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ERA/AFCAP Workshop

Issues and Concerns Related to the Revised ERA Specifications and Design Manuals

Introduction to the DCP Design Method for Low Volume Sealed Roads

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Presentation Outline

- Background
- DCP Design Principles
- DCP Design Method
- Summary and Conclusions

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DCP Design Methods

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- Current methods both characterise in situ shear strength of existing unpaved road in terms of resistance to penetration (DN value in mm/blow). However:
- DCP-CBR method converts DN values to CBR values to derive subgrade class as part of CBR design catalogue.
- DCP-DN method uses DN values to derive subgrade class as part of DN catalogue.
- Because of issues related to CBR test, focus under AFCAP 1 has been on the DCP-DN design method.

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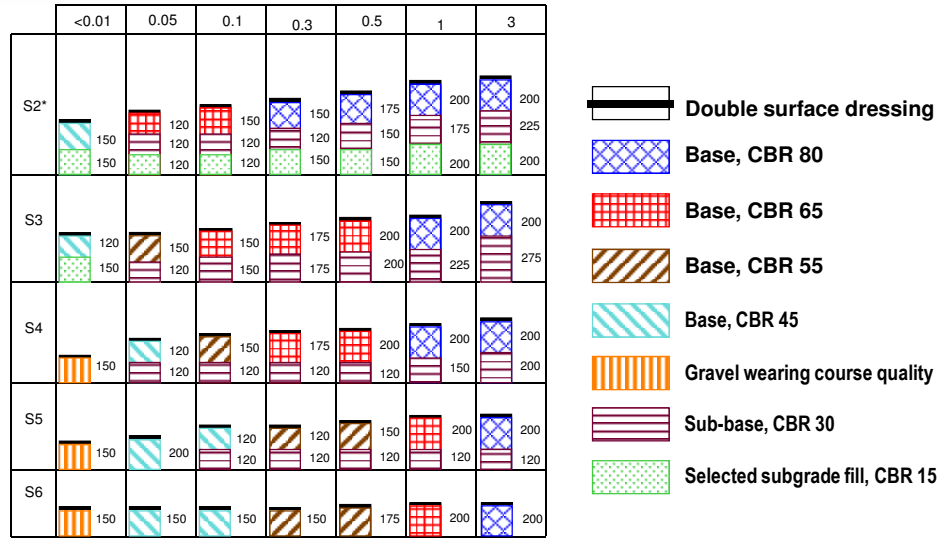
DCP-CBR Pavement Design Catalogue



Note: * Non-expansive subgrade

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CBR Issues

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- Poor reproducibility

CBR	σ	95% confidence	Range
10	4	± 8	2 – 18
30	7	± 14	16 – 44
60	12	± 24	36 – 84
80?	16	± 32	48 – 112

- Empirical test developed in 1928/29. Tried, trusted and understood, but…..
- Test procedure is time consuming, costly and requires large sample for lab testing
- Often excludes materials that are eminently "fit for purpose"
- When based on soaked condition, irrespective of climate, can be very conservative

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DCP Design Catalogue

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Traffic Class E80 x 10^6	LE 0.01 0.003 – 0.010	LE 0.03 0.010 – 0.030	LE 0.1 0.030 – 0.100	LE 0.3 0.100 – 0.300	LE 0.7 0.300–0.700	LE 1.0 0.700 – 1.0
0- 150mm Base ≥ 98% MAASHTO	DN ≤ 8	DN ≤ 5.9	DN ≤ 4	DN ≤ 3.2	DN ≤ 2.6	DN ≤ 2.5
150-300 mm Subbase ≥ 95% MAASHTO	DN ≤ 19	DN ≤ 14	DN ≤ 9	DN ≤ 6	DN ≤ 4.6	DN ≤ 4.0
300-450 mm subgrade ≥ 95% MAASHTO	DN ≤ 33	DN ≤ 25	DN ≤ 19	DN ≤ 12	DN ≤ 8	DN ≤ 6
450-600 mm In situ material	DN ≤ 40	DN ≤ 33	DN ≤ 25	DN ≤ 19	DN ≤ 14	DN ≤ 13
600-800 mm In situ material	DN ≤ 50	DN ≤ 40	DN ≤ 39	DN ≤ 25	DN ≤ 24	DN ≤ 23
DSN 800	≥ 39	≥ 52	≥ 73	≥ 100	≥ 128	≥ 143

