GEOSYNTHETICS ENGINEERING: IN THEORY AND PRACTICE

Prof. J. N. Mandal

Department of civil engineering, IIT Bombay, Powai, Mumbai 400076, India.
Tel. 022-25767328
email: cejnm@civil.iitb.ac.in
Module-5
LECTURE- 24
GEOSYNTHETICS IN PAVEMENTS

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
RECAP of previous lecture.....

- Design Problems
  - Design of Reinforced Unpaved road
    (Giroud and Han, 2004)
  - Design Method for Flexible Pavement (AASHTO, 1993)
Excel Program
DEVELOPMENT OF DESIGN METHODS FOR GEOSYNTHETIC REINFORCED FLEXIBLE AIRFIELD PAVEMENTS

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
BARENBERG DESIGN METHOD (Barenberg et al., 1975)

\[ \sigma_z = N_c \times C_u \]

\( \sigma_z \) = allowable stress on the sub-grade

\( C_u \) = undrained cohesion

\( N_c \) = bearing capacity factor

= 3.3, without geotextile

= 6.0, with geotextile

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Thickness of different components of the pavement are determined based on the California Bearing Ratio (C.B.R.) values using the following equation.

\[
t = \alpha \times \sqrt{A \times \left[ \frac{17.9 \times p_e}{CBR} - \frac{1}{\pi} \right]}
\]

(Yoder and Witczak, 1975)

- \( t \) = thickness of aggregate layer (cm)
- \( A \) = contact area of one tire (cm\(^2\))
- \( CBR \) = California Bearing Ratio (percentage)
- \( p_e \) = tire pressure of a single wheel load (SWL) or equivalent single wheel load (ESWL) = SWL/A or ESWL/A
- \( \alpha \) = load repetition factor depending on number of load repetitions and carriage configuration.
Modifications

1. The number of coverages corresponding to 25,000 annual departures of an aircraft on a pavement having 20 years of design life exceeds the maximum value of coverages \( = 1 \times 10^5 \) available in the chart provided in Aerodrome Design Manual, Part 3, Pavements, 1983 for evaluation of load repetition factor ‘\( \alpha \)’.

Hence, the original chart is extrapolated to include up to \( 3 \times 10^5 \) coverages as shown in Figure below.
Modified load repetition factor ($\alpha$) versus coverages, design life = 20 years (From Aerodrome Design Manual, Part 3, Pavements, 1983)

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Pass-to-coverage ratio is the ratio of number of annual departures to the equivalent number of departures.

**Table VIII** Pass to coverage ratio for flexible airfield pavement (Aerodrome Design Manual, ICAO, Part-3, Pavements, 2nd edition, 1983)

<table>
<thead>
<tr>
<th>Type of aircraft</th>
<th>Pass-to-coverage ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single wheel</td>
<td>5.18</td>
</tr>
<tr>
<td>Dual wheel</td>
<td>3.48</td>
</tr>
<tr>
<td>Dual tandem</td>
<td>1.84</td>
</tr>
<tr>
<td><strong>B-747</strong></td>
<td><strong>1.85</strong></td>
</tr>
<tr>
<td>DC 10-10</td>
<td>1.82</td>
</tr>
<tr>
<td>DC 10-30</td>
<td>1.69</td>
</tr>
<tr>
<td>L - 1011</td>
<td>1.81</td>
</tr>
</tbody>
</table>

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
As for example, if annual departure (N) (passes) is 1200 for B 747 type aircraft (number of landing wheels = 8),

Pass-to-coverage ratio as obtained from the Table VIII = 1.85

Coverage = \((1200/1.85) \times 20 = 12972.97\) for 20 years design life

Knowing coverage = 12972.97, load repetition factor (\(\alpha\)) determined from the modified chart \(\alpha = 0.75\)
2. In the original FAA design method, it was assumed that 95 percent of the gross weight of the aircraft is taken by the main landing gear.

