Why Test Pavements?

- Investigate cause of failure
- Design rehabilitation measures
- Monitor performance
- Check compliance with specification

Types of Tests

- 2 types:
  - Non-destructive
  - Destructive

Non-destructive

- Deflection response to load
- Riding quality
- Pavement surface condition

Destructive:

- Coreing/augering & sampling
- Insitu CBR
- Trenching

Deflection Response

- Benkelman Beam
  - Without bowls
  - With bowls
- Deflectograph
- Falling Weight Deflectometer

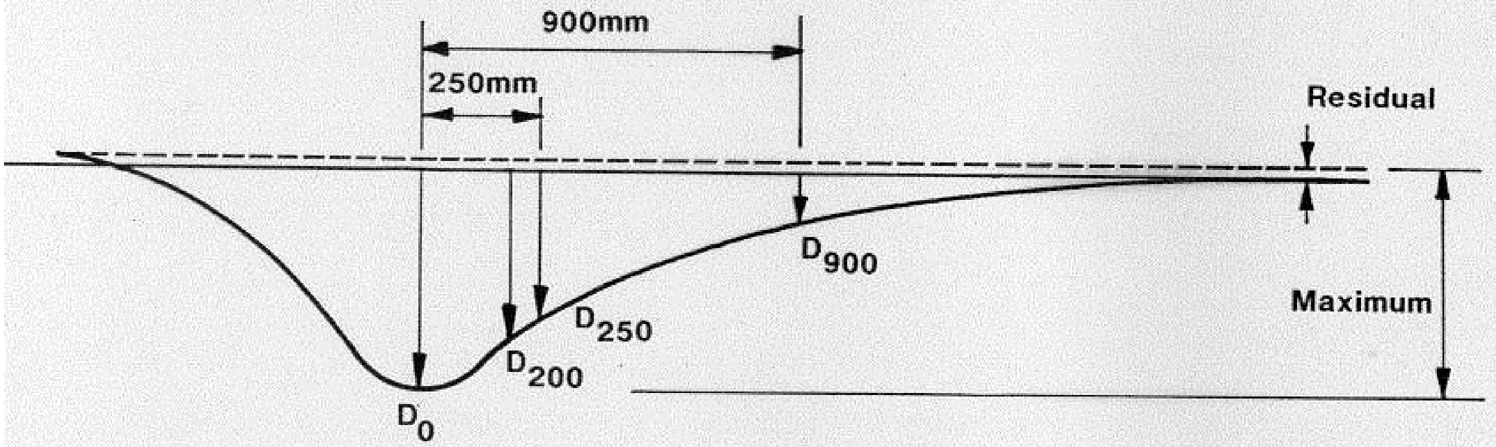
Riding quality

- NAASRA Roughness Meter
- Longitudinal profile (Quarter Car Simulation)

Pavement Surface Condition

- Rutting
    - Straight edge
    - CONDAS Trailer
- Cracking (visual assessment)
- Texture (visual assessment)

Typical Deflection Bowl



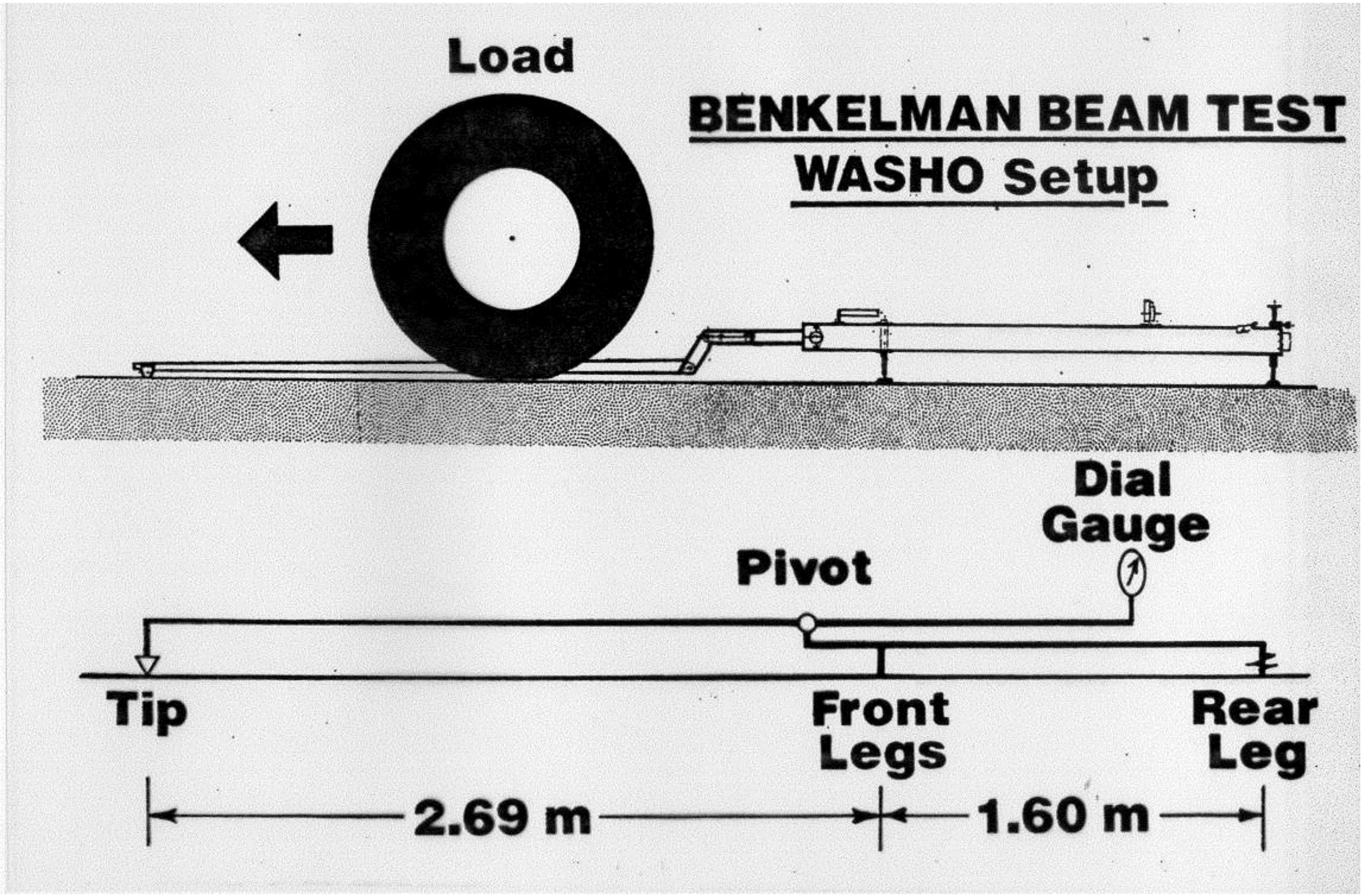
Rebound Deflection, D_0 = Max. Deflect - Residual Deflect

Deflection Ratio, $DR = D_{250} / D_0$

Curvature Function, $CF = D_0 - D_{200}$

TYPICAL DEFLECTION BOWL

Benkelman Beam Test



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

Deflection Surveys

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:

- MRDAS
- Paper backup
- Direction/lane description/wheel path description

FWD Testing

How sound is the pavement below the seal ?

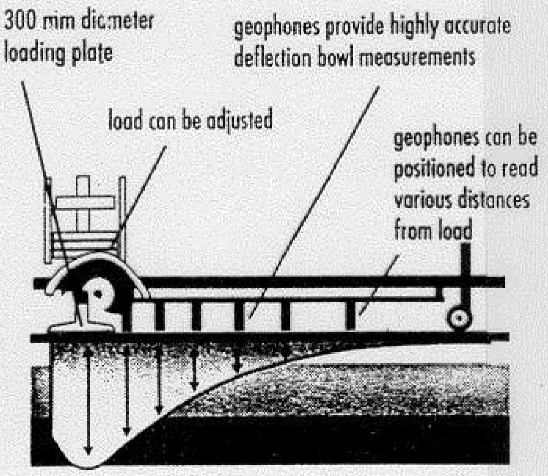
The use of a mobile means of assessing the condition of a pavement can assist road engineers in the design and cost-effective management of road seals and subgrades. An example of such a device is the Falling Weight Deflectometer (FWD), which is now used in many countries of the world.

This state-of-the-art device (a Dynatest Model 8000 FWD) together with its towing vehicle and operator are now available for hire from the Australian Road Research Board by State Road and Local Government Authorities, consultants and contractors or anyone needing to know the strength of a pavement.

What is the FWD ?

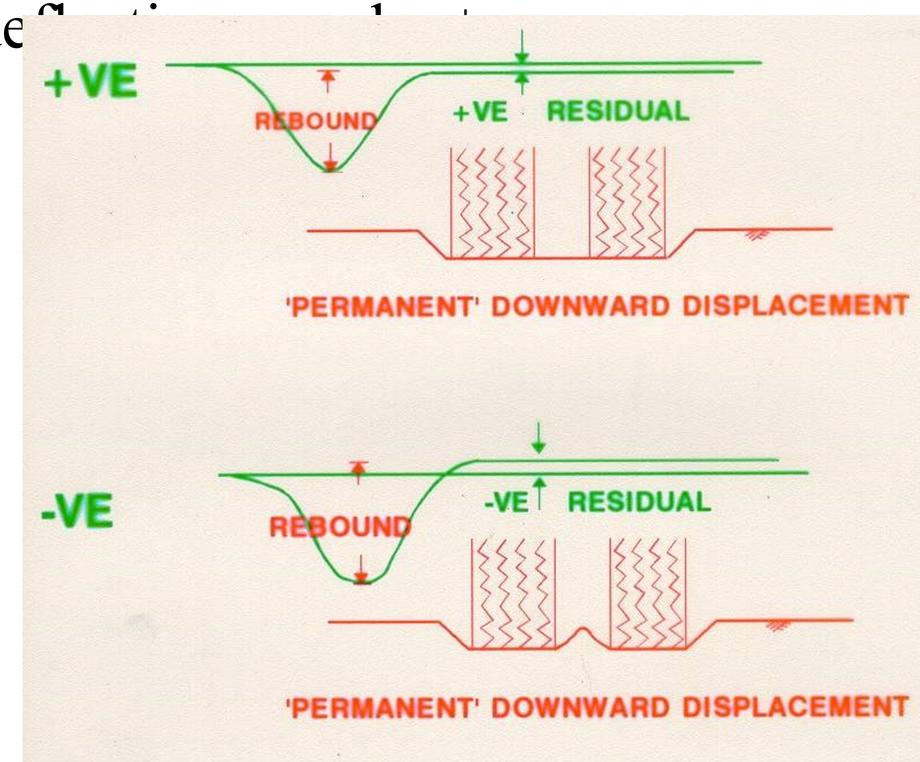
The FWD is a non-destructive pavement testing device which provides accurate data on the response of the pavement (specifically the surface deflection bowl) by simulating actual wheel loads in both response and duration. This allows more accurate and rapid measurement of pavement deflection under load than traditional methods.

A dynamic load is generated by the dropping of a mass from a pre-set height onto a 300 mm diameter plate. The magnitude of the load and the pavement response are measured by a load cell and seven geophones. One geophone is located immediately under the load, whilst the others are located at variable offsets from the centre of the load.