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DCP Method of Design

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- An alternative method of structural design that avoids the use of the CBR test to classify and quantify the strength of materials.
- It uses the DN number obtained directly from DCP measurements without converting to CBR.
- It is becoming popular because of its simplicity.
- It is especially useful for upgrading an existing gravel road to a paved standard

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Dynamic Cone Penetrometer (DCP)

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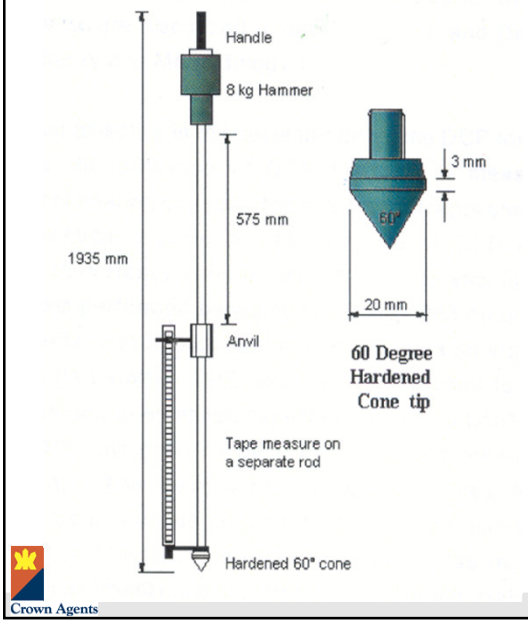

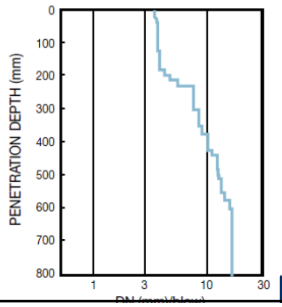

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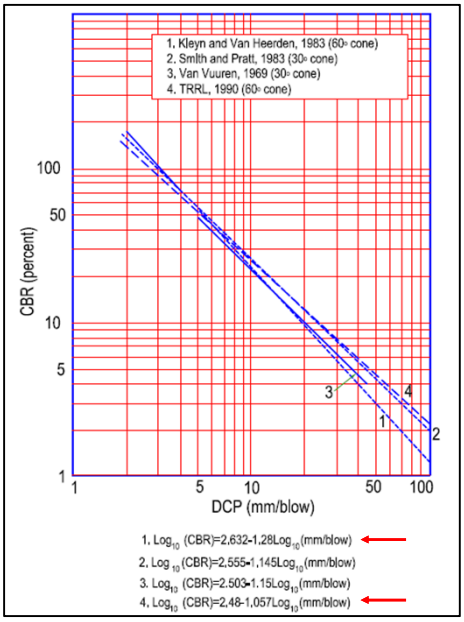
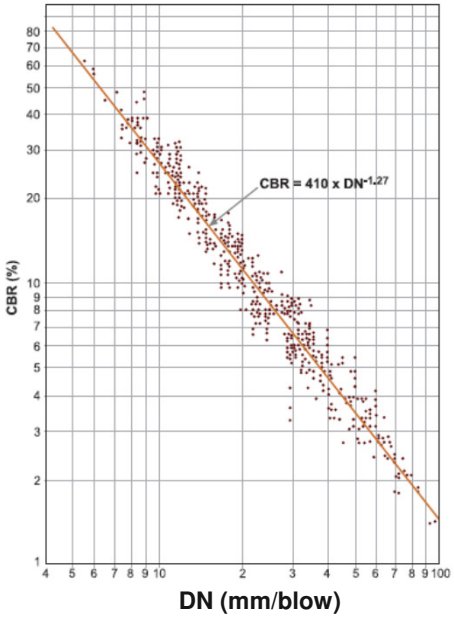
Relationship between DN and CBR



Relationship between DN and CBR



CBR-DCP relationship based on 2000+ measurements in South Africa (Kleyn)

