GEOSYNTHETICS ENGINEERING: IN THEORY AND PRACTICE

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Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Module-5
LECTURE- 23
GEOSYNTHETICS IN PAVEMENTS

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RECAP of previous lecture…..

- Stress reduction downwards with depth of granular fill
- Advantages of unpaved roads
- Design charts of U.S. forest service (USFS) for unpaved roads
- U.S. forest service design curves
- Modified California bearing ratio (CBR) test
- Design of pavement thickness without geogrid (IRC37)
Design of Reinforced Unpaved road (Giroud and Han, 2004)

**Step 1:** Calculate the radius of the equivalent contact area using following equation.

\[
r = \sqrt{\frac{P}{\pi p}}
\]

- \(r\) = radius of equivalent tire contact area (m),
- \(P\) = wheel load in kN, and
- \(p\) = tire contact pressure; (kPa).

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Step 2: Calculate the California Bearing Ration of the sub-grade soil or undrained cohesion of sub-grade soil, 

\[ c_u = f_C CBR_{sg} \]

\( c_u = \) undrained cohesion of sub-grade soil

\( f_C = \) factor equal to 30kPa

\( C.B.R_{sg} = \) sub-grade California bearing ratio (< 5)

Step 3: Calculate the allowable bearing capacity of sub-grade soil without reinforcement.

\[ P_{h=0,\text{unreinforced}} = \left( \frac{S}{f_s} \right) \pi r^2 N_c c_u = \left( \frac{S}{f_s} \right) \pi r^2 N_c f_C CBR_{sg} \]
s = Allowable rut depth is equal to 40 mm,

\( f_s = \) factor equal to 75 mm,

\( r = \) radius of the equivalent tire contact area,

\( N_c = \) bearing capacity factor equal to 3.14,

\( c_u = \) undrained cohesion of subgrade soil, and

\( CBR_{sg} = \) subgrade California bearing ratio

If the wheel load is greater than the allowable bearing capacity of subgrade soil, a base course is required without or with geosynthetics.
To calculate the base course thickness, the following steps should be followed.

**Step 4:** Determine the limit modulus ratio \( (R_E) \) and modulus ratio factor \( (f_E) \).

\[
R_E = \min \left( \frac{E_{bc}}{E_{sg}}, 5.0 \right) = \min \left[ 3.48 \left( CBR_{bc} \right)^{0.3}, 5.0 \right]
\]

\( E_{bc} = \) base course resilient modulus,  
\( E_{sg} = \) subgrade resilient modulus,  
\( CBR_{bc} = \) base course California bearing ratio, and  
\( CBR_{sg} = \) subgrade California bearing ratio,  

**Modulus ratio factor,** \( f_E = 1 + 0.204 \left( R_E - 1 \right) \)
Step 5: Determine the bearing capacity mobilization coefficient \((m)\) in term of thickness \((h)\).

\[
m = \left( \frac{s}{f_s} \right) \left\{ 1 - 0.9 \exp \left[ -\left( \frac{r}{h} \right)^2 \right] \right\}
\]

- \(m\) = bearing capacity mobilization coefficient,
- \(s\) = allowable rut depth (mm)
- \(50 < s < 100\) (as per Giroud, 2004)
- \(f_s\) = factor equal to 75 mm
- \(r\) = radius of equivalent tire contact area (m), and
- \(h\) = thickness of base course.

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Step 6: Determine the required base course thickness

\[
h = \frac{0.868 + (0.661 - 1.006J^2)\left(\frac{r}{h}\right)^{1.5} \log N}{f_E} \times \left[ \frac{P}{\pi r^2} \right]_{mN_c f_c CBR_{sg}}^{1} \]

J = aperture stability modulus of geogrid (mN/\(^0\)) (< 0.8),
J = 0 for geotextile and in unreinforced case
h = thickness of required base course (m),
P = wheel load (kN), and
\(N_c\) = bearing capacity factor = 5.71 (for geogrid)
\(N_{c,\text{geotextile}} = 5.14, N_{c,\text{unreinforced}} = 3.14\)

Calculation of the base course thickness needs iterations.