Residual Deflections

- Residual deflections represent the 'permanent' deformation of a pavement
- Residual de



Deflection Ratio

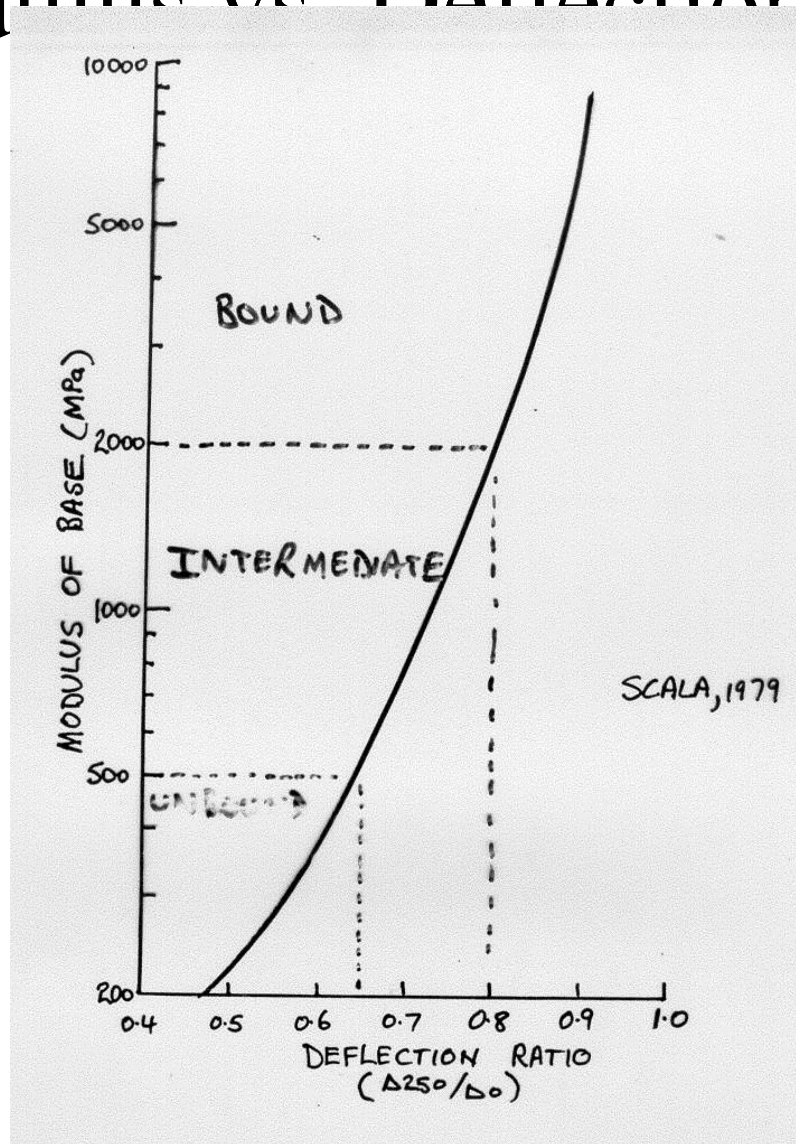
Deflection ratio is used to indicate the stiffness of the pavement structure and is ‘fairly’ independent of surfacing type (AC/spray seal) or sub-grade CBR

$$\text{Deflection Ratio} = D_{250} / D_0$$

Deflection ratio of:

- > 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

Modulus vs. Deflection Ratio



Curvature Function

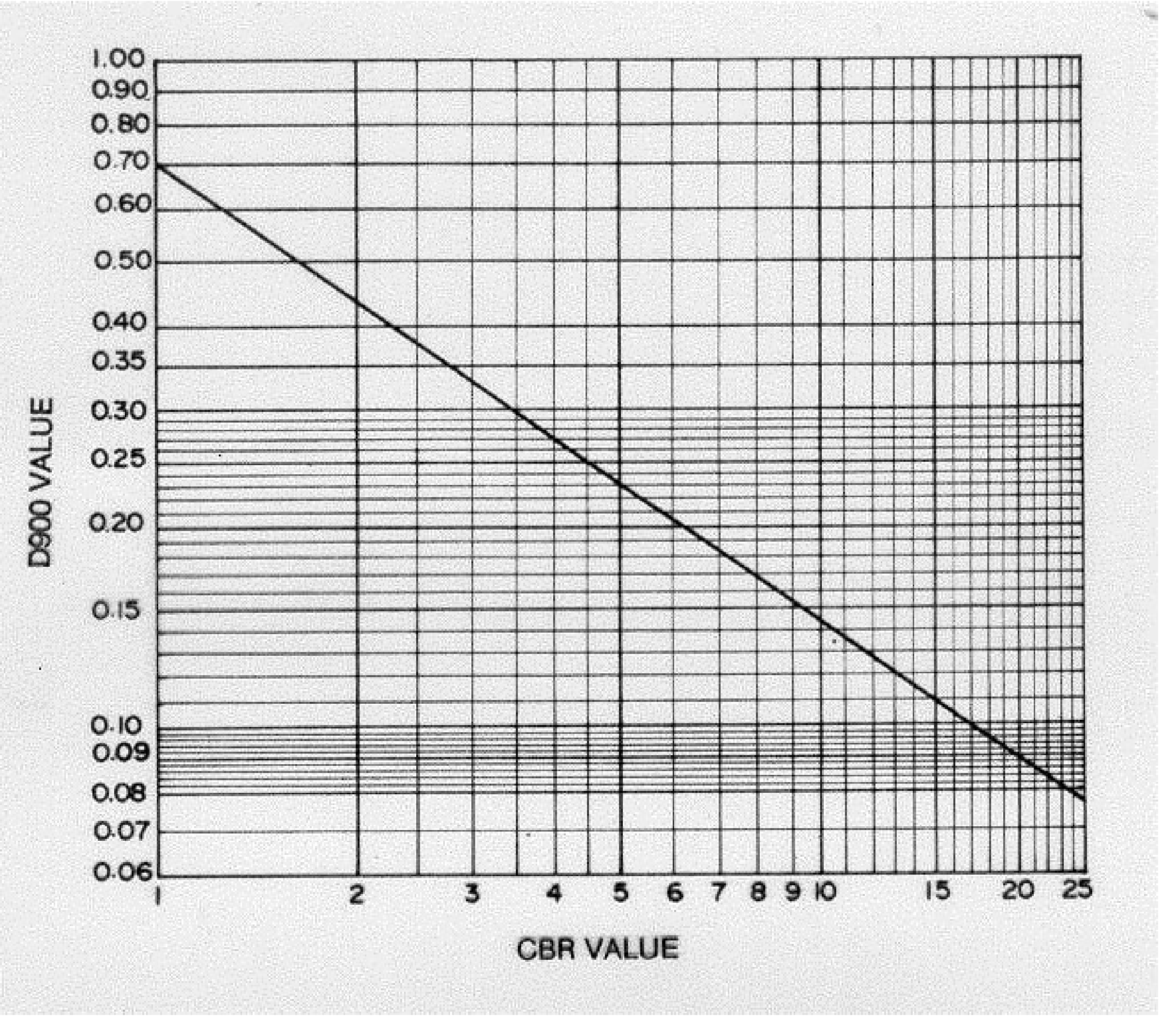
- Curvature function is used to predict the fatigue life of an applied asphalt surfacing overlay or an existing asphalt surfacing

  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%

D_{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

Typical Deflectometer Report

Pavement Testing.

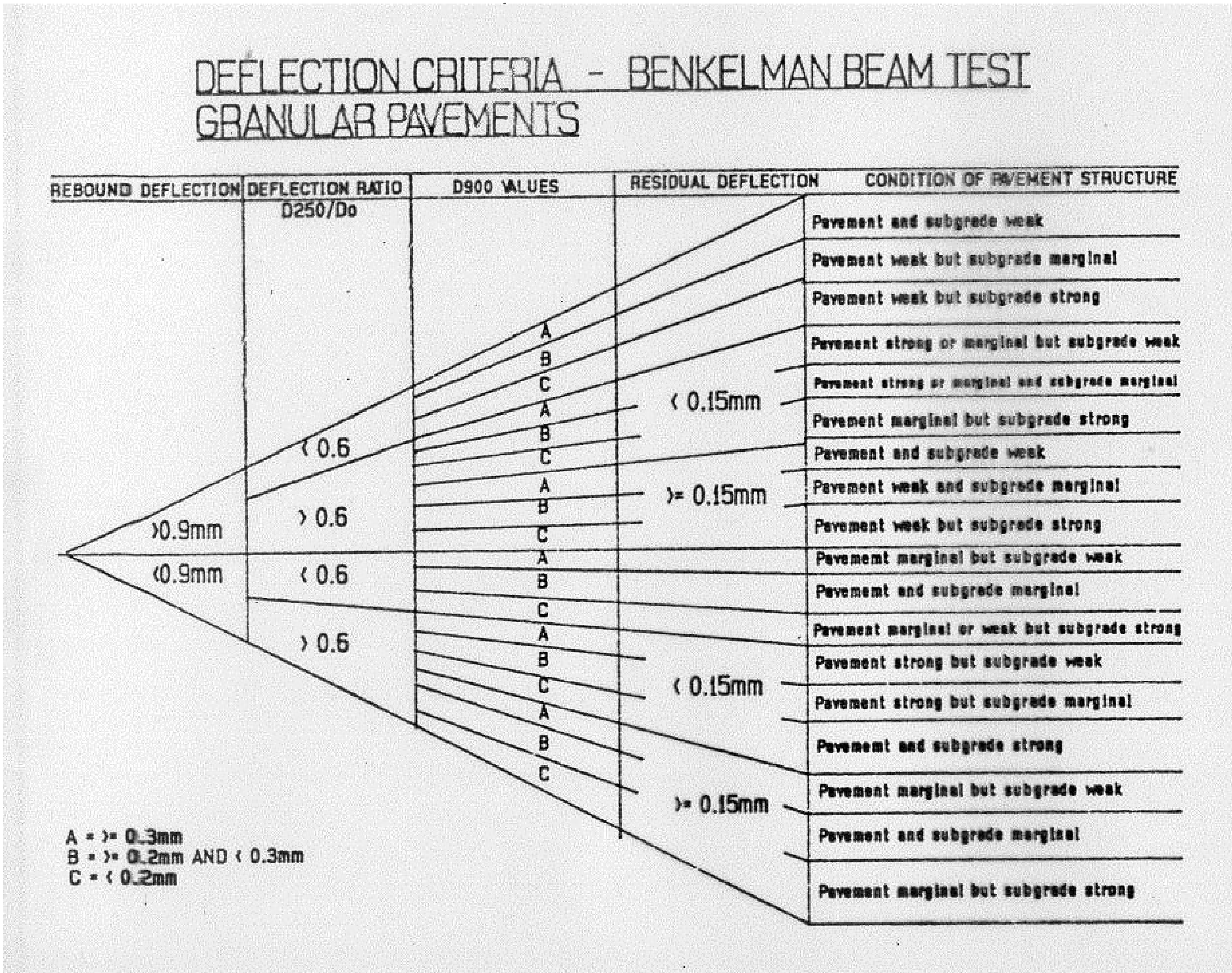
kN Heavy Weight Deflectometer Report. Date Tested: 08/07/97