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Presentation Outline

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Development of DCP Design Method

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- Extensive DCP testing was carried out in conjunction with Heavy Vehicle Simulator (HVS) testing of various roads.
  - Allowed further correlations and developments, e.g. relationships between actual road performance and DCP results

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DCP Design Approach

- Make use of beneficial traffic moulding and consolidation of gravel road pavement over many wetting and drying cycles
  - Gravel road pavement should not be disturbed during upgrading
- Optimize utilization of in situ material strength as much as possible. Achieved by:
  - determining design strength profile required
  - Intergarating required strength profile with in situ sytrength profile

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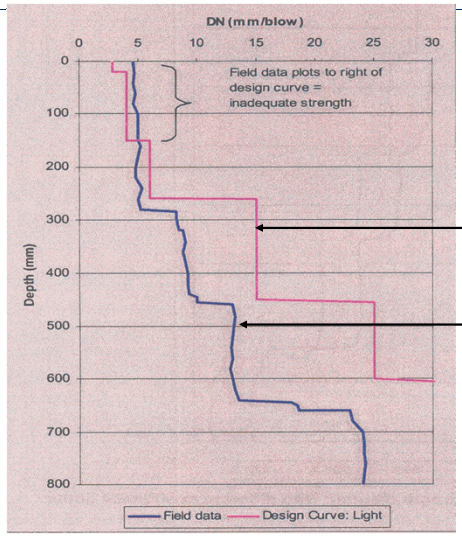
Integration of In Situ and Required Strength Profiles



Required strength profile

In situ strength profile

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Typical Moisture Related Relationship

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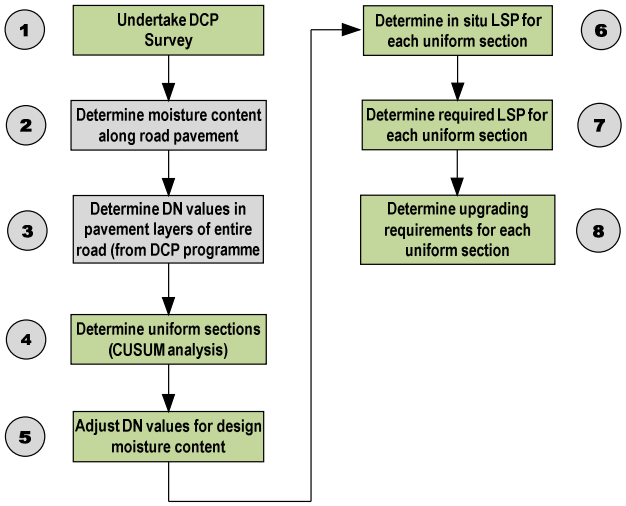

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Undertake DCP Survey

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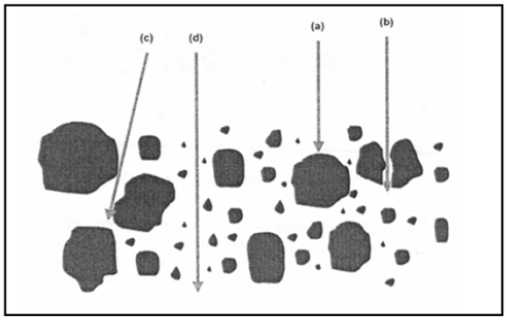
Road condition	Frequency of testing/km*
Uniform (low risk)	5
Non-uniform (medium risk)	10
Low-lying/distressed (high risk)	20



Typical DCP effects with large stones in pavement layer:

(a) cone cannot penetrate at all and the test needs to be re-done;

(b) cone breaks stone but penetration is uncharacteristically hard and DSN_{800} is high;

(c) cone tries to push stone aside. Result is high because of side friction generated on cone shaft;

