Soils
Pavement Design Factors

Wheel Loads Applied to Pavement

- Magnitude of Wheel Loads
- Type of Wheel Loads (Single or Tandem Axles)
- Number of Wheel Load Applications
- Changes over Time

Subgrade Support Provided

- Seasonal Changes in Subgrade Support
California Bearing Ratio (CBR)
CBR Inventor

O. James Porter

Soaking CBR Sample

4 days

CBR Test Setup

![Diagram of CBR Test Setup]

California Bearing Ratio

![Graph showing California Bearing Ratio with load in pounds on the y-axis and penetration in inches on the x-axis. The graph includes load values of 3000 and 4500 pounds. The CBR values are marked at 100 for each load value.](image-url)
Identify straight-line portion of stress-deflection curve
Shift stress-deflection curve until it intersects the origin.
Compare to the ideal curve.

\[
\frac{1800}{4500} = 40\%
\]

\[
\frac{900}{3000} = 30\%
\]

CBR = 40
# Typical Values of CBR

<table>
<thead>
<tr>
<th>Material</th>
<th>CBR</th>
<th>Elastic Modulus (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed Stone (GW, GP, GM)</td>
<td>20 - 100</td>
<td>20,000 - 40,000</td>
</tr>
<tr>
<td>Sandy Soils (SW, SP, SM, SC)</td>
<td>5 - 40</td>
<td>7,000 - 30,000</td>
</tr>
<tr>
<td>Silty Soils (ML, MH)</td>
<td>3 - 15</td>
<td>5,000 - 20,000</td>
</tr>
<tr>
<td>Clayey Soils (CL, CH)</td>
<td>3 - 10</td>
<td>5,000 - 15,000</td>
</tr>
<tr>
<td>Organic Soils (OH, OL, PT)</td>
<td>1 - 5</td>
<td>&lt; 5,000</td>
</tr>
</tbody>
</table>

Source: WSDOT Pavement Guide Interactive CD-ROM
## Typical Values of CBR

<table>
<thead>
<tr>
<th>General Soil Type</th>
<th>USC Soil Type</th>
<th>CBR Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse-grained soils</td>
<td>GW</td>
<td>40 - 80</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>30 - 60</td>
</tr>
<tr>
<td></td>
<td>GM</td>
<td>20 - 60</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>20 - 40</td>
</tr>
<tr>
<td></td>
<td>SW</td>
<td>20 - 40</td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>10 - 40</td>
</tr>
<tr>
<td></td>
<td>SM</td>
<td>10 - 40</td>
</tr>
<tr>
<td></td>
<td>SC</td>
<td>5 - 20</td>
</tr>
<tr>
<td>Fine-grained soils</td>
<td>ML</td>
<td>≤ 15</td>
</tr>
<tr>
<td></td>
<td>CL</td>
<td>≤ 15</td>
</tr>
<tr>
<td></td>
<td>OL</td>
<td>≤ 5</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>≤ 10</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>≤ 15</td>
</tr>
<tr>
<td></td>
<td>OH</td>
<td>≤ 5</td>
</tr>
</tbody>
</table>

Source: WSDOT Pavement Guide Interactive CD-ROM
Field CBR Test

Source: ASTM Standards on Disc, Vol. 04.03, Designation D 4429 - 04, June 2007
Field CBR

Source: http://www.ele.com/geot/cali.htm
Resilient Modulus
($M_R$)
Resilient Modulus
Resilient Modulus

Resilient Modulus

\[ M_R \]

Deviator stress vs. Axial strain diagram with line labeled \( M_R \)
Haversine Load Pulse

\[ P_{cyclic} = P_{max} \sin^2 \left( \pi \frac{t}{T} \right) \]
Granular Soils

\[ M_R = K_1 \theta^{K_2} \]

Source: WSDOT Pavement Guide Interactive CD-ROM
Cohesive Soils

\[ M_R = K_3 \sigma_d^{K_4} \]
Estimating Subgrade $M_R$

1993 AASHTO Guide

$$M_R = 1500 \times CBR$$

WARNING: Only for fine-grained soils with soaked CBR < 10.
Estimating Subgrade $M_R$

**AASHTO MEPDG**

$$M_R = 2555 \times CBR^{0.64}$$

Good for a wide range of soil types
$M_R$ vs. CBR

$M_R = 1500$ CBR

$M_R = 2555 \text{ CBR}^{0.64}$
$M_R$ vs. CBR

$M_R = 1500 \ CBR$

$M_R = 2555 \ CBR^{0.64}$
Plate Load Test
(k)
Plate Load Test
Plate Load Test
Plate Load Test
Plate Load Test

![Graph showing load vs. deflection](image-url)
Plate Load Test

\[ A = \pi r^2 = \pi (15 \text{ in})^2 = 707 \text{ in}^2 \]
Plate Load Test

Stress (psi) vs. Deflection (in)

- Residual Deflection
- Straight Portion
- $k = 378$ psi/in
Rigid Loading

\[ \sigma_z = \frac{\sigma_o}{2\sqrt{1-(r/a)^2}} \]

where \( \sigma_o = \frac{P}{\pi a^2} \) is the average pressure on the plate
Rigid Loading

\[ d_o = \frac{\pi \sigma_o a (1 - \mu^2)}{2E} \quad \Rightarrow \quad E = \frac{\pi \sigma_o a (1 - \mu^2)}{2d_o} \]

\[ \frac{\sigma_o}{d_o} = k \]
Rigid Loading

\[ E = \frac{\pi ka(1-\mu^2)}{2} \]