CUNNINGHAM HIGHWAY 17B WARWICK

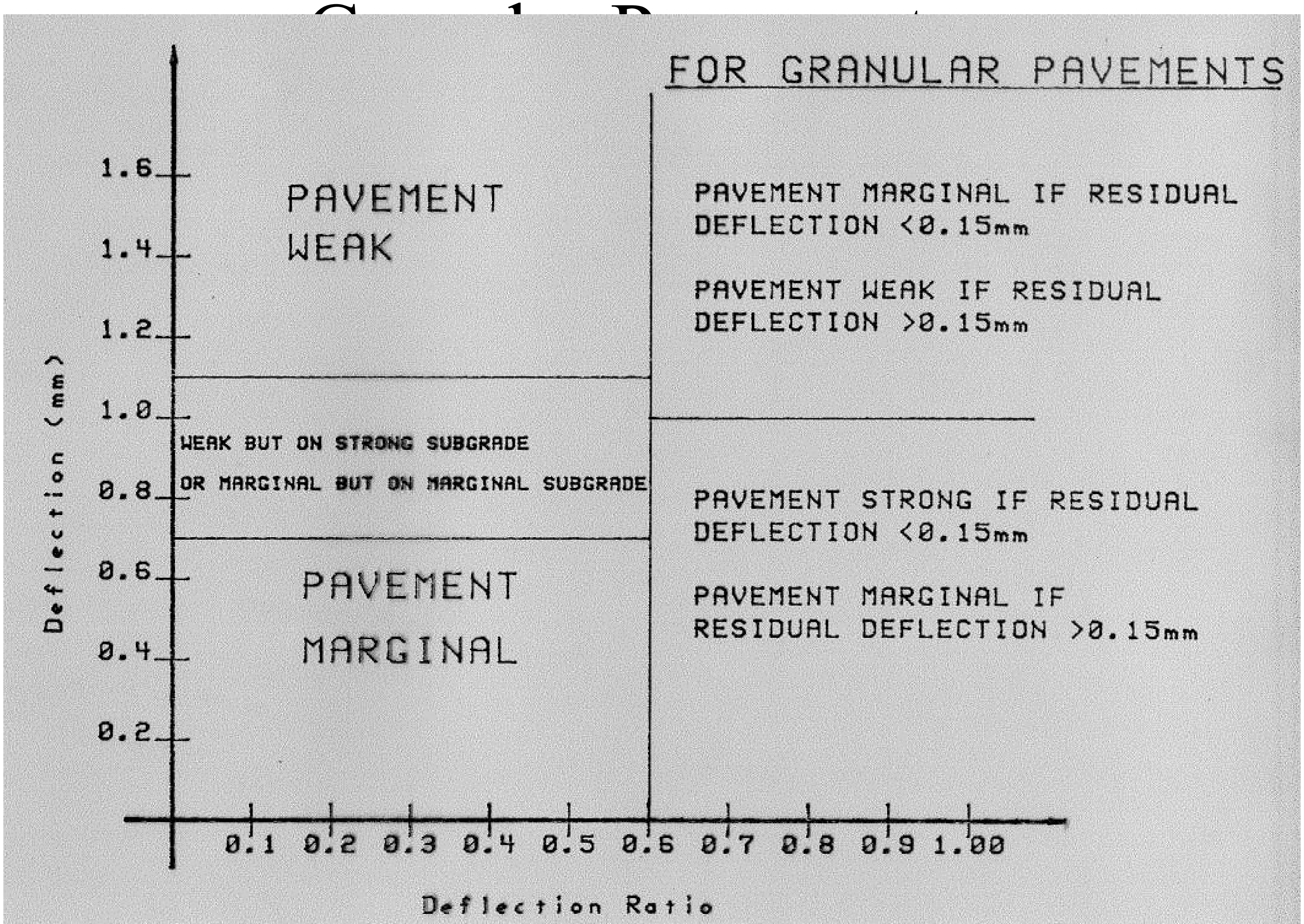
CH 101.6km - 103.2km EASTBOUND OWP

Chainage. (km)	Stress (kPa)	Surface Temp.	Air Temp.	Deflections (mm). Deflection Offsets (mm). 0	200	300	450	650	900	1500	40kN Deflection Parameters. Maximum Defln(mm).	Curvature D0- D200	Ratio D250/D0	Sgrade CBR
0.000	643	0.0	20.0	0.932	0.695	0.516	0.375	0.280	0.188	0.097	0.813	0.207	0.650	8.4
0.029	653	0.0	20.0	0.845	0.604	0.477	0.347	0.263	0.169	0.082	0.722	0.206	0.640	10.1
0.056	689	0.0	20.0	0.656	0.500	0.399	0.290	0.223	0.150	0.069	0.566	0.139	0.685	11.2
0.085	663	0.0	20.0	0.414	0.339	0.281	0.232	0.184	0.128	0.055	0.347	0.063	0.749	15.6
0.109	679	0.0	20.0	0.466	0.365	0.308	0.240	0.187	0.124	0.050	0.388	0.084	0.722	16.5
0.137	642	0.0	20.0	0.460	0.348	0.291	0.231	0.177	0.119	0.059	0.402	0.098	0.695	16.3
0.164	648	0.0	20.0	0.407	0.340	0.292	0.242	0.197	0.144	0.062	0.351	0.058	0.776	12.5
0.191	681	0.0	20.0	0.442	0.366	0.314	0.251	0.201	0.134	0.058	0.381	0.065	0.769	14.0
0.218	699	0.0	20.0	0.380	0.310	0.268	0.214	0.171	0.117	0.049	0.327	0.060	0.761	17.0
0.245	731	0.0	20.0	0.347	0.299	0.261	0.215	0.178	0.131	0.066	0.299	0.041	0.807	14.4
0.272	710	0.0	20.0	0.379	0.316	0.279	0.230	0.192	0.140	0.070	0.327	0.054	0.785	13.1
0.299	701	0.0	20.0	0.319	0.256	0.226	0.185	0.149	0.119	0.057	0.275	0.054	0.755	16.6
0.326	703	0.0	20.0	0.467	0.337	0.271	0.201	0.156	0.111	0.056	0.402	0.112	0.651	16.4

Deflection Criteria – Benkelman Beam Test



Deflection (mm) vs. Deflection Ratio for



Typical Deflection Results for New Pavements

Pavement Type	90% Deflection (mm)		Deflection Ratio D_{250}/D_0	
	Range	Mean	Range	Mean
Granular* $<10^6$	0.7 - 1.2	0.8	0.5 - 0.7	0.6
(Normal Standard) $>10^6$	0.5 - 1.0	0.6	0.5 - 0.8	0.65
Granular* $<10^6$	0.8 - 1.3	0.9	0.5 - 0.7	0.6
(Second Standard) $>10^6$	0.6 - 1.1	0.7	0.5 - 0.8	0.65
Asphalt (Full Depth)	0.35 - 0.75	0.45	0.7 - 0.9	0.8
Cemented Material* (Full Depth)	0.1 - 0.45	0.25	0.85 - 0.95	0.9
Granular* on Cemented	0.4 - 0.75	0.5	0.7 - 0.9	0.8
Asphalt on Granular	0.4 - 0.9	0.6	0.6 - 0.85	0.7
Asphalt on Cemented	0.1 - 0.4	0.25	0.85 - 0.95	0.9
Asphalt on Granular on Cemented	0.25 - 0.65	0.45	0.7 - 0.9	0.85

* with thin bitumen surfacing

Table 9.2 Typical Deflection Results for New Pavements

Design Exercise 1

The results of a Benkelmen 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

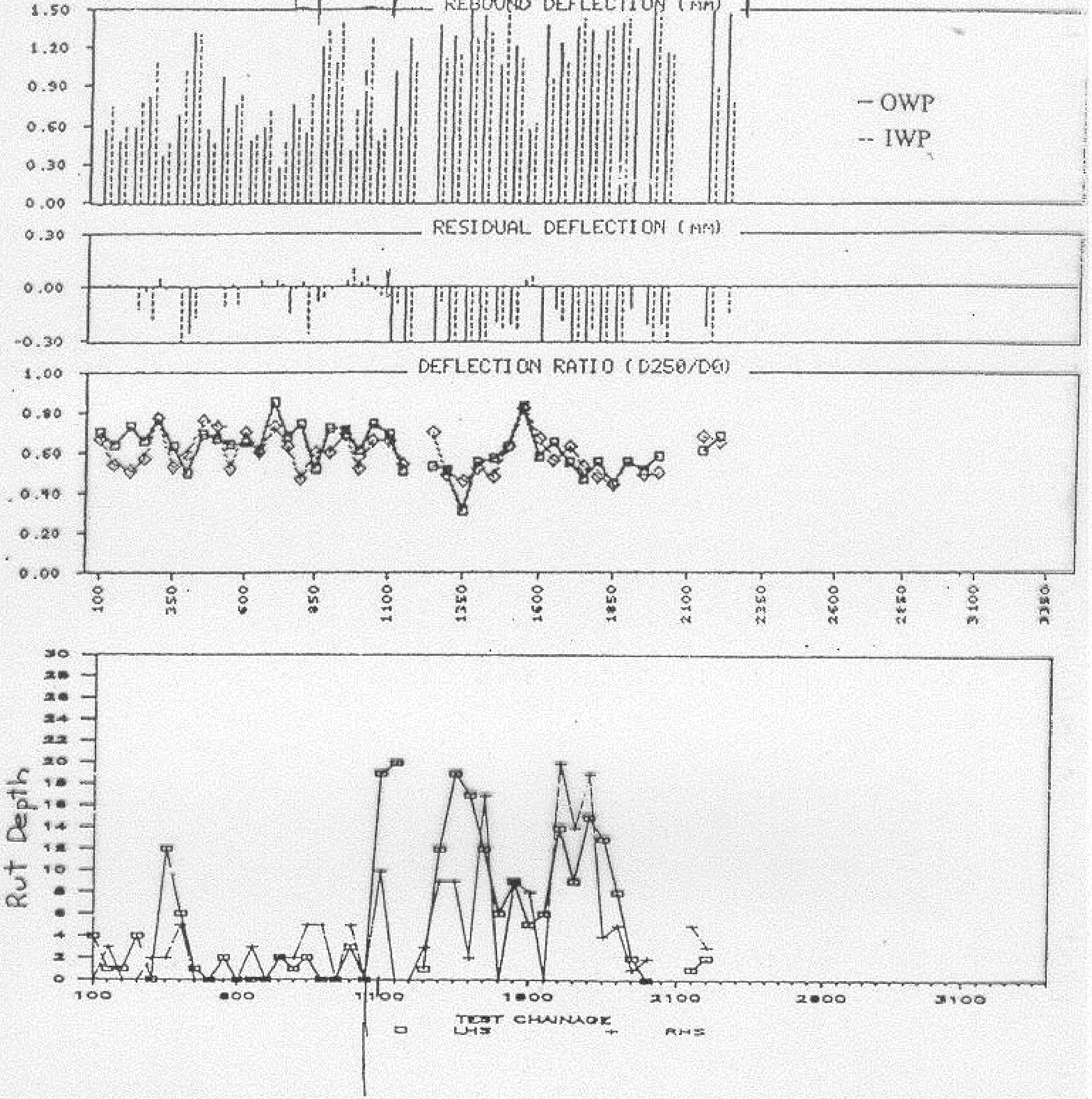
Design Exercise 1 (cont.)

3. For these sections, based on the deflection results, comment on the following:

   - stiffness of the pavement material

   - condition of the subgrade

Example 1


REBOUND DEFLECTION (mm)
– OWP
-- IWP
RESIDUAL DEFLECTION (mm)
DEFLECTION RATIO (D250/D0)
Rut Depth
TEST CHAINAGE
LHS
RHS

CANEOOYA SHIRE TOONOONA - KAYAKA ROAD CRAYTON CONNECTION - CANEOOYA

SOUTH WEST DIVISION

INNER WHEEL PATH

Date Tested : 28/10/88

Run No.	Chainage (M)	0 mm	150 mm	300 mm	450 mm	600 mm	900 mm	1200 mm	Defl Ratio	D0 - D200	Max Defl	Resid Defl	Rebm Defl	Sgrade CBR
1	100	0.747	0.684	0.439	0.299	0.208	0.132	0.093	0.653	0.152	0.776	0.027	0.747	11.5
2	150	0.593	0.452	0.268	0.181	0.118	0.064	0.032	0.531	0.225	0.586	-0.006	0.593	25.0
3	200	0.776	0.646	0.348	0.265	0.198	0.126	0.080	0.501	0.270	0.641	-0.135	0.776	12.4
4	250	1.085	0.836	0.586	0.443	0.344	0.204	0.130	0.567	0.398	0.904	-0.181	1.085	6.1
5	300	0.491	0.460	0.366	0.254	0.185	0.101	0.058	0.763	0.080	0.470	-0.020	0.491	16.9
6	350	1.021	0.866	0.499	0.376	0.325	0.194	0.127	0.527	0.350	0.703	-0.318	1.021	6.5
7	400													
8	450	0.478	0.434	0.328	0.240	0.171	0.080	0.065	0.754	0.082	0.471	-0.007	0.478	23.7
9	500	0.574	0.539	0.377	0.262	0.184	0.120	0.070	0.722	0.108	0.478	-0.116	0.574	13.2
10	550	0.847	0.744	0.374	0.294	0.233	0.142	0.109	0.519	0.270	0.747	-0.100	0.847	10.4
11	600	0.526	0.481	0.314	0.225	0.161	0.096	0.053	0.673	0.101	0.535	0.007	0.526	18.3
12	650	0.731	0.535	0.404	0.283	0.212	0.137	0.084	0.555	0.235	0.732	0.000	0.731	10.8
13	700	0.471	0.435	0.312	0.212	0.167	0.074	0.035	0.729	0.085	0.501	0.030	0.471	25.0
14	750	0.672	0.565	0.379	0.304	0.213	0.139	0.065	0.624	0.179	0.641	-0.031	0.672	10.6
15	800	0.856	0.584	0.388	0.321	0.242	0.162	0.113	0.452	0.343	0.597	-0.297	0.856	8.5
MEAN		0.706	0.576	0.387	0.283	0.211	0.126	0.082	0.618	0.207	0.627	0.087	0.706	14.2
SDEV		0.197	0.148	0.079	0.067	0.061	0.042	0.031	0.103	0.110	0.132	0.102	0.197	6.53
CVAR (%)		27.9	24.8	20.5	23.7	28.8	33.0	37.4	16.6	53.2	21.1	115.1	27.9	46.0
90%H		0.959	0.766	0.488	0.369	0.290	0.180	0.121	0.486	0.348	0.797	0.220	0.959	5.85
									10% low		ABS values			10% low

Number Bowls = 14 Number Results = 14 Number of Sites =38 LHS Cal. factor = 1125 File = C:\SOML\327-1.DAT