(d) Usually provides a normal result

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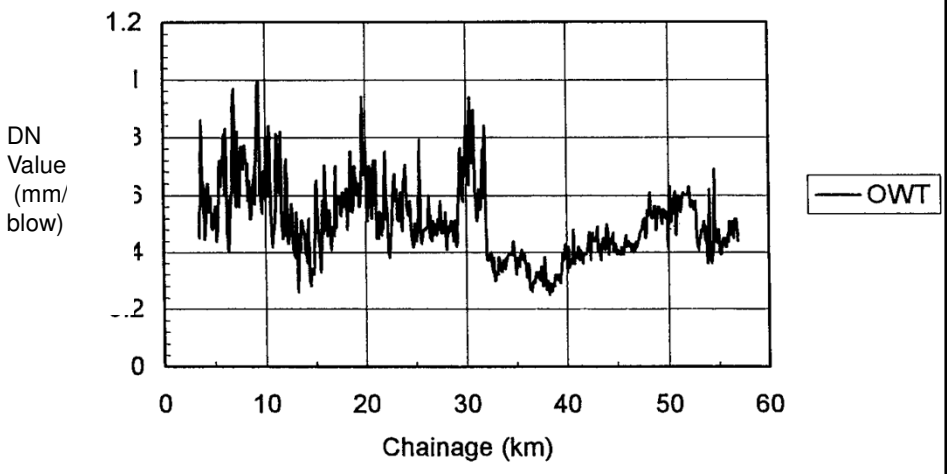
Obtain DN Values Along Road



DCP provides a good "picture" of in situ ground conditions

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Determine Uniform Sections

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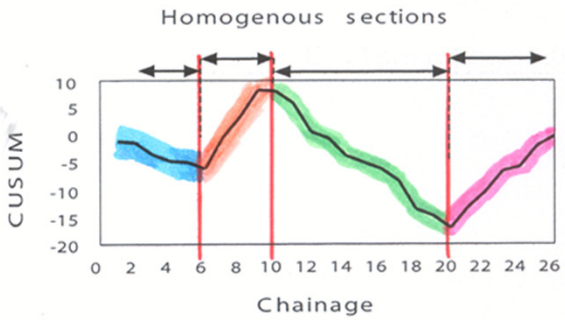
	B	C	
Chainage (Km)	Measured DCP (DN Value -mm/blow)	Difference from average (A-B)	CUSUM (Accumulated values of C)
1	14	-1.2	-1.2
2	13	-0.2	-1.4
3	15	-2.2	-3.6
4	14	-1.2	-4.8
5	13	-0.2	-5.0
6	14	-1.2	-6.2
7	7	5.8	-0.2
8	9	3.8	3.4
9	8	4.8	8.2
10	13	-0.2	8.0
11	15	-2.2	5.8
12	18	-5.2	0.6
13	14	-1.2	-0.6
14	16	-3.2	-3.8
15	14	-1.2	-5.0
16	14	-1.2	-6.2
17	15	-2.2	-8.4
18	18	-5.2	-13.6
19	14	-1.2	-14.8
20	15	-2.2	-17.0
21	9	3.8	-13.2
22	10	2.8	-10.4
23	9	3.8	-6.6
24	12	0.8	-5.8
25	9	3.8	-2.0
26	11	1.8	-0.2
Average: A = 12.8			



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Determine Uniform Sections

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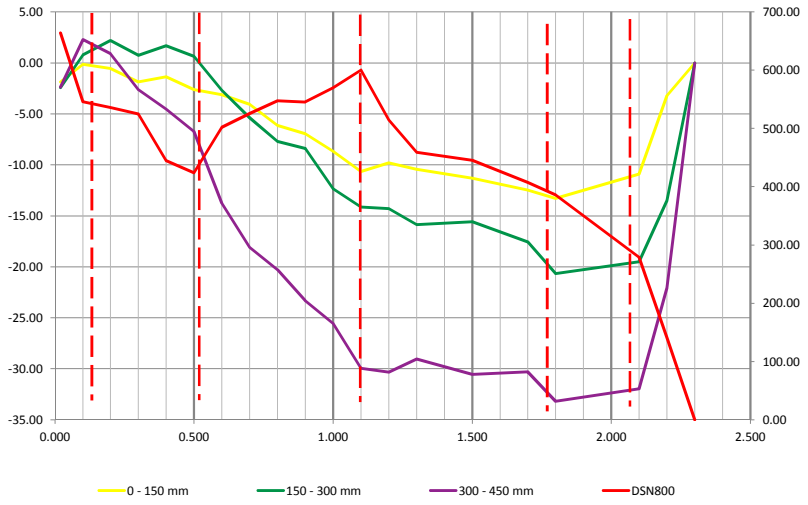