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If the calculated ‘h’ value does not match the assumed ‘h’ value, ‘m’ value is to be recalculated and is used as the assumed value for the next iteration. The process is to be repeated until the calculated value is approximately equal to assumed value.

**Step 7:** Determine the reduction in base course thickness using geogrid or geotextile \((\Delta h) = h_0 - h\)

Let, \(h_0 = \) thickness of required base course for unreinforced case (m)

\(h = \) thickness of required base course with geogrid or geotextile (m)
Example 4.4
Two lane carriageway roads, plain terrain
Number of commercial vehicles as per last count (P) = 1000
Axle load = 81.6 kN; Wheel load = 81.6/2 = 40.8 kN
Tire pressure (p) = 500 kPa
Subgrade CBR = 2%
Traffic loading category = E [450 to 1500 CVD]
Number of years between last count and year of completion of construction (x) = 5 years
Annual growth rate of commercial vehicles (r) = 10%
Design life of pavement after completion = 15 years

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Solution:

Design as per IRC-37, 2001 (only for unreinforced condition):

\[ A = P(1 + r)^x \times D \]

\[ N_s = \left( \frac{365 \times A [(1 + r)^n - 1]}{r} \right) \times F \]

D = lane distribution factor = 75% (see Table)

F = vehicle damage factor = 3.5 (see Table)

\[ A = 1000 \times (1 + 0.1)^5 \times 0.75 = 1208 \]

\[ N_s = \frac{365 \times 1208 \times [(1 + 0.1)^{15} - 1]}{0.1} \times 3.5 = 49.03 \times 10^6 \]

\[ N_s \approx 50 \times 10^6 = 50 \text{ million standard axles (msa)} \]
From design chart, for 2% CBR and 50 msa standard axle, Total pavement thickness = 925 mm = 0.925 m

Design Chart for determining pavement thickness, traffic 10-150 msa (IRC-37, 2001)
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Pavement composition (Reference from IRC 37):

Bituminous surfacing = 21.5 cm
[Bituminous Concrete (B.C.) = 4 cm
Bituminous Macadam (D.B.M.) = 17.5 cm]
Design as per Giroud and Han, 2004 (without and with reinforcement):

<table>
<thead>
<tr>
<th>Input data</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axle load (kN), Q</td>
<td>135</td>
</tr>
<tr>
<td>Wheel load (kN), P</td>
<td>67.5</td>
</tr>
<tr>
<td>Tire pressure (kPa), p</td>
<td>500</td>
</tr>
<tr>
<td>Radius of the equivalent tire contact area (m), r</td>
<td>0.207</td>
</tr>
<tr>
<td>Base course C.B.R. (%) C.B.R.\textsubscript{bc}</td>
<td>20</td>
</tr>
<tr>
<td>C.B.R. of the subgrade soil (%) C.B.R.\textsubscript{sg}</td>
<td>2</td>
</tr>
<tr>
<td>Allowable rut depth (mm), s</td>
<td>40</td>
</tr>
<tr>
<td>Factor (kPa), f\textsubscript{c}</td>
<td>30</td>
</tr>
<tr>
<td>Factor (kPa), f\textsubscript{s}</td>
<td>75</td>
</tr>
<tr>
<td>Geogrid aperture stability modulus (m N/°), J</td>
<td>0.65</td>
</tr>
<tr>
<td>Number of axle passes, N</td>
<td>50 x 10\textsuperscript{6}</td>
</tr>
<tr>
<td>Bearing capacity factor, N\textsubscript{c, unreinforced}</td>
<td>3.14</td>
</tr>
<tr>
<td>N\textsubscript{c, geogrid}</td>
<td>5.71</td>
</tr>
<tr>
<td>N\textsubscript{c, geotextile}</td>
<td>5.14</td>
</tr>
</tbody>
</table>
## Output User Interface

For unpaved road in unreinforced condition:

<table>
<thead>
<tr>
<th>Assumed base course thickness, $h_{\text{assumed}}$ (m)</th>
<th>0.3</th>
<th>1.11</th>
<th>0.82</th>
<th>0.88</th>
<th>0.86</th>
<th>0.87</th>
<th>FINISHED</th>
<th>#VALUE!</th>
</tr>
</thead>
</table>

1. Limited modulus ratio, $R_E$ | 4.274 |
2. Modulus ratio factor, $f_E$ | 1.668 |
3. Bearing capacity mobilization factor, $m$ | 0.235 | 0.069 | 0.083 | 0.079 | 0.080 | 0.079 | #VALUE! | #VALUE! |

| Required base course thickness, $h_{\text{final}}$ (m) | 1.11 | 0.82 | 0.88 | 0.86 | 0.87 | 0.87 | #VALUE! | #VALUE! |

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For unpaved road with geogrid:

<table>
<thead>
<tr>
<th>Assumed base course thickness, $h_{\text{assumed}}$ (m)</th>
<th>0.3</th>
<th>0.35</th>
<th>0.37</th>
<th>FINISHED</th>
<th>#VALUE!</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Limited modulus ratio, $R_E$</td>
<td>4.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Modulus ratio factor, $f_E$</td>
<td>1.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Bearing capacity mobilization factor, m</td>
<td>0.235</td>
<td>0.195</td>
<td>0.182</td>
<td>#VALUE!</td>
<td>#VALUE!</td>
</tr>
</tbody>
</table>

| Required base course thickness, $h_{\text{final}}$ (m) | 0.35 | 0.37 | 0.37 | #VALUE! | #VALUE! |

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For unpaved road with geotextile:

<table>
<thead>
<tr>
<th>Assumed base course thickness, $h_{\text{assumed}}$ (m)</th>
<th>0.3</th>
<th>0.77</th>
<th>0.65</th>
<th>0.67</th>
<th>FINISHED</th>
<th>#VALUE!</th>
</tr>
</thead>
</table>

1. Limited modulus ratio, $R_E$  
2. Modulus ratio factor, $f_E$  
3. Bearing capacity mobilization factor, $m$

| 0.235 | 0.086 | 0.099 | 0.097 | #VALUE! | #VALUE! |

Required base course thickness, $h_{\text{final}}$ (m)

| 0.77 | 0.65 | 0.67 | 0.67 | #VALUE! | #VALUE! |
For geogrid reinforced unpaved road, a factor of safety is considered = 1.5

**Percentage of saving (%):**

<table>
<thead>
<tr>
<th>Thickness of base course for unreinforced unpaved road (mm), $h_{\text{unreinforced}}$</th>
<th>870 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of base course with geogrid (mm), $h_{\text{geogrid}}$</td>
<td>$370 \times 1.5$ = 555 mm</td>
</tr>
<tr>
<td>Thickness of base course with geotextile (mm), $h_{\text{geotextile}}$</td>
<td>670 mm</td>
</tr>
<tr>
<td>% Saving (geogrid)</td>
<td>36.21%</td>
</tr>
<tr>
<td>% Saving (geotextile)</td>
<td>23%</td>
</tr>
</tbody>
</table>

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Geogrid and geocomposite layers are to be provided in between subgrade and sub-base layers.

The geocomposite layer will drain out the infiltrated water from base course and the uplifted water from subgrade.

Base course thickness using geogrid = 55.5 cm ≈ 56 cm

**Pavement composition (Geogrid reinforced):**

*Bituminous surfacing* (Reference to IRC: 37) = 21.5 cm surfacing consisting of 4 cm bituminous concrete (B.C.) and 17.5 cm dense bituminous macadam (D.B.M.)

**Base course:** 20 cm Water Bound Macadam (W.B.M) (20 % C.B.R.)

**Sub-base:** 35 cm granular material of CBR not less than 30%

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Pavement Section [Traffic (N) = 50 msa, Axle load = 135 kN]

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Pavement drainage system

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At 250 mm geogrid can be introduced either at the bottom or in the middle of the base course for specific geogrid

Geogrid reinforced base course for paved highway (Carroll et al. 1987)

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A flexible pavement for a road (2 lanes each direction) needs to be designed for 25-years life.