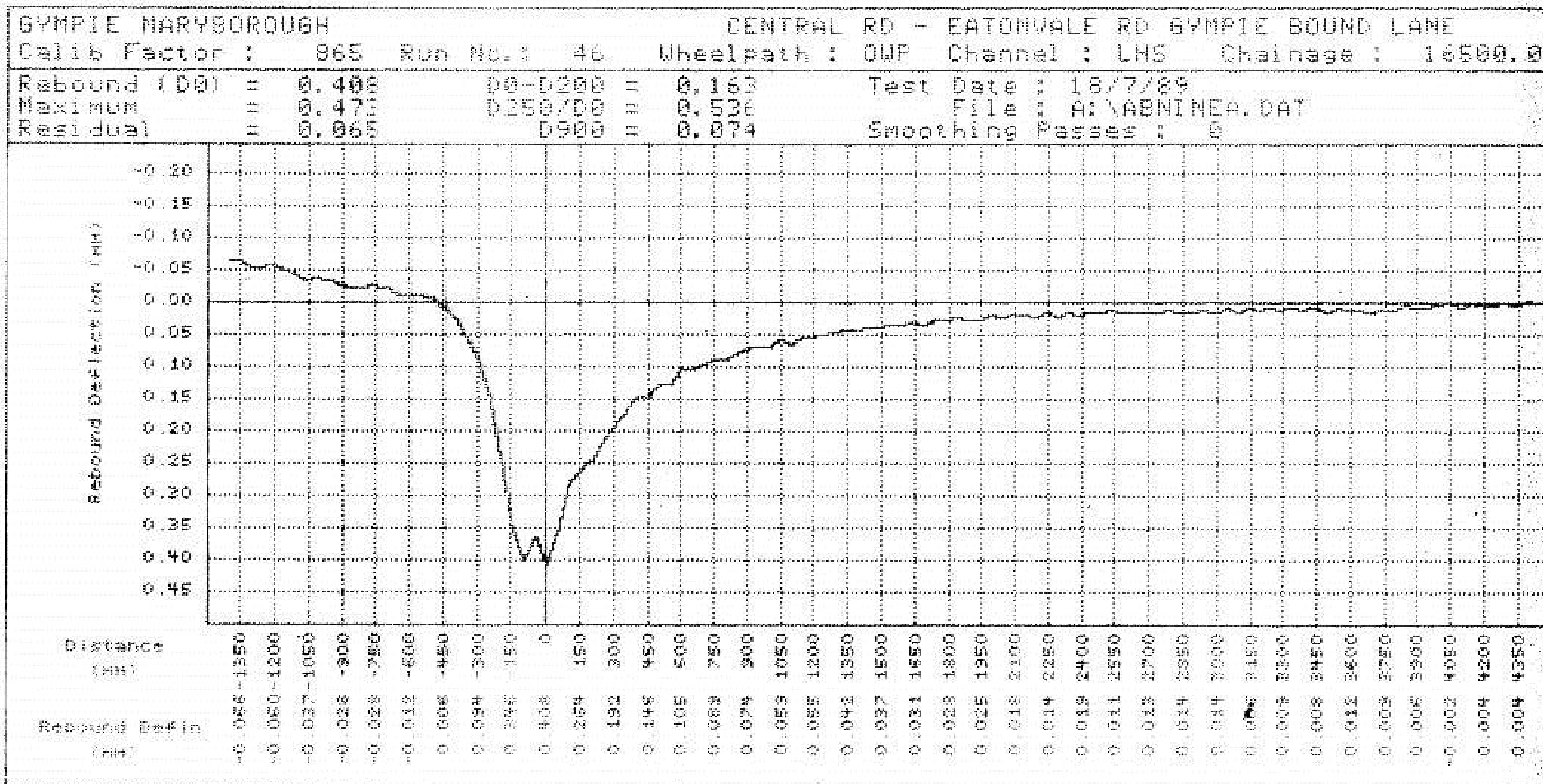
Exercise 1 Answers

Rep. Def. D

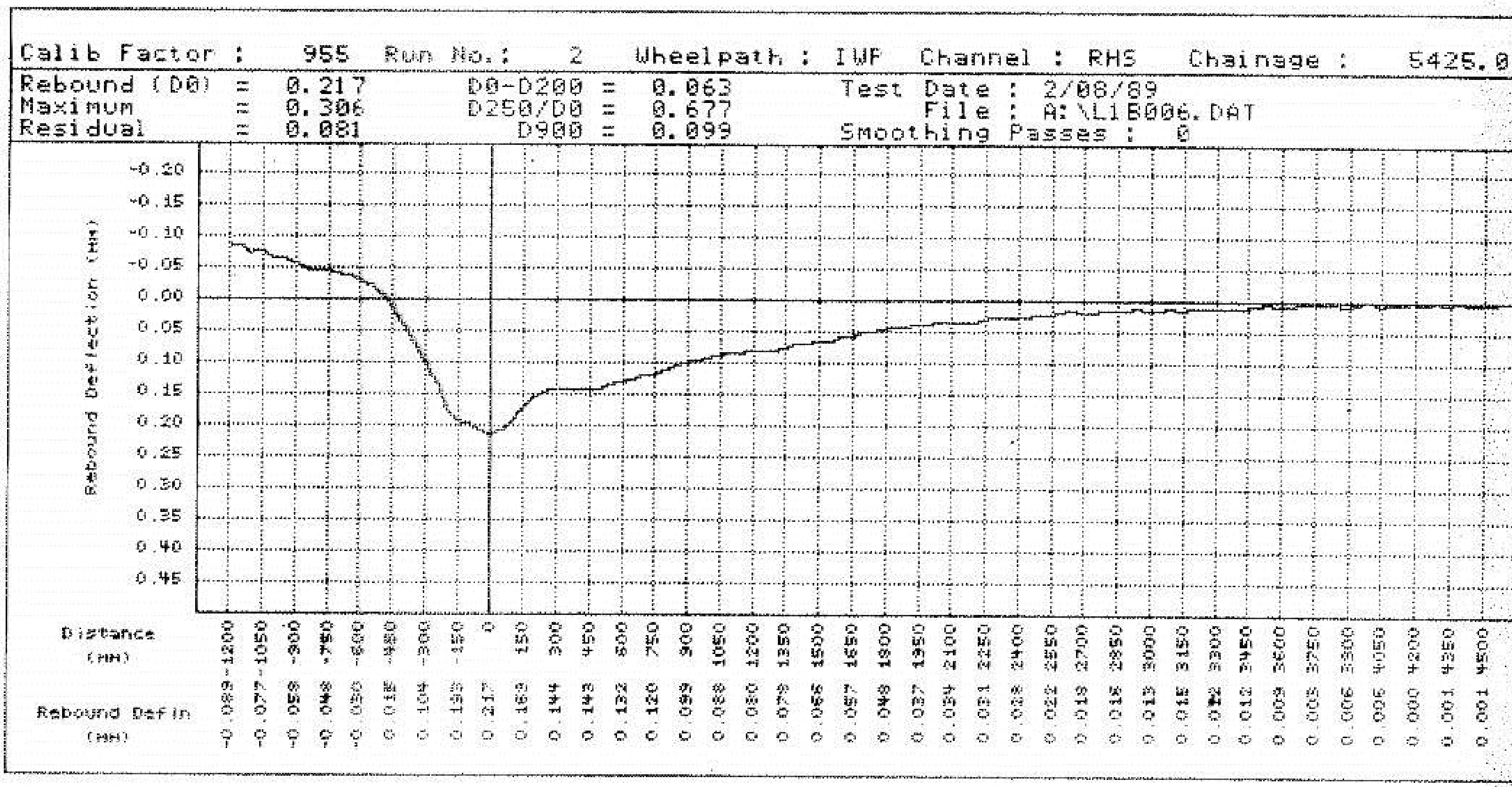
Seasonal Correction S/c * D

Section	Wheel Path	Rebound Deflection				~~S/C * Dr~~	Adopted ~~Dr~~ D	D900	S/C* D900	D_{250}/D_0 10% L	Mean D_0 - D_{200} curvature
		MEAN $\bar{x}$ (mm)	SD (mm)	CV (%)	~~Dr~~ (mm)	(mm)	(mm)	(mm)	(mm)		
100 to 800	OWP	0.639	0.161	25.2	0.844	0.844		0.18		0.612	0.153
	IWP	0.706	0.197	27.9	0.959	1.15	1.15	0.18	0.22 CBR 5	0.486	0.207
800 to 2200	OWP	1.286	0.168	13.1	1.501	1.501		0.233		0.433	0.473
	IWP	1.256	0.152	12.1	1.451	1.74	1.74	0.255	0.306 CBR 35	0.447	0.458

Deflection Bowl



Deflection Bowl



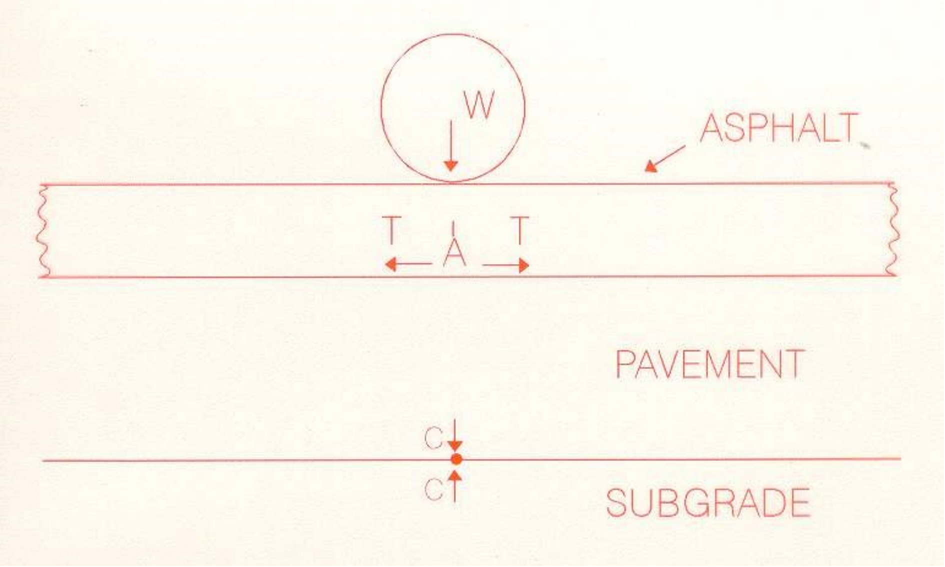
Summary of likely symptoms for moisture in new construction (guidelines for interpreting bowl data)

Problem	Likely symptoms
Moist base	1. Residual deflections >0.15 mm or >25% of maximum deflection. Negative residuals may indicate weak surfacing and squeezing between the truck wheels, whereas positive residuals may indicate stiffer surfacing and shoving of the base sideways or ahead of the wheels. 2. Ten percentile lowest (10%L) deflection ratios are likely to be <0.60. However, very wet bases can exhibit significant plastic deformations which mask the real deflection ratio and give a high deflection ratio value. 3. Kinks and other shape abnormalities in the bowl shapes, resulting from plastic deformation to the pavement. Boel shapes are best examined individually on a computer screen using the analysis software.

Summary of likely symptoms for moisture in new construction (guidelines for interpreting bowl data)

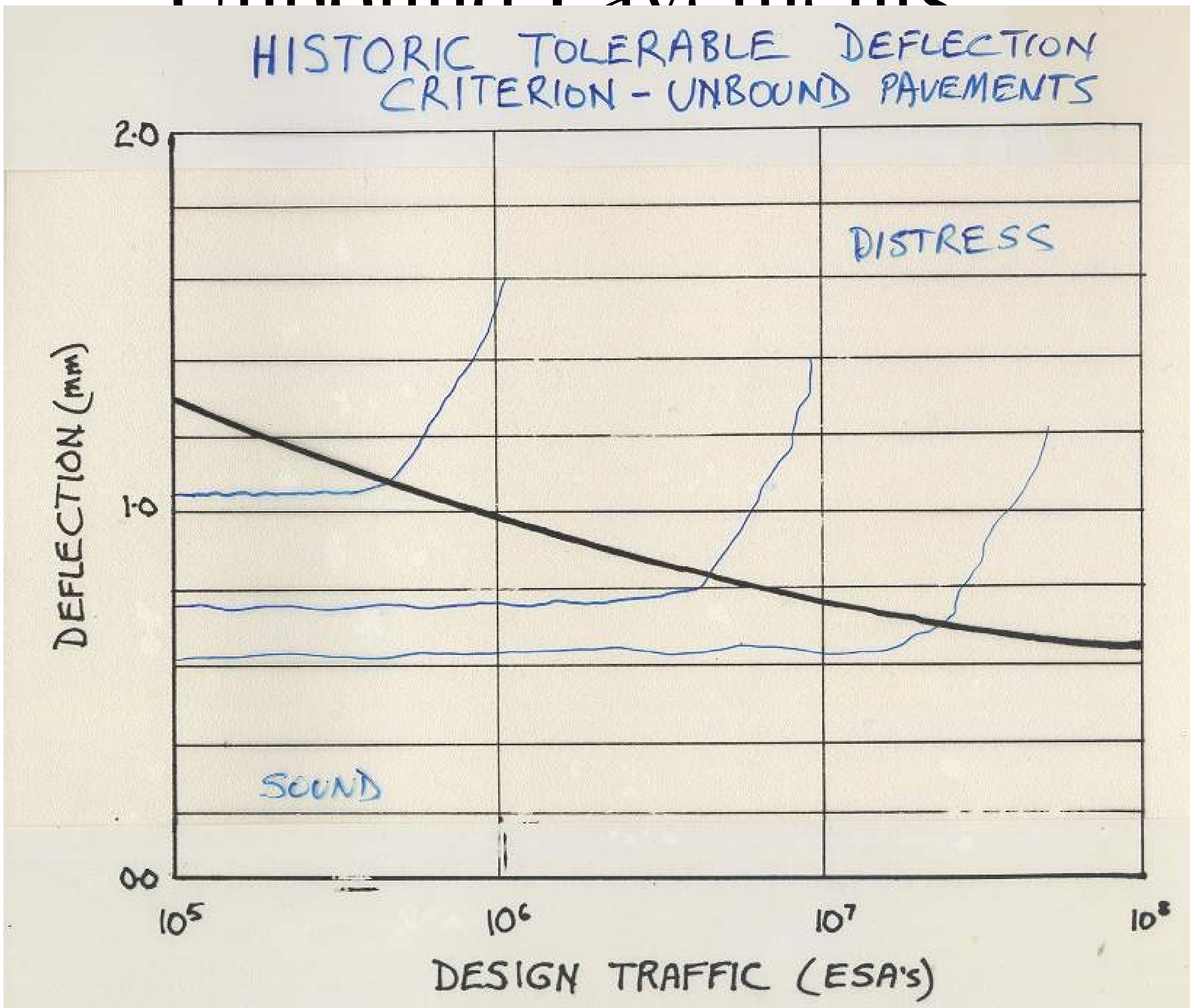
Problem	Likely symptoms
Moist subgrade and dry pavements	1. Rebound deflections are likely to be high, in excess or well in excess of 1.00 mm. 2. CBR values estimated from D_{900} values will be low (e.g. CBR <5).
Moist base and moist subgrade	1. All or most of the above symptoms are likely to be present.

