Deflection Response

- Benkelman Beam
- Deflectograph
- Falling Weight Deflectometer

Deflectograph (PAVDEF)

Heavy weight deflectometer

HWD/FWD Loading system
Transport and Main Roads

HWD/FWD Bowl

Deflection Measurement Devices
- Benkelman Beam: Standard Axle Load
  - 550 kPa Contact Stress
- Deflectograph: Standard Axle Load
  - 750 kPa Contact Stress
- FWD/HWD: Variable Load
  - Variable Contact Stresses
  - Fixed Contact Area

Overlay Design Methodology
- Deflection Reduction Method using Subgrade CBR (D₉₀₀) Estimate
- Deflection Reduction Method using equivalent CBR from Subgrade Modulus obtained by Back Analysis
- Mechanistic Design Method using calculated insitu Pavement and Subgrade Moduli from Back Analysis

Typical Deflection Bowl Shapes under a Standard Axle (40 kN) Load for the various Deflection Devices used by Main Roads – see next slide

Typical Deflection Bowls
Granular base – 40kN Load
Typical Deflection Bowls
CTB – 40kN Load

The absolute value of 40 kN deflection measurements on Bound Heavy Duty Pavements are too low for effective/confident back analysis.

Need higher loads for testing Bound Heavy Duty Pavements

Typical Deflection Bowls
CTB – 40, 60 + 80 kN Loads

Deflection Surveys

The spacing of successive deflection tests is as follows:

**Urban Areas**
- Both inner and outer wheel paths for all lanes
- 25 m: heavy commercial vehicle lane (usually the outer lane)
- 50 m: fast lane
- 10 m: areas of high distress

**Rural Areas**
- Both inner and outer wheel paths for all lanes
- 50 m: all lanes (this would be staggered between adjacent lanes)

The recording for deflection surveys consists of:
- Direction/lane description
- Wheelpath description
Typical results from deflection testing

Deflection vs. Distance

- Deflection Bowl
  - Typical Deflection Bowl
  - Rebound Deflection, $D_0 = \text{Max. Deflect} - \text{Residual Deflect}$
  - Deflection Ratio, $DR = \frac{D_{250}}{D_0}$
  - Curvature Function, $CF = \frac{D - D_0}{200}$
Benkelman Beam Test

Residual Deflections

- Residual deflections represent the ‘permanent’ deformation of a pavement
- Residual deflections can be +ve or -ve

Deflection Ratio

Deflection ratio is used to indicate the stiffness of the pavement structure and is ‘fairly’ independent of surfacing type (AC/spray seal) or sub-grade CBR

\[ \text{Deflection Ratio} = \frac{D_{250}}{D_0} \]

- > 0.8 indicates CTB or CTSB bound pavement
- 0.6 – 0.8 indicates good quality unbound pavement
- < 0.6 indicates a possible weakness in the pavement materials

Curvature Function

- Curvature function is used to predict the fatigue life of an applied asphalt surfacing overlay or an existing asphalt surfacing

\[ \text{Curvature Function} = D_0 - D_{200} \]

- Representative curvature is determined as the mean of the curvature functions
- Representative of C.F. should have a C.V. of < 30%

Modulus vs. Deflection Ratio

D\text{900} Value vs. CBR Value
Bowl Survey Data

- Deflection → Strength
- Defln. Ratio → Stiffness
- Residual Defln. Ratio → Upper Pvt. or Surface
- Curvature → Asphalt Fatigue
- Deflection 900 → Subgrade

Historic Tolerable Deflection Criterion – Unbound Pavements

Deflection Reduction Overlay Design Philosophy

Tolerable Deflection Normal Design Standard
Design Exercise 1

The results of a Benkelman beam deflection survey for a section of Toowoomba – Karara Road is attached.

1. Determine homogenous lots for both inner and outer wheelpaths.
2. Compare the representative values of the following for the homogenous sections for both inner and outer wheel paths:
   - rebound deflections
   - residual deflections
   - deflection ratio
   - curvature function

Design Exercise 1 (cont.)

3. For these sections, based on the deflection results, comment on the following:
   - stiffness of the pavement material
   - condition of the subgrade

Selection of Homogenous Lots

- Study bowl plots and delete bad bowls
- If AC surfacing – temperature correction
- Plot rebound deflections and residual deflections (check high/low)
- Visually subdivide rebound deflection plots into uniform subsections

Selection of Homogenous Lots (cont.)

