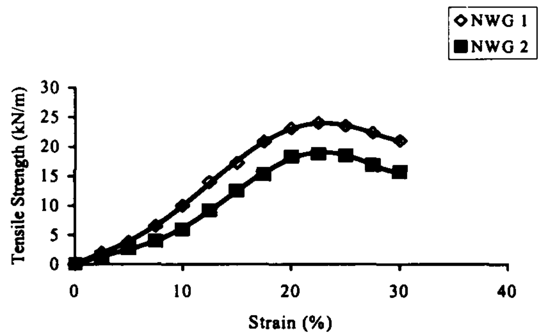


**Fig. 9 Tension test results of nonwoven geotextiles**

The Mild steel tank has been filled with CH group soil - 1 at its bottom up to 250 mm thick over a 50 mm sand blanket. Geotextile reinforcing fabric, held in position by tying it to a square frame with a binding wire to simulate field condition is placed at subgrade soil surface. Fig. 10 (a) shows the fabricated square frame used for holding the fabric in position at interface of subgrade soil and sub base material in model pavement layers. The mode of fabric tying to the fabricated square frame is shown in Fig. 10 (b). Moorum layer of 50 mm thick has been compacted at its maximum dry density and respective optimum moisture content obtained in I.S heavy compaction conditions. Above the moorum layer, a WBM layer of 50 mm has been laid. Grade III aggregate along with 20 percent moorum as screening - binding material has been used to form WBM layer (Morth, 2001).

**Table 6 Engineering properties of Moorum**

| S. No | Engineering Property | Value |
|---|---|---|
| 1 | Specific gravity | 2.67 |
| 2 | Grain size analysis | |
| | a) Gravel (%) | 26.4 |
| | b) Sand (%) | 53.4 |
| | c) Fines (%) | 20.2 |
| 3 | Plasticity characteristics | |
| | a) Liquid limit (%) | 24.8 |
| | b) Plastic limit (%) | 19.2 |
| | c) Plasticity Index (%) | 5.6 |
| 4 | Compaction characteristics (I.S Heavy compaction condition) | |
| | a) Optimum moisture content (%) | 7.6 |
| | b) Maximum dry density (Mg/m$^3$) | 2.05 |
| 5 | Soaked CBR value (%) | 23.2 |
| 6 | Undrained shear parameters | |
| | a) Cohesion (kN/m$^2$) | 12.0 |
| | b) Angle of internal friction | 42° |

**Table 7 Properties of woven and nonwoven geotextiles**

| Property | Woven Geotextile | | Non-woven Geotextile | |
|---|---|---|---|---|
| | WG 1 | WG 2 | NWG 1 | NWG 2 |
| Density of Material ($g/m^2$) | 217 | 158 | 330 | 220 |
| Average Thickness (mm) | 0.46 | 0.29 | 3.4 | 2.58 |
| Grab Tensile Strength (kN/m) | 56 | 27 | 17.5 | 22.5 |
| Corresponding Strain (%) | 21 | 22 | 25 | 25 |

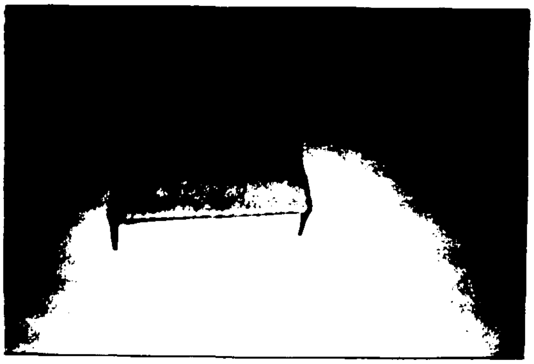

**Fig. 10a Square frame used to hold the fabrics in position at interface of subgrade soil and subbase material**

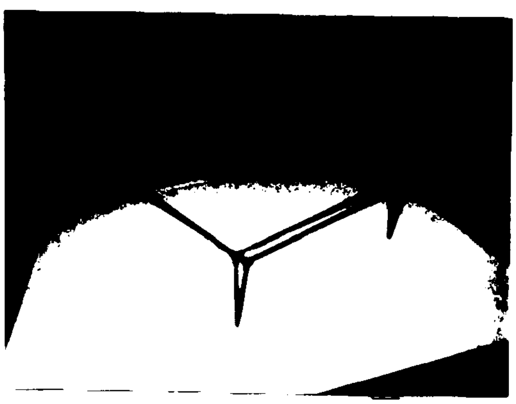

**Fig. 10b Nonwoven geotextile tied to square frame for use in wheel tracking tests**

**Table 8a Gradation of aggregate**

| IS Sieve Designation (mm) | Percent by Weight Passing |
|---|---|
| 90 | 100 |
| 63 | 100 |
| 53 | 60 |
| 45 | 5 |
| 22.4 | 0 |