Asphalt Fatigue

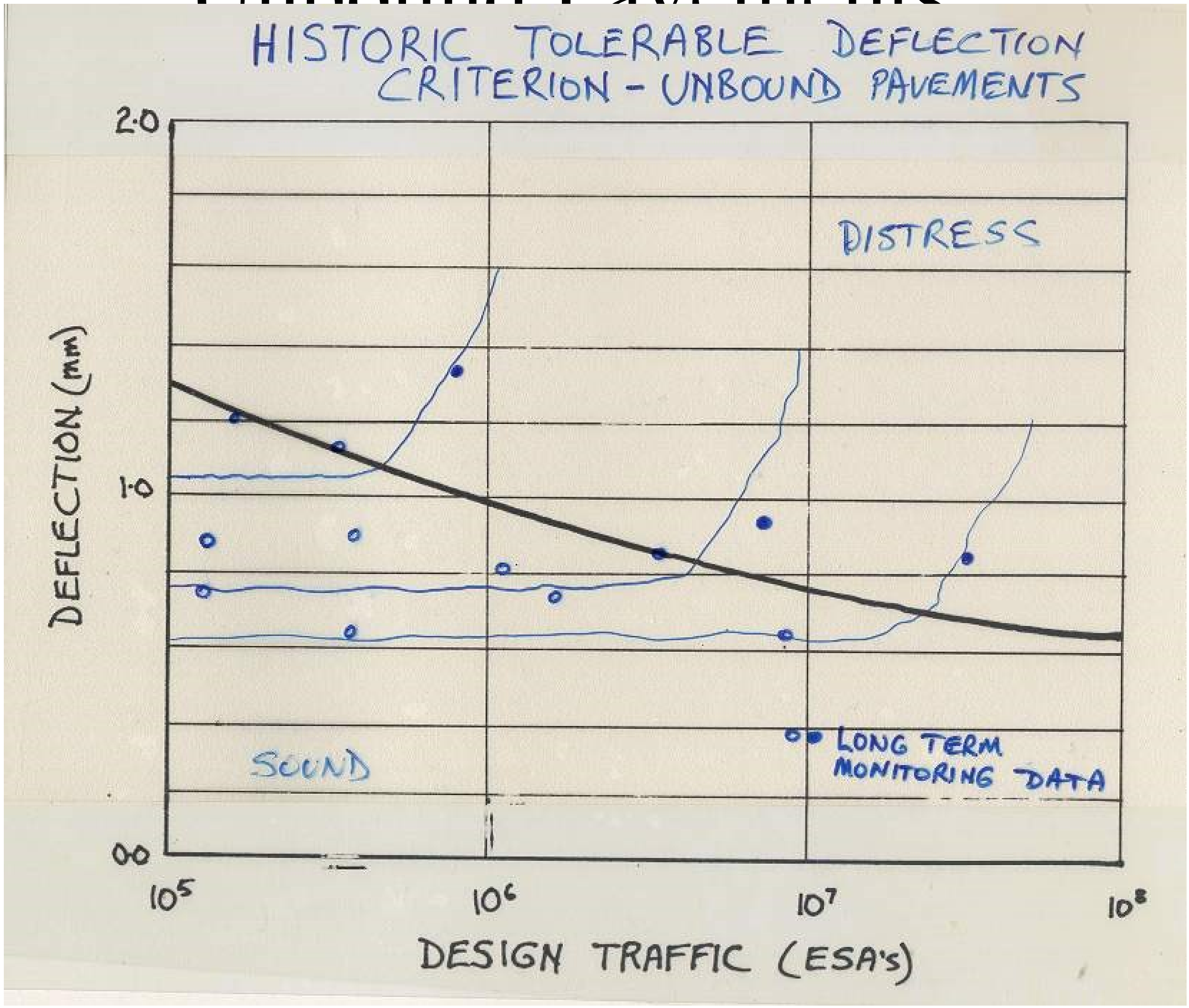


- Tensile Strain in asphalt depends on:
  - Traffic (E.S.A.'s)
  - Temperature
  - Thickness

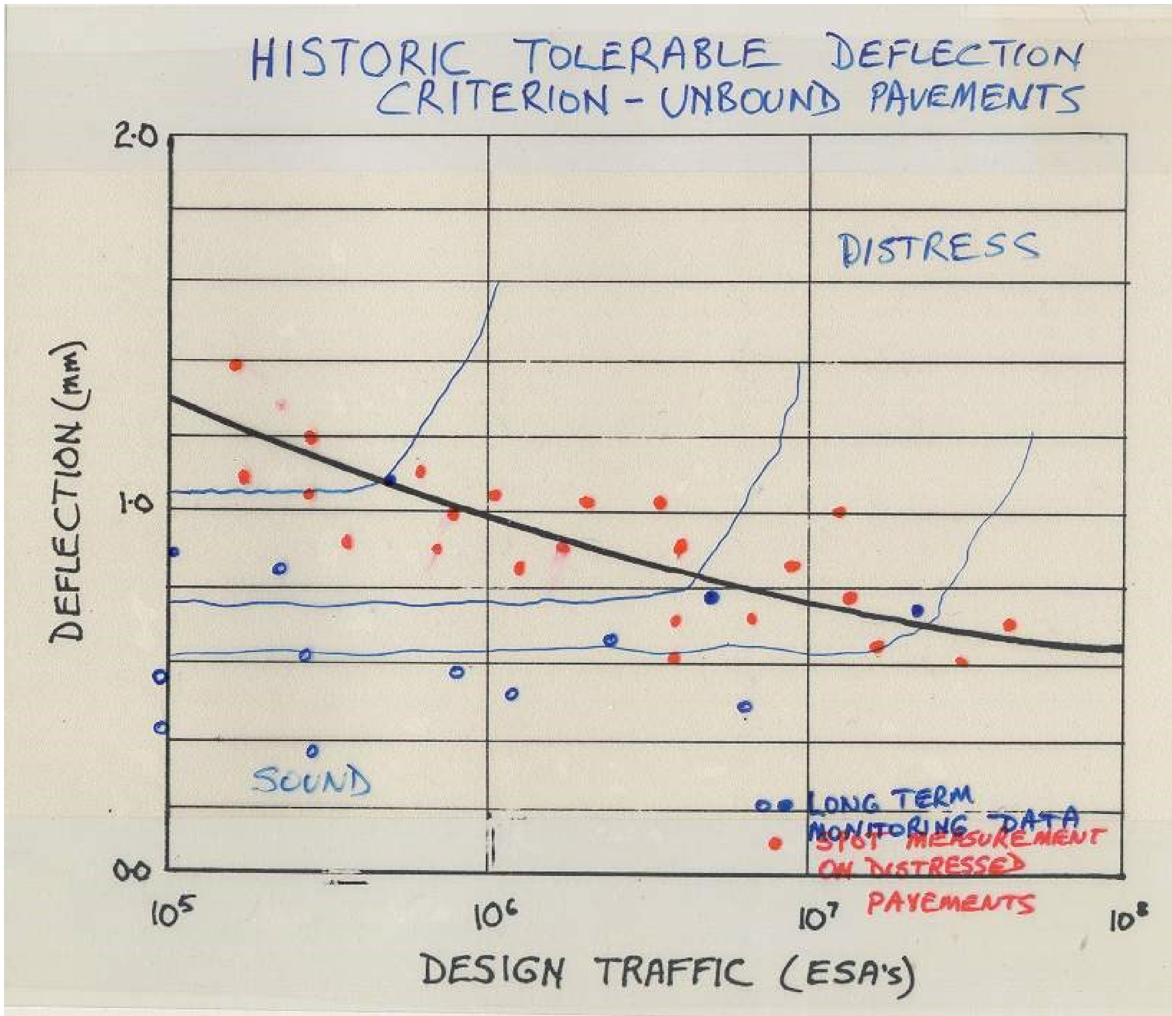
Historic Tolerable Deflection Criterion – Unbound Pavements



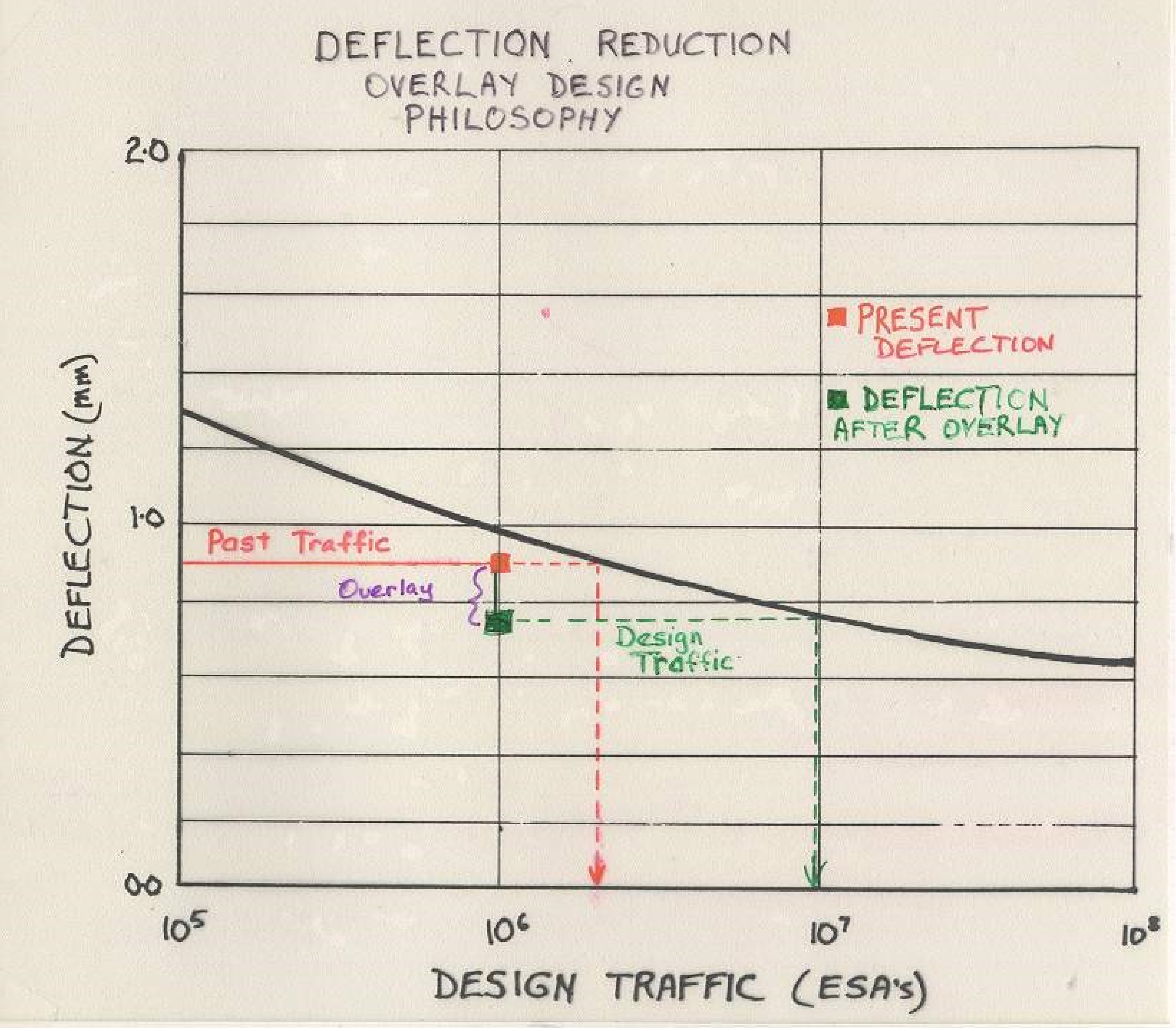
Historic Tolerable Deflection Criterion – Unbound Pavements



