Comparision of Flexible Pavement Thickness for weak and Strong Subgrade Soils

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I. INTRODUCTION

1.1 PAVEMENT

Pavement is the actual travel surface especially made durable and serviceable to withstand the traffic load commuting upon it. Pavement grants friction for the vehicles thus providing comfort to the driver and transfers the traffic load from the upper surface to the natural soil. A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade.

II. TYPES OF PAVEMENTS

Flexible pavements which reflect the deformation of sub-grade and the subsequent layers to the surface. Flexible, usually asphalt, is laid with no reinforcement or with a specialized fabric reinforcement that permits limited flow or repositioning of the roadbed underground changes.

The design of flexible pavement is based on load distributing characteristic of the component layers. The black top pavement including water & gravel bound macadam fall in this category.

Flexible pavement on the whole has low or negligible flexible strength flexible in their structural action). The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain transfer through contact points of granular structure.

The vertical compressive stress is maximum on the pavement surface directly under the wheel load and is equal to contact pressure under the wheels. Due to the ability to distribute the stress to large area in the shape of truncated cone the stresses get decreased in the lower layer.

IV. TYPES OF FLEXIBLE PAVEMENT

Conventional flexible pavements are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

Full - depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub-grade. This is more suitable when there is high traffic and local materials are not available.

Contained rock asphalt mats are constructed by placing dense/open graded aggregate layers in between two asphalt layers. Modified dense graded asphalt concrete is placed above the sub-grade will significantly reduce the vertical compressive strain on soil sub-grade and protect from surface water.

V. COMPONENTS OF FLEXIBLE PAVEMENT

Typical layers of a conventional flexible pavement includes seal coat, surface course, tack coat, binder course, prime coat, base course, sub-base course, compacted sub-grade, and natural sub-grade.

Figure: 1. Flexible Pavement
VI. METHODS USED IN THE DESIGN OF FLEXIBLE PAVEMENTS CBR METHOD

The following sub sections describe the various variables and parameters involved in design of flexible pavement of road as per IRC 37 - 2001.

Traffic- CV/Day Annual traffic census 24 X 7:
For structural design, commercial vehicles are considered. Thus vehicle of gross weight more than 8 tones load are considered in design. This is arrived at from classified volume count.

Wheel loads:
Urban traffic is heterogeneous. There is a wide spectrum of axle loads plying on these roads. For design purpose it is simplified in terms of cumulative number of standard axle (8160 kg) to be carried by the pavement during the design life. This is expressed in terms of million standard axles or msa

Design Traffic:
Computation of design Traffic In terms of cumulative number of standard axle to be carried by the pavement during design life.

\[ N = \frac{365 \times A \times [(1+r)n - 1]}{x F x D x r} \]

Group Index Method:-
In order to classify the fine grained soils within one group and for judging their suitability as sub grade material, an indexing system has been introduced in HRB classification which is termed as Group Index. Group Index is function of percentage material passing 200 mesh sieve (0.074mm), liquid limit and plasticity index of soil and is given by equation:

\[ GI = 0.2a + 0.005ac + 0.01bd \]

VII. TRIAXIAL METHOD

L.A.Palmer and E.S.Barber in 1910 proposed the design method based on Boussinesq’s displacement for homogeneous elastic single layer: The thickness of pavement.

\[ T = \sqrt{\left(\frac{3P}{2\pi \Delta Es}\right)^2 - a^2} \]

IRC 37:2001) Design of flexible pavements:

Scope:
These guidelines will apply to design of flexible pavements for Expressway, National Highways, State Highways, Major District Roads, and other categories of roads. Flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to IRC/ MOST standards.

Design criteria:
The flexible pavements has been modeled as a three layer structure and stresses and strains at critical locations have been computed using the linear elastic model. To give proper consideration to the aspects of performance, the following three types of pavement distress resulting from repeated (cyclic) application of traffic loads are considered, vertical compressive strain at the top of the sub-grade which can cause sub-grade deformation resulting in permanent deformation at the pavement surface.

- Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.
- Pavement deformation within the bituminous layer.

Failure Criteria:

Figure.2. Failure Criteria

Design procedure:
The pavement designs are given for subgrade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35 C. The later thicknesses obtained from the analysis have been slightly modified to adapt the designs to stage construction. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength.

I. Design traffic in terms of cumulative number of standard axles; and
II. Value of sub grade.

Design traffic:
The method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. This requires the following information.

1. Initial traffic in terms of CVPD
2. Traffic growth rate during the design life
3. Design life in number of years
4. Vehicle damage factor (VDF)
5. Distribution of commercial traffic over the carriage way.

Pavement thickness design charts
For the design of pavements to carry traffic in the range of 1 to 10 msa, use chart 1 and for traffic in the range 10 to 150 msa, use chart 2 of IRC:37 2001. The design curves relate pavement thickness to the cumulative number of standard axles to be carried over the design life for different sub-grade CBR values ranging from 2 % to 10 %. The total thickness consists of granular sub-base, granular base and bituminous surfacing. The individual layers are designed based on the recommendations given below and the subsequent tables.
VIII. EXPERIMENTS CONDUCTED

1. Standard compaction test
2. Grain size sieve analysis
3. California bearing ratio test
4. Liquid limit test
5. Plastic limit test

GRAIN SIZE DISTRIBUTION BY SIEVE ANALYSIS

Determine the relative properties of different grain sizes which make up a given soil mass.