- Determine statistical values
  - Mean (μ)
  - Standard Deviation (s.d.)
  - Coefficient of variation (s.d./μ)
  For both IWP and OWP for rebound deflection
- If CV < 30% lot is homogenous
- If CV > 30% lot requires further subdivision until CV is < 30%
Moisture Correction Factors

Depend on:
- Subgrade type
- Rainfall
- Location of water table
- Pavement type

Moisture Correction (cont.)

- Moisture correction factors are applied to the IWP Deflections in order to simulate the worst expected conditions in the outer wheel path

Seasonal Correction Factors

Moisture Correction

- Moisture movement occurs in pavements generally in the outer wheel paths only (assuming reasonable pavement drainage)
- CBR of the subgrade also varies with moisture
- Example:
Asphalt Fatigue

• Tensile Strain in asphalt depends on:
  - Traffic (E.S.A.'s)
  - Temperature
  - Thickness

Curvature Function

• Curvature function is used to predict the fatigue life of an applied asphalt surfacing overlay or an existing asphalt surfacing.

\[
\text{Curvature Function} = D_0 - D_{200}
\]

Asphalt Overlay Process

Curvature Function = D₀ − D₂₀₀

Representative curvature is determined as the mean of the curvature functions.

Asphalt Stiffness Relationships

Asphalt correction factor for deflection

Asphalt Temperature Correction for Deflection

Existing Asphalt Thickness (mm)
Worked example of QDMR procedures for asphalt overlay design

Asphalt Overlay Process
1. For Subgrade Life \( N_p \) & \( D_{loc} \) value, determine \( D_{tol} \)

Asphalt Overlay Process (cont)
2. Check \( D_{tol} \) > or < \( D_{REP} \) deflection
3. Determine thickness \( T_{AC} \) for curvature before overlay and design traffic (ESA’s)

Asphalt Overlay exercise
Fill in the top white cells of spreadsheet
- temp.zone number – see Queensland map sheet 34
- temperature of existing asphalt – see FWD printout - sheet 12
- Depth of existing asphalt – see trench profile – sheet 3
- Asphalt correction factor for deflection – see sheet 36

Overlay Design (cont)
- Temperature Corrections
  - Deflections affected by temperature
  - Zones for Queensland
  - Corrections to both deflection and curvature functions
Asphalt Fatigue Criteria

Influence of Temperature Variations
1. Rebound Deflection (\(D_0\))
2. Curvature Function (\(D_0 - D_{200}\))

Asphalt correction factor for deflection

Asphalt correction factor for curvature function – see sheet 37

• Speed Corrections
  o Modulus increases with rate of loading
  o Speed of beam testing must lower than operating traffic speed
  o Corrections
  o Applicable for asphalt overlay on asphalt
Before and After Deflections Asphalt overlay chart

**CHART 14-Asphalt Overlay Design (2600MPa): Zone 3 - 80kph**

- **Deflection Before Overlay**
- **Deflection After Overlay**

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.56</td>
<td>0.242</td>
</tr>
<tr>
<td>75</td>
<td>0.64</td>
<td>0.198</td>
</tr>
<tr>
<td>100</td>
<td>0.74</td>
<td>0.05</td>
</tr>
<tr>
<td>125</td>
<td>0.87</td>
<td>0.01</td>
</tr>
<tr>
<td>150</td>
<td>less</td>
<td>less</td>
</tr>
</tbody>
</table>

**Chart 30 Zone 3 - 80Kph**

**Asphalt Overlay Design: Zone 3 - 80kph**

- **Design Traffic (ESA)**
- **Curvature Before Overlay**

<table>
<thead>
<tr>
<th>Curvature (1E5, 1E6, 1E7)</th>
<th>75mm</th>
<th>100mm</th>
<th>125mm</th>
<th>150mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>75mm</td>
<td>0.56</td>
<td>0.64</td>
<td>0.74</td>
<td>0.87</td>
</tr>
<tr>
<td>100mm</td>
<td>0.56</td>
<td>0.64</td>
<td>0.74</td>
<td>0.87</td>
</tr>
<tr>
<td>125mm</td>
<td>0.56</td>
<td>0.64</td>
<td>0.74</td>
<td>0.87</td>
</tr>
<tr>
<td>150mm</td>
<td>0.56</td>
<td>0.64</td>
<td>0.74</td>
<td>0.87</td>
</tr>
</tbody>
</table>