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Adjust DN Values for Moisture Environment

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Chainage (km)	Point No	DN 0-150 (Base)	Percentile of minimum strength Profile (max. penetration rate – DN)		
			20th	50th (Mean)	80th
0.00	1	2.29	3.46	5.24	8.19
0.25	2	4.44			
0.50	3	2.00			
0.75	4	8.67			
1.00	5	3.75			
1.25	6	8.07			
1.50	7	5.11			
1.75	8	5.37			
2.00	9	6.60			
2.25	10	10.12			
Anticipated long-term in-service moisture content in pavement					
Drier than at time of DCP survey			3.46	N/A	N/A
Same as at time of DCP survey			N/A	5.24	N/A
Wetter than at time of DCP survey			N/A	N/A	8.19

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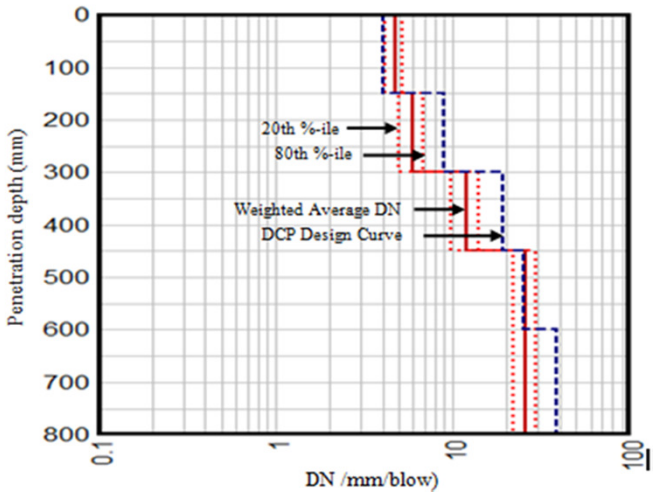
Compare In Situ & Required LSP for Uniform Section



Layer strength diagram for average analysis of uniform sections

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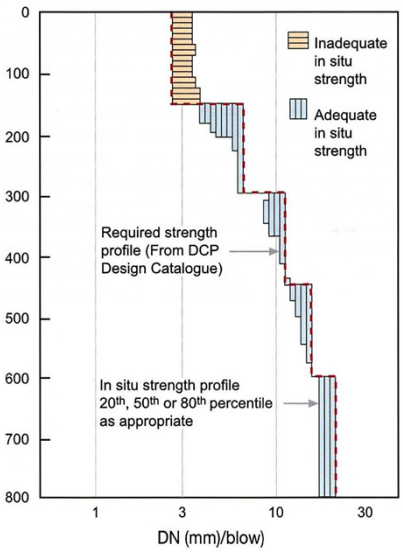
Compare In Situ & Required LSP for Uniform Section



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Determine Upgrading Requirements (Cont'd)

- **Reworking the existing layer**
  - if only the density is inadequate and the required DN value can be obtained at the specified construction density and anticipated in-service moisture content.
- **Replacing the existing layer**
  - if material quality (DN value at specified construction density and anticipated in-service moisture content) is inadequate, then appropriate quality material will need to be imported to serve as the new upper pavement layer(s).
- **Augmenting the existing layer**
  - if material quality (DN value) is adequate but the layer thickness is inadequate, then imported material of appropriate quality will need to be imported to make up required thickness prior to compaction.