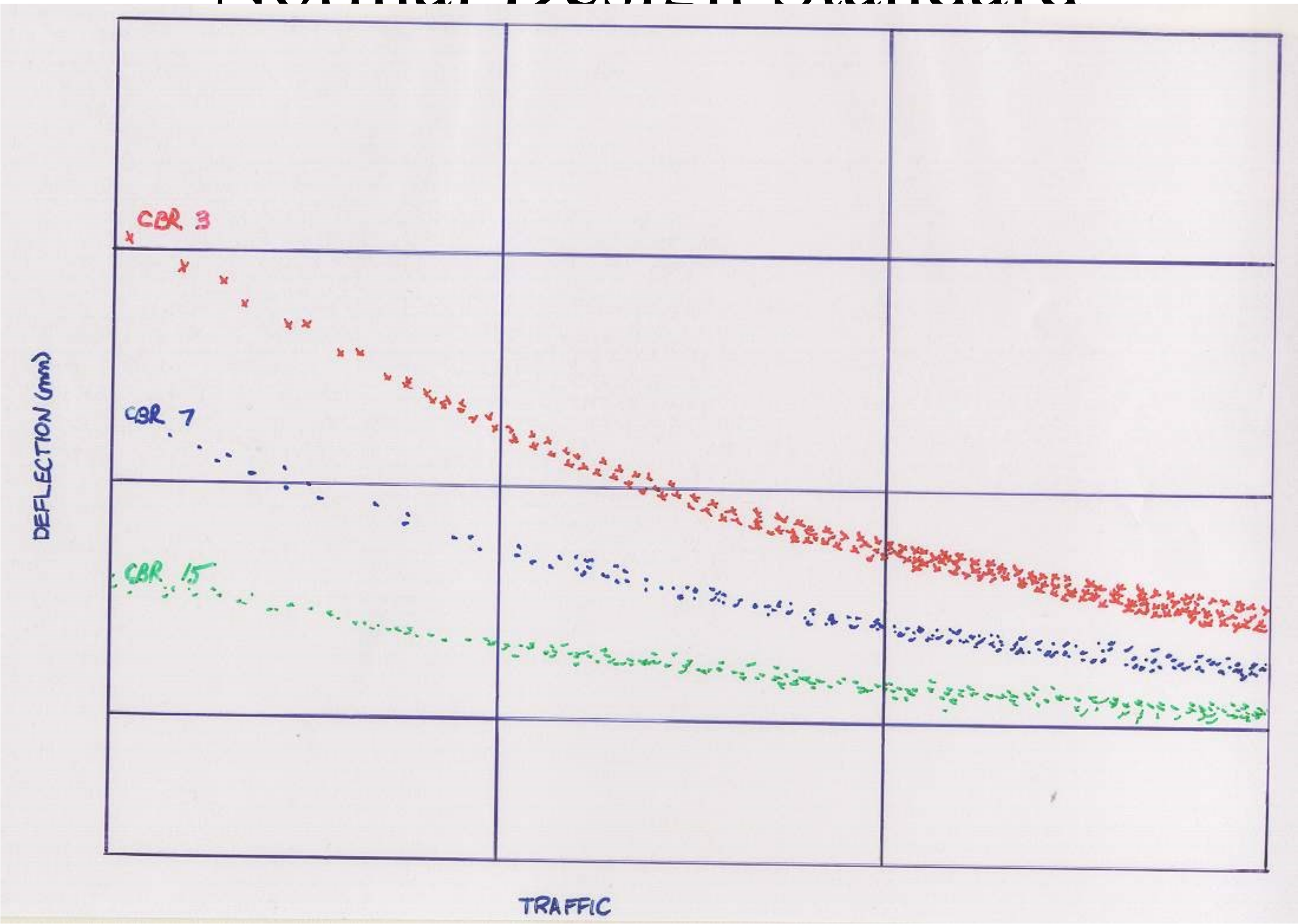
Historic Tolerable Deflection Criterion – Unbound Pavements



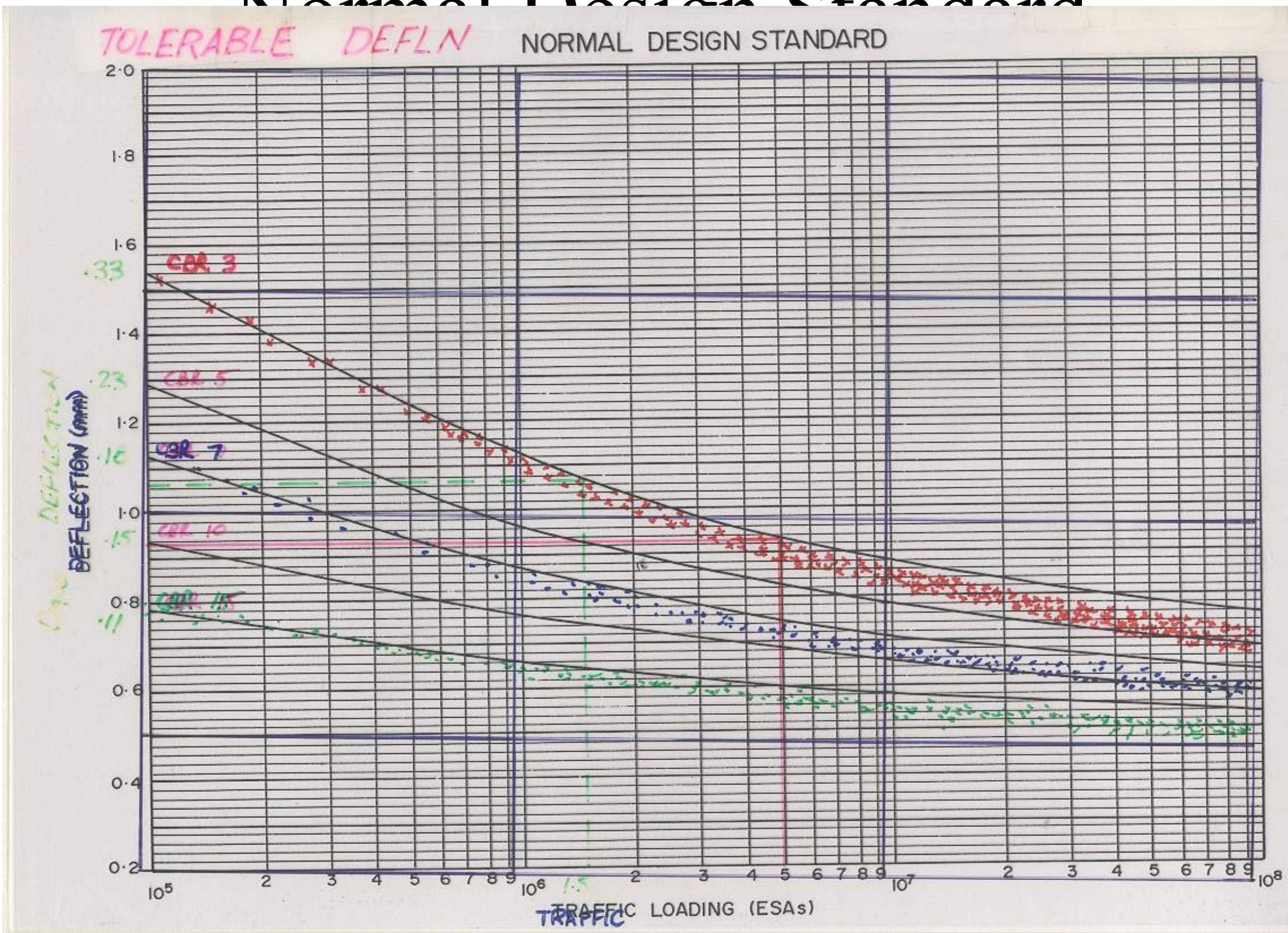
Deflection Reduction Overlay Design Philosophy



Tolerable Deflection
Normal Design Standard



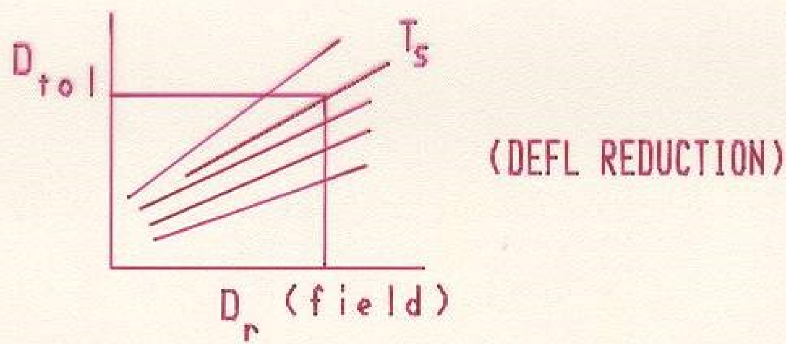
Tolerable Deflection
Normal Design Standard



Granular Overlay Process

1. FOR SUBGRADE LIFE, N_S, & D_{900} VALUE, DETERMINE D_{tol}

2. DETERMINE THICKNESS, T_S FOR DEFLECTION REDUCTION TO D_r

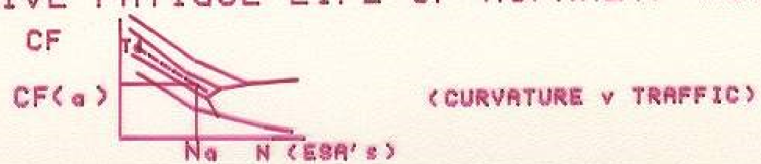


Asphalt Overlay Process

1. FOR SUBGRADE LIFE, Ns, DET. THICKNESS VIA

2. CHECK REDUCTION IN CURVATURE DUE TO Td.

3. DERIVE FATIGUE LIFE OF ASPHALT, Na.



4. COMPARE Nes & Na.

DECISION OPTIONS.

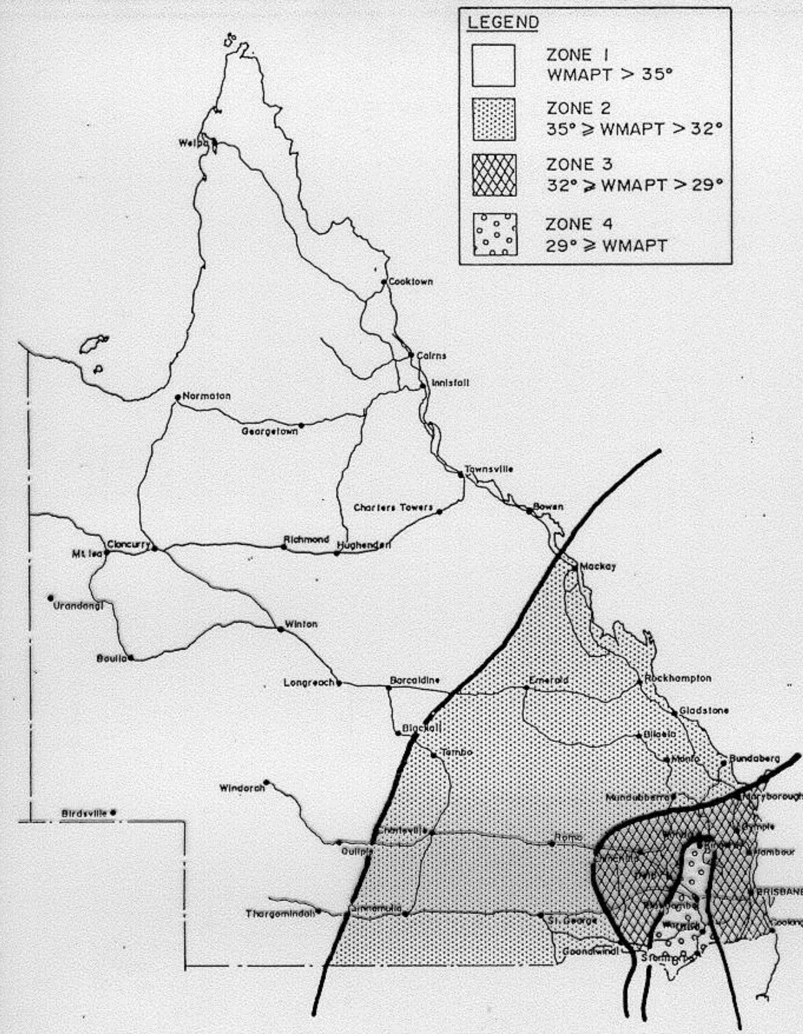
(I) MIN LIFE Nes, THICK, COSTLY

(II) STAGE, REPEATED OVERLAYS

(III) OVERLAY, MILL OFF AFTER Na, OVERLAY -> Na

(IV) OTHERS (INTERLAYERS, POLYMER MODIFIED ASPHALT, ETC.).