**Table 8b Engineering properties of aggregate**

| S. No. | Property | Value |
|---|---|---|
| 1 | Specific Gravity | 2.82 |
| 2 | Crushing Value (%) | 20.2 |
| 3 | Impact Value (%) | 21.7 |
| 4 | Abrasion Value (%) | 22.5 |

The prepared model pavement system has been subjected to a contact pressure of 551.3 $kN/m^2$ (Yoder, 1975) through model wheel of wheel tracking test apparatus. The value of surface rut has been observed for 10,000 repetitions of loading from model wheel. The results of surface settlement (rut) observed from the wheel tracking tests on reinforced model pavement systems with woven and non woven geotextiles have been presented in Table 9. Considering the surface settlement to be resulting from deformation of subgrade, the strains caused in the fabrics have been calculated based on elliptical deformed form as it is more likely in soft soils due to initial punching of pavement layer material into subgrade prior to mobilisation of strength of reinforcing fabric. The tensile strengths of geotextile fabrics at the estimated strain values have been also given in the Table 10. It has been observed that none of the fabrics have teared during the tests. The design requirements on the basis of parabolic, circular shape, two inclined straights and elliptical fabric deformed shapes for model pavement layers used in the wheel tracking test have been calculated and are presented in Table 10. The design data has been obtained for a settlement of 25 mm at subgrade level.

**Table 9 Wheel tracking test results of reinforced pavement component layers**

| Geotextile Type | Surface Settlement Observed (mm) | Strains Produced in Fabric Based on Total Rut (%) | Tensile Strength of Fabric at Estimated Strain (kN/m) |
|---|---|---|---|
| WG 1 | 24.5 | 13.9 | 37.5 |
| WG 2 | 25.3 | 14.3 | 22.0 |
| NWG 1 | 26.2 | 14.8 | 17.0 |
| NWG 2 | 30.2 | 17.2 | 14.5 |

**Table 10 Design requirements of reinforcing fabrics based on analytical procedures**

| Parabolic Form | | Circular Arc Form | | Deformed Form as Two Inclined Straights | | Elliptical Form | |
|---|---|---|---|---|---|---|---|
| Tension (kN/m) | Strain (%) | Tension (kN/m) | Strain (%) | Tension (kN/m) | Strain (%) | Tension (kN/m) | Strain (%) |
| 20.1 | 7.0 | 18.4 | 7.3 | 35.2 | 5.4 | 11.2 | 14.2 |

By comparing the results of wheel tracking tests presented in Table 9 with the analytical design data developed in Table 10, it can be seen that consideration of elliptical deformed shape of fabric at subgrade gives reasonable estimate of fabric requirements. If the other forms of deformation are correct, then the fabrics under study would have teared or resulted in very high surface settlements (Rut). Moreover elliptical deformed form leads to formation of right angle kinks at the boundary of load spread which is in agreement with Binquet and Lee (1975) theory of reinforced soil beds on soft soils for bearing capacity improvement. So, elliptical form of deformation may be adopted in designing the reinforcing fabrics of reinforced flexible pavements over soft clays. The design data presented in Table 6 based on elliptical deformation shape of fabric at subgrade indicates the various options for different design pavement thickness and corresponding requirement for reinforcing fabric. Among several design thickness options, the selection of appropriate design thickness and proportions of pavement component layers are to be done based on geotextile available and settlement control criteria.

## CONCLUSIONS

1. The design requirement of reinforcing fabrics held in position depends on supporting strength of soil and deformed shape of fabric at subgrade.

2. The fabric deformation shape considered for design significantly affects the design requirement of fabric. Hence, it is essential to adopt proper deformed shape of fabric at subgrade based on subgrade supporting ability.

3. For soft soil, the consideration of parabolic, circular and two inclined straights combination modes of fabric deformed shapes yield requirement of high stiffness fabric as reinforcement. Such deformations are unlikely in subgrades of low strength and hence, design based on such consideration will be uneconomical.

4. Elliptical or uniform deformation shapes of fabric at subgrade should be adopted for design of reinforced flexible pavements as they satisfy formation of right angle kinks at the boundaries of load dispersion as given by Binquet and Lee in the theory of reinforced soil beds over soft soils.

5. The wheel tracking tests on model reinforced flexible pavement systems over high compressible clay subgrade reveal that the design based on elliptical deformed shape is sufficient to withstand contact pressure of model wheel.

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