Material Selection

- **DN value serves as criterion for selecting materials to be used in upper/base layer of LVSR pavement.**
- **Provided design DN value is achieved, then in service performance indirectly takes account of actual grading and plasticity at given moisture and density which do not need to be separately specified.**
  - DN value provides is a composite measure of materials resistance to penetration (= shear strength) at given moisture and density and is affected by material grading and plasticity.
  - Limits also placed on GM 1.0 – 2.2

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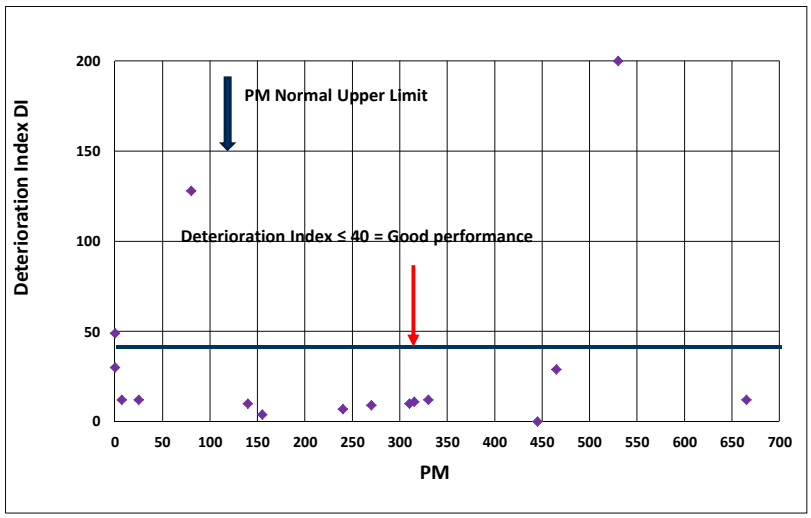
PM– Poor Correlation With Performance



Mozambique Back-Analysis Project

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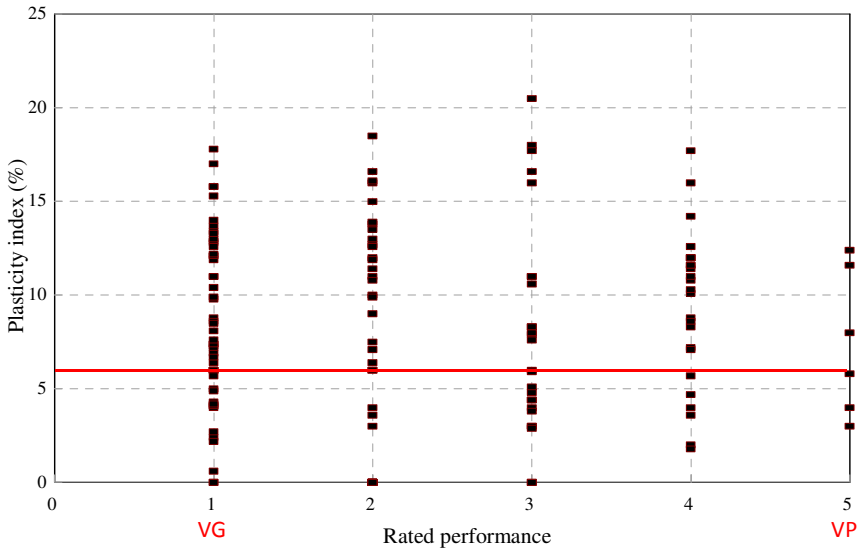
PI– Poor Correlation With Performance



AFCAP Determination of Laboratory DN Value

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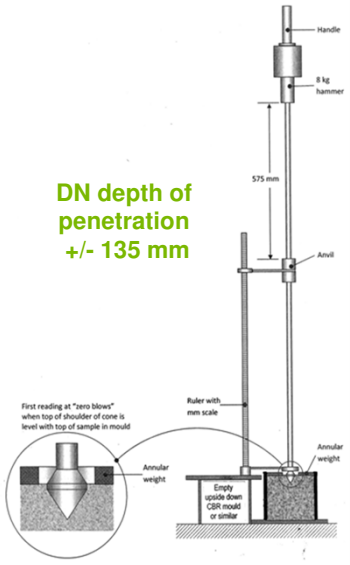
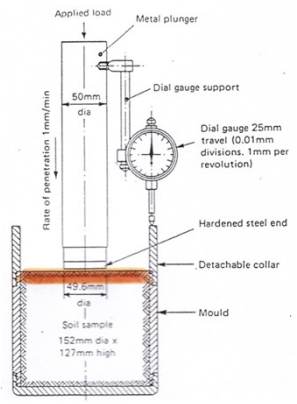
DN depth of penetration +/- 135 mm