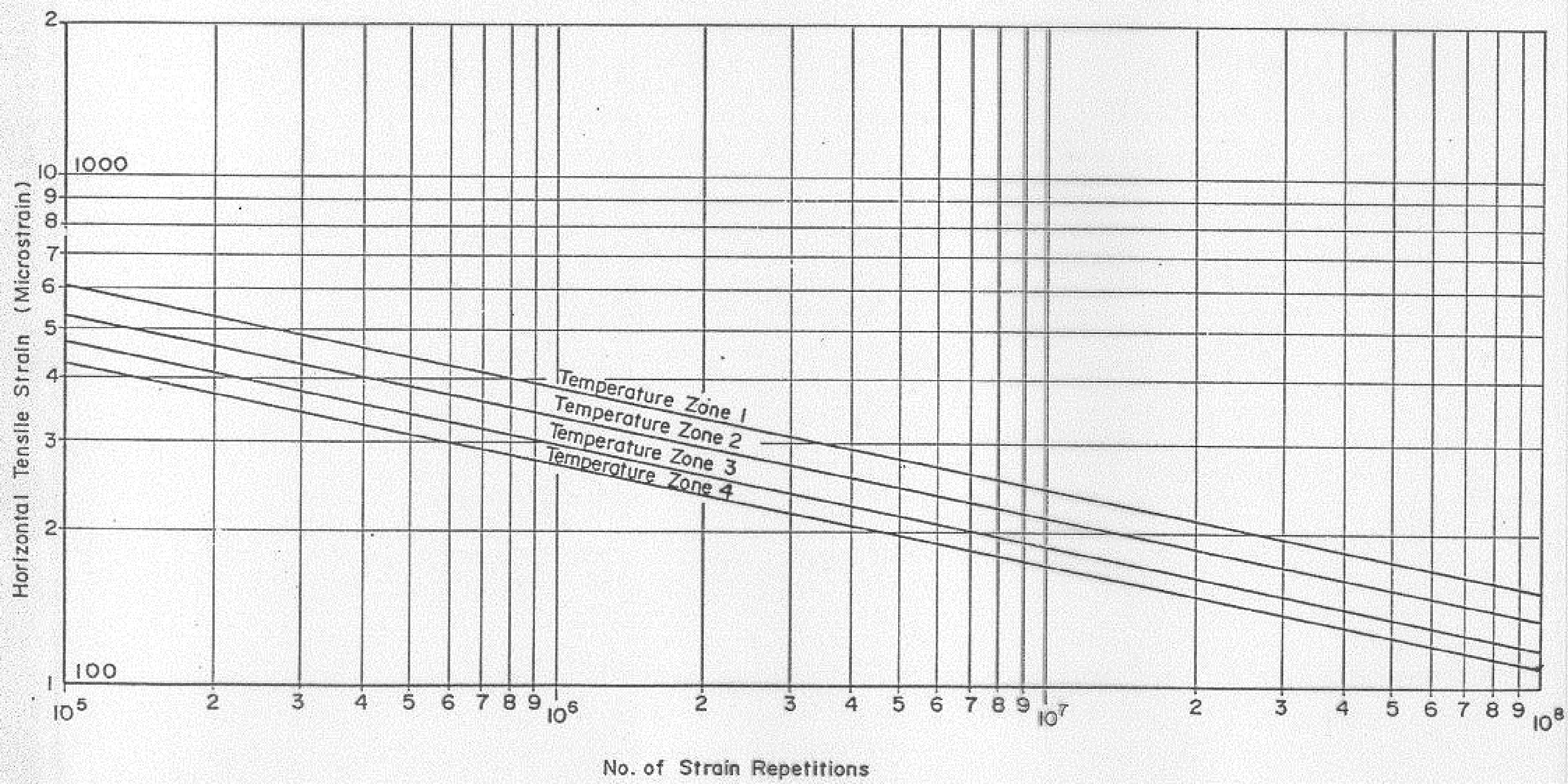
Temperature Zones for Design of Pavements with Asphalt Layers