However, in the present study, it is assumed that 100-135 percent of the gross weight of the aircraft is taken by the main landing gear. For single wheel gear aircraft no such special assumption is needed.
Percentage of gross weight of aircraft taken by main landing gear of various aircraft (modified method)

<table>
<thead>
<tr>
<th>Type of aircraft</th>
<th>Assumed percent of gross weight carried by main landing gear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual wheel gear</td>
<td>100</td>
</tr>
<tr>
<td>Dual tandem wheel gear</td>
<td>105</td>
</tr>
<tr>
<td>DC 10-10, 10C, F</td>
<td>105</td>
</tr>
<tr>
<td>A300-B2, B4</td>
<td>105</td>
</tr>
<tr>
<td>B747-100, SR, 200B, C, F</td>
<td>135</td>
</tr>
<tr>
<td>B747 SP</td>
<td>135</td>
</tr>
</tbody>
</table>

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
For B747-100, SR, 200B, C, F, assumed percent of gross weight carried by main landing gear = 135%

- Gross weight of aircraft = 385560 kg (given)
- Carried weight by the main landing gear = 385560 x 1.35 = 520506 kg

- No of wheels = 8, ESWL = 520506/8 = 65063.25 kg
- Contact area (A) = 1580.64 cm²

So, Tire pressure \( (p_e) \) = ESWL/A

\[
= \frac{65063.25}{1580.64} = 41.16 \text{ kg/cm}^2
\]

So, thickness can be determined from the following equation,

\[
t = \alpha \times \sqrt{A \times \left[ \frac{17.9 \times p_e}{\text{CBR}} - \frac{1}{\pi} \right]}
\]

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
COMBINATIONS OF BARENBERG DESIGN METHOD AND MODIFIED FAA METHOD

In this method, the thickness of aggregate layer for various CBR values is determined using the design equation given by Yoder and Witczak (1975) considering all the modifications.

The C.B.R. values can be converted into the corresponding un-drained cohesion values,

\[ C_u = 30 \times CBR; \quad C_u = \text{undrained cohesion (kPa)} \]

If the bearing capacity is provided, we can easily determine the C.B.R. value using the above relation and mentioned Barenberg equation. The appropriate bearing capacity factor, \( N_c \), has to be considered for reinforced (6.0) and unreinforced case (3.3).
### Table IX
Different types of aircrafts, gross weight and number of annual departures.

<table>
<thead>
<tr>
<th>Type of Aircrafts</th>
<th>Gross Weight (kg)</th>
<th>Number of annual departures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single wheel</td>
<td>13,600 – 34,000</td>
<td>1,200 – 25,000</td>
</tr>
<tr>
<td>Dual wheel</td>
<td>22,700 – 90,700</td>
<td>1,200 – 25,000</td>
</tr>
<tr>
<td>Dual-tandem wheel</td>
<td>45,000 – 181,400</td>
<td>1,200 – 25,000</td>
</tr>
<tr>
<td>B 747-100,SR,200B,C,F</td>
<td>136,080 – 385,560</td>
<td>1,200 – 25,000</td>
</tr>
<tr>
<td>B747 SP</td>
<td>136,080 – 317,520</td>
<td>1,200 – 25,000</td>
</tr>
<tr>
<td>DC 10 – 10, 10CF</td>
<td>90,720 – 204,120</td>
<td>1,200 – 25,000</td>
</tr>
<tr>
<td>A 300 – B2, B4</td>
<td>142,000 – 157,000</td>
<td>1,200 – 25,000</td>
</tr>
</tbody>
</table>
Design charts are prepared for different types of aircrafts, gross weights and number of annual departures.

X-axis represents the CBR value and Y-axis represents the thickness value.

For unreinforced case, the thickness will directly be obtained from the design charts. For reinforced case, the thickness will be corresponding to the C.B.R. value two times that of unreinforced case.

- As for example, if thickness has to be determined at C.B.R. = 2, for unreinforced case one will use the design charts directly.

However, for reinforced case, we have to find out the thickness at C.B.R. = 4 from the same design chart.

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Flexible pavement design curve for critical areas, B747-100, SR, 200 B,C,F for gross weight 385,560 kg

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
### Unreinforced and reinforced aggregate thickness and percentage saving in aggregate for B747-100, SR, 200 B, C, F aircraft for a departure of 1200

<table>
<thead>
<tr>
<th>Gross weight of aircraft (kg)</th>
<th>C.B.R.</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$h_u$</td>
<td>$h_r$</td>
<td>% Reduct</td>
<td>$h_u$</td>
</tr>
<tr>
<td>136,080</td>
<td>222</td>
<td>156</td>
<td>29.73</td>
<td>156</td>
</tr>
<tr>
<td>181,440</td>
<td>235</td>
<td>163</td>
<td>30.64</td>
<td>163</td>
</tr>
<tr>
<td>226,800</td>
<td>284</td>
<td>200</td>
<td>29.58</td>
<td>200</td>
</tr>
<tr>
<td>272,160</td>
<td>316</td>
<td>220</td>
<td>30.38</td>
<td>220</td>
</tr>
<tr>
<td>317,520</td>
<td>310</td>
<td>218</td>
<td>29.7</td>
<td>218</td>
</tr>
<tr>
<td>362,880</td>
<td>334</td>
<td>236</td>
<td>29.34</td>
<td>236</td>
</tr>
<tr>
<td>385,560</td>
<td>330</td>
<td>236</td>
<td>28.5</td>
<td>236</td>
</tr>
</tbody>
</table>

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
When cracks occur over pavement overlay, i.e. asphalt overlay, water can percolate through it causing rapid deterioration of the highway.