CALIFORNIA BEARING RATIO TEST

Determine the California bearing ratio by conducting a load penetration test in the laboratory. The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by the tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

Results:-

**Subgrade-1**
California Bearing Ratio sub grade-1 = (5.58+6.09+6.09)/3
= 5.92 ≈ 6%

Therefore CBR=6%

DETERMINATION OF LIQUID LIMIT

Determine the liquid limit for the given soil sample. Liquid limit is significant to know the stress history and general and general properties of the soil met with construction. From the results of liquid limit the compression index may be estimated. The compression index value will help us in settlement analysis. The Liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. At this limit the soil posses low shear strength

Observations and Calculations:-

<table>
<thead>
<tr>
<th>Table 1. Subgrade 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determination Number</td>
</tr>
<tr>
<td>Container no</td>
</tr>
<tr>
<td>Weight of container (gm) W1</td>
</tr>
<tr>
<td>Weight of container + wet soil (gm) W2</td>
</tr>
<tr>
<td>Weight of container + dry soil (gm) W3</td>
</tr>
<tr>
<td>Weight of water (%) W2-W3</td>
</tr>
<tr>
<td>weight dry soil (gm) W3-W1</td>
</tr>
<tr>
<td>Moisture content (%) ((W2-W3)/(W3-W1)*100</td>
</tr>
<tr>
<td>No of blows</td>
</tr>
</tbody>
</table>

Figure 4. Moisture content vs. No of blows

From graph Liquid limit of the soil sample is 46% at 25 blows.
Table 2. Sub Grade-2

<table>
<thead>
<tr>
<th>Determination Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container no</td>
<td>Lid-B</td>
<td>Lid-2</td>
<td>Lid-1</td>
<td>Lid-3</td>
</tr>
<tr>
<td>Weight of container (gm) W1</td>
<td>21.5</td>
<td>20.5</td>
<td>20.5</td>
<td>21</td>
</tr>
<tr>
<td>weight of container + wet soil (gm) W2</td>
<td>37</td>
<td>46</td>
<td>39</td>
<td>42</td>
</tr>
<tr>
<td>weight of container + dry soil (gm) W3</td>
<td>32.5</td>
<td>38</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td>Weight of water (%) W2-W3</td>
<td>4.5</td>
<td>8</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>weight dry soil (gm) W3-W1</td>
<td>11</td>
<td>17.5</td>
<td>12.5</td>
<td>13</td>
</tr>
<tr>
<td>Moisture content (%) ((W2-W3)/(W3-W1))*100</td>
<td>40.91</td>
<td>45.71</td>
<td>48.00</td>
<td>61.54</td>
</tr>
<tr>
<td>No of blows</td>
<td>40</td>
<td>31</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

Results:-
- PL of sub grade-1 is 15.38%
- PL of sub grade-2 is 21.43%

Pavement Design

Table 4. Data obtained from experiments and available data:

<table>
<thead>
<tr>
<th>Sub Grade-1</th>
<th>Sub Grade-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR 9%</td>
<td>CBR 6%</td>
</tr>
<tr>
<td>LL 46%</td>
<td>LL 47%</td>
</tr>
<tr>
<td>PL 15.38%</td>
<td>PL 21.43%</td>
</tr>
</tbody>
</table>

Cumulative traffic 150 msa

10.1 CBR Method:-

Subgrade-1
CBR 9% and for cumulative traffic 150 msa
As per IRC 37-2001
The thickness of pavement is 655 mm
The composition is maintained as per IRC 37-2001 (shown below)

Subgrade-1
CBR 6% and for cumulative traffic 150 msa
As per IRC 37-2001
The thickness of pavement is 720 mm
The composition is maintained as per IRC 37-2001 (shown below)

10.2 Group index method:-
GI=0.2a+0.005ac+0.01bd
Design chart by Group Index value
Sub grade-1
LL=46% PL=15.38%
Plasticity Index (PI) = LL-PL
=46-15.38
=30.62
Portion of material passing through 0.075mm IS sieve (by sieve analysis) =2.50%
Therefore
a = 0
b = 0
c = LL=40
46-40 = 6
d = PI-10
= 30.62-10 = 20.62

X. REFERENCES

[2]. Text book by S. Kanna and Justeo
[3]. WWW.ijera.com
[4]. www.thefreedictionary.com
[5]. www.nptel.ac.in

Moisture content vs. No of blows

From graph Liquid limit of the soil sample is 47% at 25 blows.

IX. DETERMINATION OF PLASTIC LIMIT

Determine the plastic limit of the soil sample.
Soil is used for making bricks, tiles and soil cement blocks in addition to its use as foundation structures.

Table 3. Observations and Calculations:-

<table>
<thead>
<tr>
<th>Sub Grade</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container no</td>
<td>73</td>
<td>33</td>
</tr>
<tr>
<td>Weight of container (gm) W1</td>
<td>21.5</td>
<td>30</td>
</tr>
<tr>
<td>weight of container + wet soil (gm) W2</td>
<td>32</td>
<td>38.5</td>
</tr>
<tr>
<td>weight of container + dry soil (gm) W3</td>
<td>30.6</td>
<td>37</td>
</tr>
<tr>
<td>Weight of water (%) W2-W3</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>weight dry soil (gm) W3-W1</td>
<td>9.1</td>
<td>7</td>
</tr>
<tr>
<td>Moisture content ((W2-W3)/(W3-W1))*100</td>
<td>15.38</td>
<td>21.43</td>
</tr>
</tbody>
</table>