- Average sub-grade CBR = 2%
- Expected traffic: tandem axle 36 kips, 100,000/year. No annual growth rate to be considered.
- Terminal serviceability, \( p_t = 2.5 \)
- Reliability level (R) = 95%; standard deviation, \( S_o = 0.35 \)
- Asphalt layer coefficient \( (a_1) = 0.40 \), base course layer coefficient, \( (a_2) = 0.14 \), sub-base layer coefficient \( (a_3) = 0.08 \).
- Drainage condition is “Good”; pavement is exposed to saturation moisture more than 25% of the time.
Solution:

Without reinforcement:

Step 1: Determination of $W_{18}$

$W_{18} = \text{predicted number of 18,000 lb equivalent single axle load (ESAL) applications}$

(a) For tandem axle 36 kips, $p_t = 2.5$ and assumed SN of 6.0, the axle load equivalency factor $= 1.38$ (From Table I)

Hence, first year traffic estimate

$= \text{Expected traffic} \times \text{axle load equivalency factor}$

$= 100,000 \times 1.38 = 138,000$

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(b) For analysis period of 25 years and no growth, traffic growth factor = 25 (From Table II)

Hence,

\[ w'_{18} = \text{Traffic growth factor} \times \text{First year traffic estimate} \]

\[ = 25 \times 138,000 = 3,450,000 \]
### Table I Axle load equivalency factors for flexible pavements, tandem axles and $p_t = 2.5$ (AASTHO, 1993)

<table>
<thead>
<tr>
<th>Axle load (kips)</th>
<th>Pavement Structural Number (SN)</th>
<th>Axle load equivalency factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>24</td>
<td>0.231</td>
<td>0.273</td>
</tr>
<tr>
<td>26</td>
<td>0.327</td>
<td>0.370</td>
</tr>
<tr>
<td>28</td>
<td>0.451</td>
<td>0.493</td>
</tr>
<tr>
<td>30</td>
<td>0.611</td>
<td>0.648</td>
</tr>
<tr>
<td>32</td>
<td>0.813</td>
<td>0.843</td>
</tr>
<tr>
<td>34</td>
<td>1.06</td>
<td>1.08</td>
</tr>
<tr>
<td>36</td>
<td>1.38</td>
<td>1.38</td>
</tr>
<tr>
<td>38</td>
<td>1.75</td>
<td>1.73</td>
</tr>
<tr>
<td>40</td>
<td>2.21</td>
<td>2.16</td>
</tr>
</tbody>
</table>

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### Table II Traffic growth factor (AASTHO, 1993)

<table>
<thead>
<tr>
<th>Analysis period (years)</th>
<th>Traffic growth factor</th>
<th>Annual Growth Rate, Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No growth</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>17.29</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>24.30</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
<td>32.03</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
<td>40.57</td>
</tr>
<tr>
<td>35</td>
<td>35</td>
<td>49.99</td>
</tr>
</tbody>
</table>

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(c) Generally for most roadways, \( D_D = 0.5 \)

\( D_D = \) a directional distribution factor

From Table III, \( D_L = 0.90 \) (two lanes in each direction)

Hence, \( w_{18} = D_D \times D_L \times w'_{18} \)

\[
= 0.50 \times 0.90 \times 3,450,000 \\
= 1,552,500
\]
(d) **Table IV** helps to choose the reliability level.