Potholes and reflection cracks in some highways of India

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Modes of Crack Propagation (After Rankilor, Bonar 1997)

Movement in a crack due to thermal variation

Movement in a crack due to moisture variation

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Opening and vertical shearing of cracks

Traffic induced horizontal shear of a crack

Traffic induced scissor shear at a crack end

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
We generally clean, fill and resurface the pavement with bituminous layer (Asphaltic cement) of thickness ranging from 25 mm to 100 mm as an overlay on the existing pavement. However, it is observed that reflection crack occurs from the old pavement into and through the new overlay.

- Geosynthetics can be used as a superior moisture barrier as well as retarding the reflection cracks in the pavements.

It is conventional to maintain the roads years after years. Therefore, a water barrier layer is needed to protect the pavement from degradation due to ingress of water.

Geosynthetics for pavement overlay

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Impregnated nonwoven geotextiles:
Proper Coating with asphalt
Use of geosynthetic to prevent reflection cracking in pavements

- It can be used beneath the overlay to reduce crack propagation along its length.
- It can also increase the stiffness and load bearing capacity of asphalt concrete pavement.

Asphalt reinforced geogrid

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Types of geosynthetics for pavement overlays:

Standard asphalts or polymer modified bituminous layer are used as overlay of pavements. Different types of geosynthetics available for asphalt overlays are:

- Nonwoven geosynthetics (Synthetics/Naturals)
- Woven geosynthetics (Synthetics/Naturals)
- Asphalt reinforced geogrid
- Geogrids (Polyester, HDPE etc.)
- Geocomposite materials
- Glass grids
- Polypropylene
- Nylon
- Jute
- coir

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Geosynthetic functions:

- Reinforcement,
- Water barrier,
- Cushion,
- Separation, and
- Filtration

Use of proper geosynthetics will be helpful for retardation of reflection cracking.
- It will reduce the maintenance cost as well as increase the roadway life.
- It will also increase the serviceability of pavement overlays.

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Brown, Brodrick and Hughes (1984) reported that geogrid is good to minimize rutting. Type of geogrids play a very important role.

Polypropylene or polyethylene will not properly bond together with asphalt. Bituminous coated flexible geogrid ensure good bonding.

Geogrids shrink on hot asphalt for molecular stress relaxation and loss strength. Even then geogrids act as good crack arresters for prevention of reflection cracking in pavement.

Bituminous coated glass grid has high tensile strength and high modulus, low creep and low elongation. So, It can be used for rehabilitation or retardation of reflective cracks in an existing pavements.
**Tack coat:** The exact quality of tack coat is reported by Button et al. (1982),

\[ Q_{ef} = 0.36 + Q_s \pm Q_c \]

- \( Q_{ef} \) = required amount of bituminous tack coat (l/m²),
- \( Q_s \) = required amount of bitumen for saturation of geotextile (l/m²), and
- \( Q_c \) = Adjustment factor based on sealant required for the existing condition of the surface layer (l/m²).

The geotextile is saturated with bitumen at 120°C for 2 minutes. Button et al. (1982) reported that the value of \( Q_{ef} \) varies from 0.09 to 0.59 based on the surface condition of pavement.

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay
Construction of overlay:

- The ground surface must be free from all kind of debris, ruts, dust etc.

- The cracks should be filled with hot mix and asphalt.

- Tack coat is needed to spread over the entire surface of existing pavement.

- The geotextile should be placed in order that there should not be any wrinkle or fold.
- Care should be taken so as there should not be any damage of geotextile due to the movement of track on the pavement surface.

- The overlapping of geotextile should be between 12 cm and 18 cm.

- The temperature of bitumen should not exceed 135°C to 150°C. After proper curing, traffic should be opened.
Please let us hear from you

Any question?
Prof. J. N. Mandal

Department of civil engineering, IIT Bombay,
Powai, Mumbai 400076, India.
Tel. 022-25767328
email: cejnm@civil.iitb.ac.in

THANKS FOR LISTENING