CBR depth of penetration +/- 2.54/5.0 mm



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AFCAP DN/Density/Moisture Relationship

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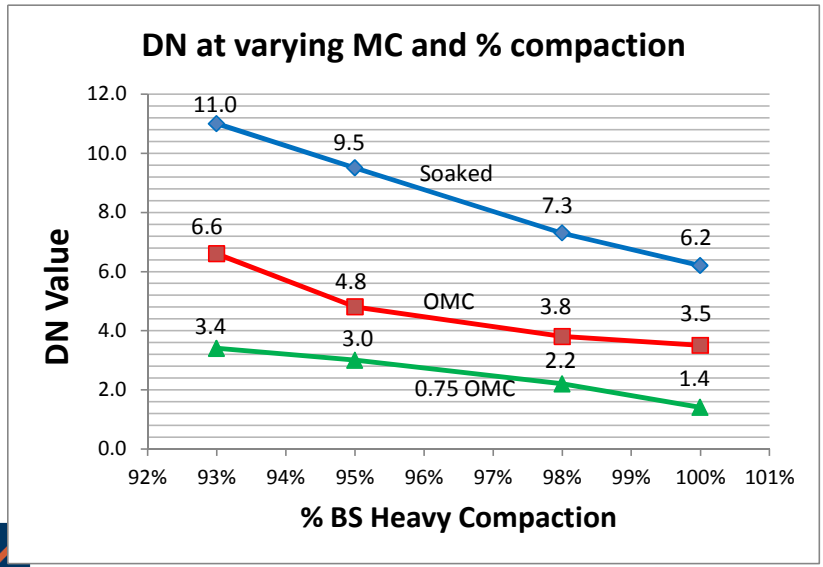

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Adjust DN Values for Moisture Environment

Anticipated long-term in-service moisture content in pavement	Percentile of minimum strength profile (maximum penetration rate – DN mm/blow)	
	Design traffic < 0.5 MESA	Design traffic 0.5 – 1.0 MESA
Drier than at time of DCP survey	20	30
Same as at time of DCP survey	50	65
Wetter than at time of DCP survey	80	90

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Summary of DCP Method-Strengths

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- Relatively low cost, robust apparatus that is quick and simple to use allowing comprehensive characterization of the in situ road conditions.
- Provides improved precision limits compared to the CBR test
- Very little damage is done to the pavement being tested (effectively non-destructive) and very useful information is obtained.
- The pavement is tested in the condition at which it performs and the test can be carried out in an identical manner both in the field and in the laboratory.
- The simplicity of test allows repeated testing to minimize errors and also to account for temporal effects.
- The laboratory DN value is determined over a depth of 150 mm and not just the top 25 – 50 mm as with the CBR test.
- The method is as good or better than any other method in taking into account variations in moisture content and provides data quickly for analysis.

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Summary of DCP Method - Limitations

- Use in very coarse granular or lightly stabilized materials.
- Very hard cemented layers in the pavement structure
- The possibility of not recording very weak or thin layers when taking depth measurements every 5 blows
- Poorly executed tests (hammer not falling the full distance, non-vertical DCP, excessive movement of the depth measuring rod, etc.).
- Changes to standard specifications and the associated bidding documents.
- As with all empirical methods, use outside the type of environment (materials, climate, traffic, etc.) in which it was developed.

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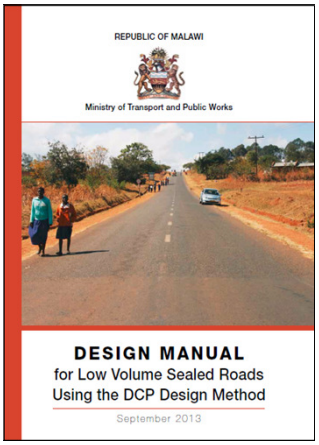
DCP Design Manual



- **Builds on pioneering work done in RSA, UK and Australia)**
- **Reduced reliance on conventional testing**
- **Supports an existing design approach**
- **Demonstration projects so far in Kenya and DRC and Tanzania.**

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Examples of DCP Designed Roads

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Danger Point road, South Africa (10 years after construction)

Road D379 Kiambu, Kenya (after 2 years)

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Thank You

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