From **Table V**, $Z_R = -1.645$ for $R = 0.95$

Therefore, $F_R = 10^{(-Z_R \times S_o)} = 10^{(-1.645 \times 0.35)} = 3.764$

Finally, $W_{18} = w_{18} \times F_R$

$$= 1,552,500 \times 3.764$$

$$= 5,843,610 \approx 5.8 \text{ msa}$$

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### Table III: Lane Distribution Factor, $D_L$ (AASTHO, 1993)

<table>
<thead>
<tr>
<th>Number of Lanes in Each Direction</th>
<th>Percent of ESAL in Design Lane ($D_L$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>80-100</td>
</tr>
<tr>
<td>3</td>
<td>60-80</td>
</tr>
<tr>
<td>4</td>
<td>50-75</td>
</tr>
</tbody>
</table>

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Table IV  Suggested Levels of Reliability (AASTHO, 1993)

<table>
<thead>
<tr>
<th>Functional Classification</th>
<th>Recommended Level of Reliability (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban</td>
</tr>
<tr>
<td>Interstate and Other Freeways</td>
<td>85-99.9</td>
</tr>
<tr>
<td>Principal Arterials</td>
<td>80-99</td>
</tr>
<tr>
<td>Collector</td>
<td>80-95</td>
</tr>
<tr>
<td>Local</td>
<td>50-80</td>
</tr>
</tbody>
</table>
Table V Standard normal deviate for different values of reliability, $R$

<table>
<thead>
<tr>
<th>Reliability (%)</th>
<th>$Z_R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.000</td>
</tr>
<tr>
<td>60</td>
<td>-0.253</td>
</tr>
<tr>
<td>70</td>
<td>-0.524</td>
</tr>
<tr>
<td>85</td>
<td>-0.841</td>
</tr>
<tr>
<td>90</td>
<td>-1.282</td>
</tr>
<tr>
<td><strong>95</strong></td>
<td><strong>-1.645</strong></td>
</tr>
<tr>
<td>99</td>
<td>-2.327</td>
</tr>
<tr>
<td>99.9</td>
<td>-3.090</td>
</tr>
</tbody>
</table>
Step 2: Determination of serviceability

Given $p_t = 2.5; p_o = 4.2$ (if not given)

$p_o =$ Initial design serviceability index

$\Delta \text{PSI} = p_o - p_t = 4.2 - 2.5 = 1.7$

Step 3: Determination of subgrade Resilient Modulus ($M_R$)

$M_R (\text{psi}) = 1,500 \times \text{CBR} = 1,500 \times 2 = 3000 \text{ psi}$

$M_R (\text{kPa}) = 6.89 \times 1500 \times \text{CBR}$

$= 6.89 \times 1500 \times 2$

$= 20670 \text{ kPa}$
Step 4: Determination of Structural Number (SN)

Basic empirical equation for design of flexible pavement by American Association of State Highway and Transportation (AASHTO, 1993) is as follows (in FPS units).

\[
\log_{10}(W_{18}) = Z_R \cdot S_o + 9.36 \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{1094} + 2.32 \log_{10}(M_R) - 8.07 \\
0.40 + \frac{\Delta PSI}{(SN + 1)^{5.19}}
\]

Here, \( W_{18} = 5843610, Z_R = -1.645, S_o = 0.35, \Delta PSI = 1.7 \) and \( M_R = 3000 \) psi

Determine the structural number (SN) by trial and error method or use the design charts given.

Therefore, \( SN = 6.16 \)

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Design chart of CBR vs. SN for 1 to 10 msa (R = 95% and $S_o = 0.35$)

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Step 5: Estimation of pavement thickness

For unreinforced case,

$$SN = a_1.D_1 + a_2.D_2.m_2 + a_3.D_3.m_3$$

$D_1$, $D_2$ and $D_3$ = thickness (in inches) of the surface, base and sub-base respectively

$a_1$, $a_2$, $a_3$ = structural layer coefficients for the surface, base and sub-base respectively (The layer coefficients depend upon the resilient modulus of the material.)

$m_2$, $m_3$ = drainage coefficient for base course and sub-base course respectively

As SN value has already been determined in step 4, $D_1$, $D_2$ and $D_3$ can be obtained by trial and error.
(a) Generally, the typical layer coefficients used by AASTHO road test are as follows:

\[ a_1 = \text{Asphalt concrete surface course} = 0.40-0.44, \]
\[ a_2 = \text{Crushed stone base course} = 0.10-0.14, \]
\[ a_3 = \text{Sandy graved sub-base} = 0.060-0.11 \]

We obtain \( a_1 = 0.40, \ a_2 = 0.14, \ a_3 = 0.08 \) (given)

(b) Drainage: Modified layer coefficients are used to account for the improved drainage conditions. The quality of drainage and recommended drainage coefficients can be obtained from Tables VI and VII respectively.