TEMPERATURE ZONES FOR DESIGN OF PAVEMENTS WITH ASPHALT LAYERS

FIGURE 3·11

Asphalt Fatigue Criteria

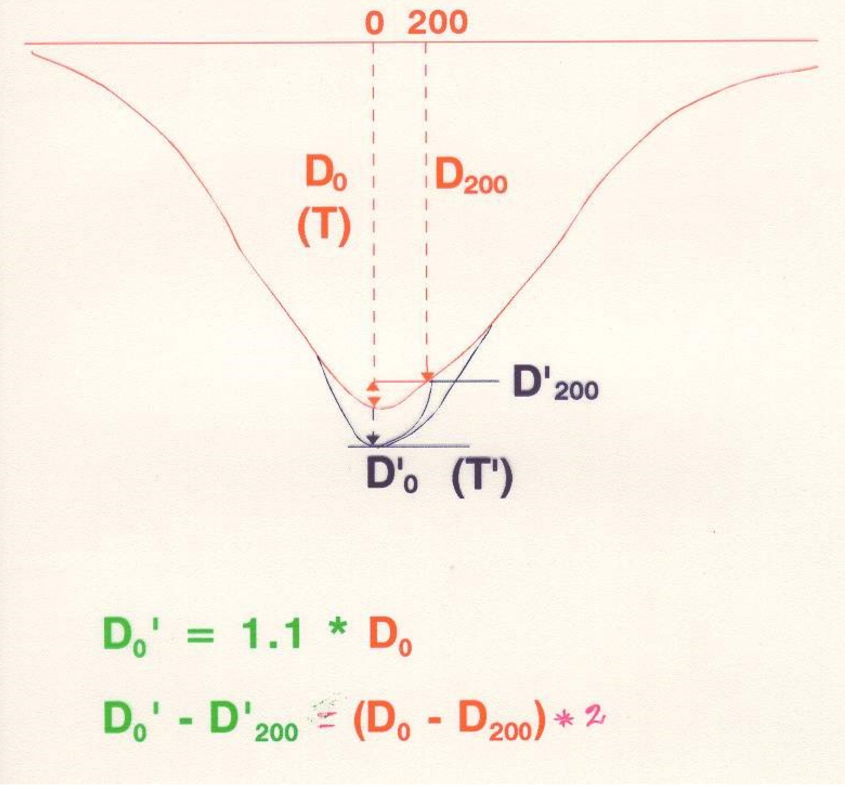


ASPHALT FATIGUE CRITERIA

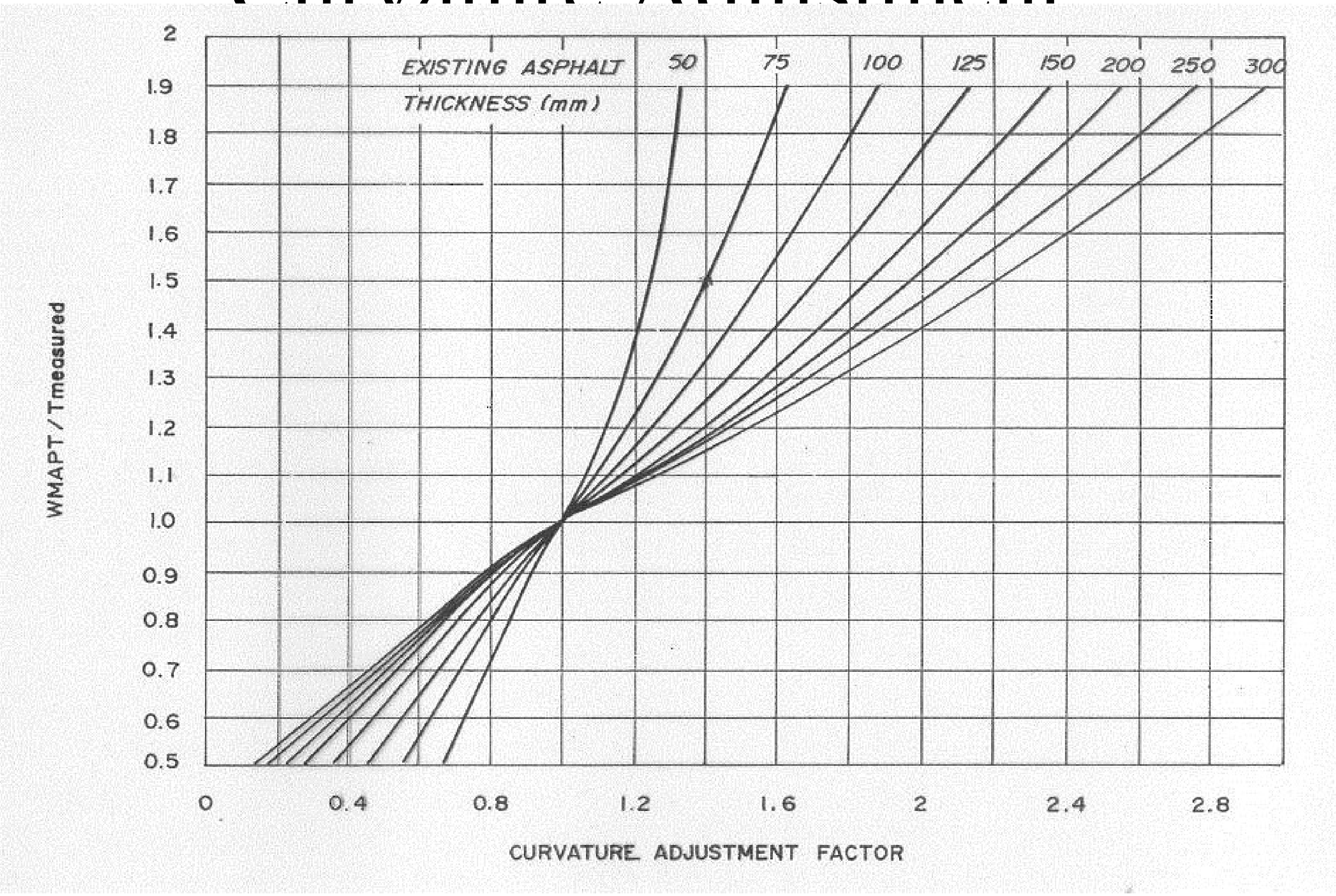
FIGURE 4·4

Influence of Temperature Variations

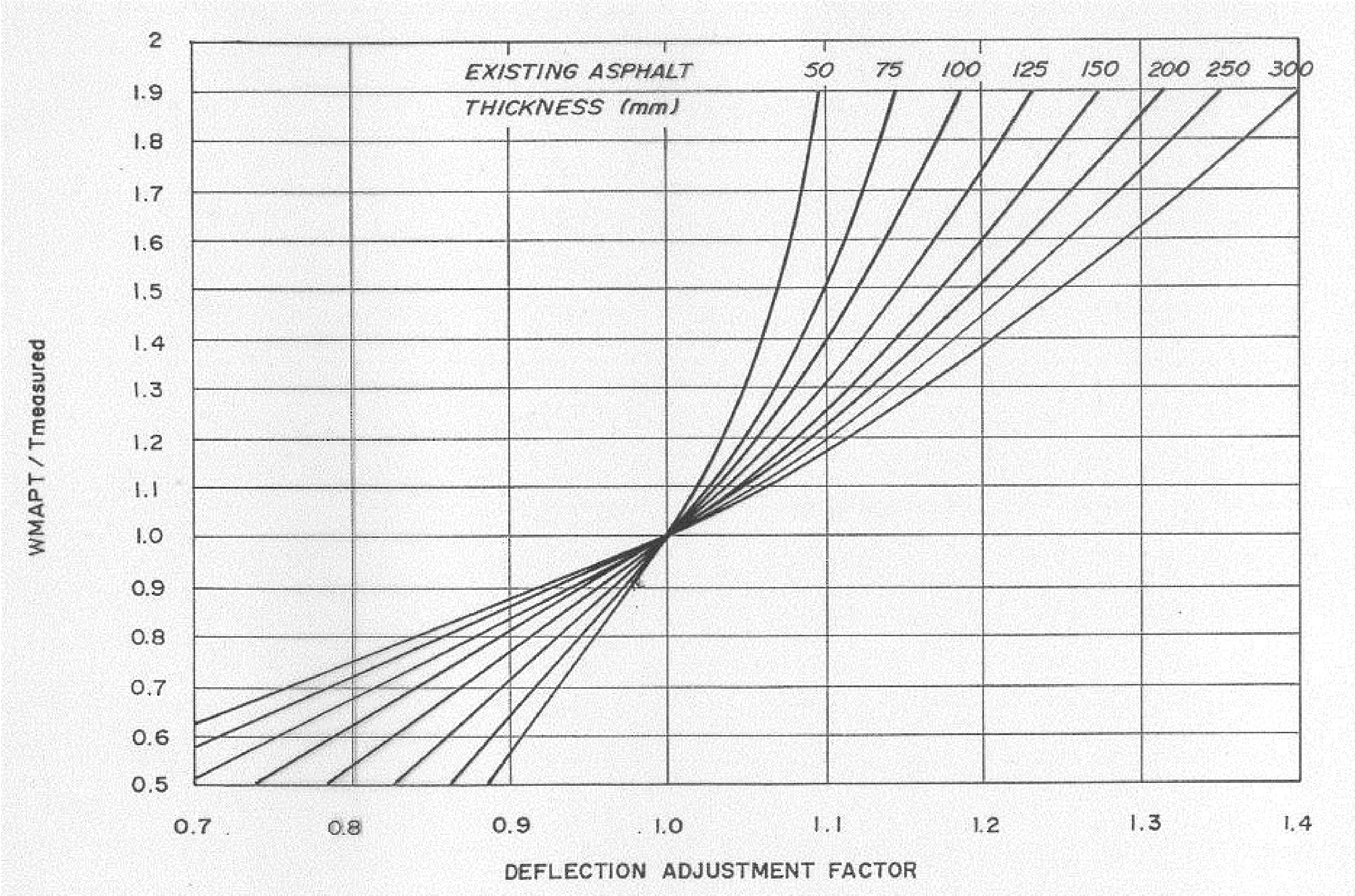
1. Rebound Deflection (D_0)
2. Curvature Function (D – D)



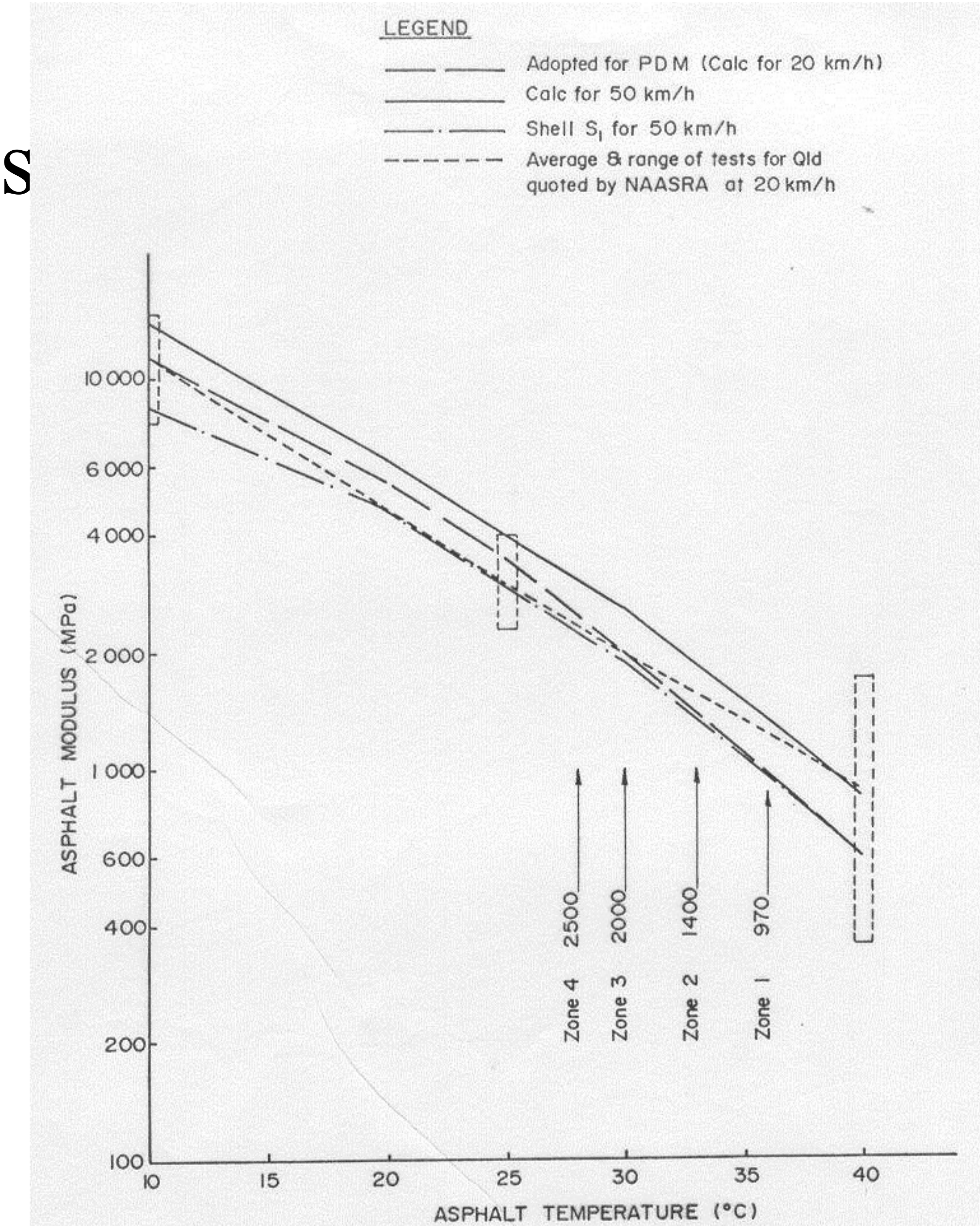
Temperature Correction Curve Curvature Adjustment



Temperature Correction Curve Deflection Adiustment



Asphalt Stiffness Relationships



ASPHALT STIFFNESS RELATIONSHIPS

FIGURE 3·10

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 ($\bar{x}$)
  - Standard Deviation (s.d.)
  - Coefficient of variation (s.d./$\bar{x}$)

  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%

Seasonal Correction Factors

	Period When Deflection Measured			
	End of Wet Season	End of Dry Season		
	Districts			
Pavement Condition	All Districts	1,2,6,12,13, 14	3,4,5,7,10, 15	8,9,11
Weak Pavements 90%H > 1.5 mm	1 (1)	1.2 (1.3)	1.1 (1.2)	1.2 (1.4)
Intermediate Pavements 1.5 mm > 90%H > 0.9 mm	1 (1)	1.2 (1.3)	1.1 (1.2)	1.3 (1.5)
Strong Pavements 90%H < 0.9 mm	1 (1)	1.2 (1.3)	1.1 (1.2)	1.4 (1.6)

* Value in brackets apply for silty and clayey silt subgrades where greater variation in deflection level may be expected.

Note: In situations where the water table is within one metre of subgrade level throughout most of the year, no correction should be applied.

TABLE 1
SEASONAL CORRECTION FACTORS

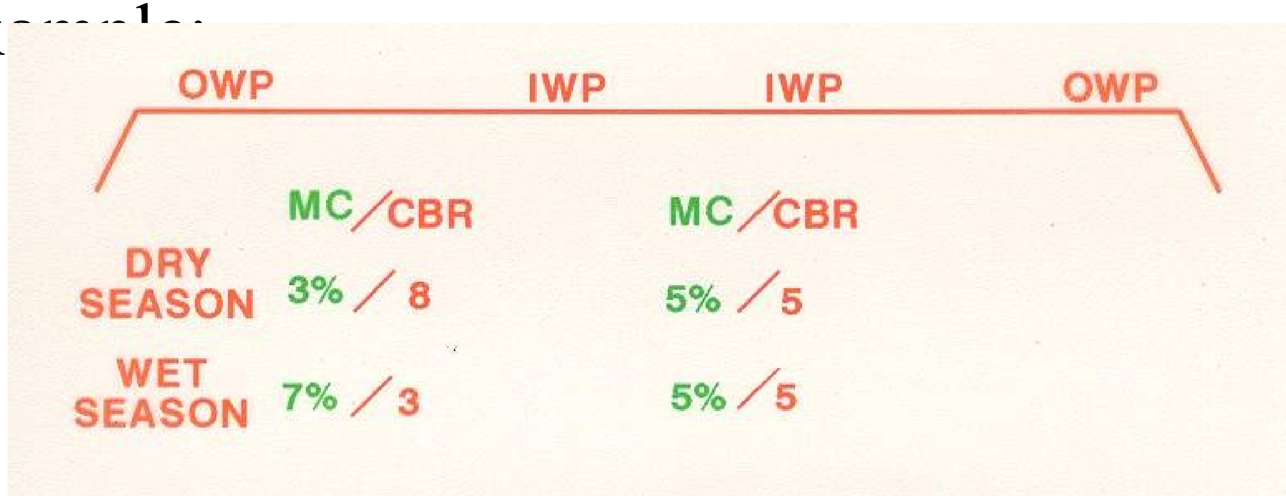
Moisture Correction Factors

Depend on:

- Subgrade type
- Rainfall
- Location of water table
- Pavement type

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:



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

Case Study 1

- Metro South District – Church Street
- Granular, thin asphalt, built 1974
- Past traffic = 1.8 X 10^6 ESAs
- Details of results for the homogenous section: OWP, Westbound:
  - 1. Summary of Condition Assessment

    Pavement Shape: fair – good

    Some minor patching

    Onset of cracking, mainly OWP

    Rutting length→ 20 mm in OWP over = 20%

Case Study 1 (cont.)

- Details of results for the homogenous section: OWP, Westbound:
  - 2. Structural Assessment
    - Rep. Defln. = 0.99 mm, $D_{900} = 0.27$
    - Defln. Ratio = 0.55
    - Residuals → 0.16, < 25% Max. Defln.

- Verified → Overlay Design

Case Study 2

- Tarong Power Station access road
- Granular pavement, chip seal, 4 yrs old, past traffic: 3 X 10^5 ESA
- Details of Results for typical section: OWP, Eastbound
  - 1. Structural Assessment
    - Rep. Defln. = 0.95 mm, D_{900} = 0.20
    - Defln. Ratio = 0.55 mm
    - Residuals = <0.15 mm, < 25% max

Case Study 2 (cont.)

- Details of Results for typical section: OWP, Eastbound
  - 2. Visual Assessment
    - Extensively cracked, rutted, patched
- NOT VERIFIED
  - Investigation material quality
    - No overlay design
    - CBR charts

Possible Causes for Dr < Expected in Case Study 2

- Distress results from pavement material inadequacy under load
  - Additional testing (pavement and subgrade material properties) needed to verify this and hence determine type of remedial treatment

- Non – Load associated factors are active and have significantly increased distress
  - E.g. Degradation of pavement materials under environmental influences

Solution – Case 2

- Do not proceed with an overlay design based on deflection levels
- Look for alternative treatments/design methods
- The following alternative treatments could be considered:
  - Surface subsurface drainage improvements
  - Provision of a competent seal
  - Sealing or improvements to shoulders
  - Modification or stabilisation of pavement materials

Possible Case - 3

- Granular Pavement
- Past traffic 2 X 10^6 ESAs
  - 1. Structural Assessment
    - Reb. Defln = 1.2 mm; D_{900} = 0.23
    - Defln. Ratio = 0.65
    - Residuals = 0.16; < 25% max Defln.
  - 2. Visual Assessment
    - Pavement Shape: fair – good
    - Some minor patching
    - Some minor rutting
- Overlay design based on deflection is possible by considering the possible causes

Case 3 (Dr > Expected)

Possible Causes	**Solutions**
Deflection testing in extreme climatic conditions	Overlay design based on moisture corrected IWP deflection levels
Inadequate surface or subsurface drainage	•Correct surface profile and/or competent seal •Provide subsurface drainage •Widen to full width •Overlay design based on moisture corrected IWP deflection levels

Case 3 (Dr > Expected) (cont.)

Possible Causes	**Solutions**
Recent reseal gives a false impression of surface condition	Overlay design based on the representative deflection level
Non typical deflection response for the type of pavement	Testing of pavement and subgrade materials