As the drainage condition is “Good” and pavement is exposed to saturation moisture more than 25% of the time, \( m_2 = 1.0 \) and \( m_3 = 1.0 \)
<table>
<thead>
<tr>
<th>Quality of Drainage</th>
<th>Duration of Water Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>2 hours</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>1 day</td>
</tr>
<tr>
<td>Fair</td>
<td>1 week</td>
</tr>
<tr>
<td>Poor</td>
<td>1 month</td>
</tr>
<tr>
<td>Very poor</td>
<td>Water will not drain</td>
</tr>
</tbody>
</table>

**Table VI** Drainage Conditions (AASTHO, 1993)
Table VII  Recommended $m_i$ Values (as per AASTHO, 1993)

<table>
<thead>
<tr>
<th>Quality of Drainage</th>
<th>Recommended $m_i$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent of Time Pavement is Exposed to Moisture Levels Approaching Saturation</td>
</tr>
<tr>
<td></td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Excellent</td>
<td>1.40-1.35</td>
</tr>
<tr>
<td>Good</td>
<td>1.35-1.25</td>
</tr>
<tr>
<td>Fair</td>
<td>1.25-1.15</td>
</tr>
<tr>
<td>Poor</td>
<td>1.15-1.05</td>
</tr>
<tr>
<td>Very Poor</td>
<td>1.05-0.95</td>
</tr>
</tbody>
</table>
We have already calculated by trial and error, SN = 6.16

\[ 6.16 = 0.40D_1 + 0.14D_2 + 0.08D_3 \]

or, \[ 6.16 = 0.40D_1 + 0.14D_2 + 0.08D_3 \]

Assuming surface layer depth \( (D_1) = 0.21 \) m

Assuming base course depth \( (D_2) = 0.25 \) m

Hence, sub-base depth \( (D_3) = 0.47 \) m

**Total thickness** = \( (0.21 + 0.25 + 0.47) = 0.93 \) m

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Step 6: Design for Reinforced Case

For reinforced case we know that,

\[ SN = a_1.D_1 + a_2.D_2.m_2 + (LCR).a_3.D_3.m_3 \]

(N.B. \( D_1, D_2 \) and \( D_3 \) are in inches)

\( a_1 = 0.40, a_2 = 0.14, a_3 = 0.08 \) (given)

\( m_2 = 1.0 \) and \( m_3 = 1.0 \)

LCR value depends on CBR of subgrade and types of reinforcement used.
Here, LCR = 1.4 for CBR = 2

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Already calculated, SN = 6.16

\[ 6.16 = 0.40 \times D_1 + 0.14 \times D_2 \times 1 + 1.4 \times 0.08 \times D_3 \times 1 \]

or, \[ 6.16 = 0.40 \times D_1 + 0.14 \times D_2 + 0.112 \times D_3 \]

Assuming surface Layer Depth \((D_1)\) = 0.21 m

Assuming base course Depth \((D_2)\) = 0.25 m

Hence, sub-base Course Depth \((D_3)\) = 0.33 m

Total thickness = \((0.21 + 0.25 + 0.33) = 0.79 \text{ m}\)
Step 7: Saving of sub-base course material (%) 

\[
\%\text{Saving} = \frac{\text{unreinforced subbase depth} - \text{reinforced subbase depth}}{\text{unreinforced subbase depth}} \times 100
\]

\[
\%\text{Saving} = \frac{0.47 - 0.33}{0.47} \times 100 = 28.57\%
\]

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Pavement Design without and with Geosynthetics

\(W_{18} = 5.8 \text{ msa}\)

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Please let us hear from you

Any question?

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THANKS FOR LISTENING