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A New Approach for Upgrading Gravel Roads to a Low Volume Sealed Standard Based on the Use of the Dynamic Cone Penetrometer

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Outline of Presentation

- Background
- DCP Design Method
- Material Selection and Specification
- Compaction Quality Control Using the DCP
- Strengths and limitations of DCP design method
- Summary

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Background

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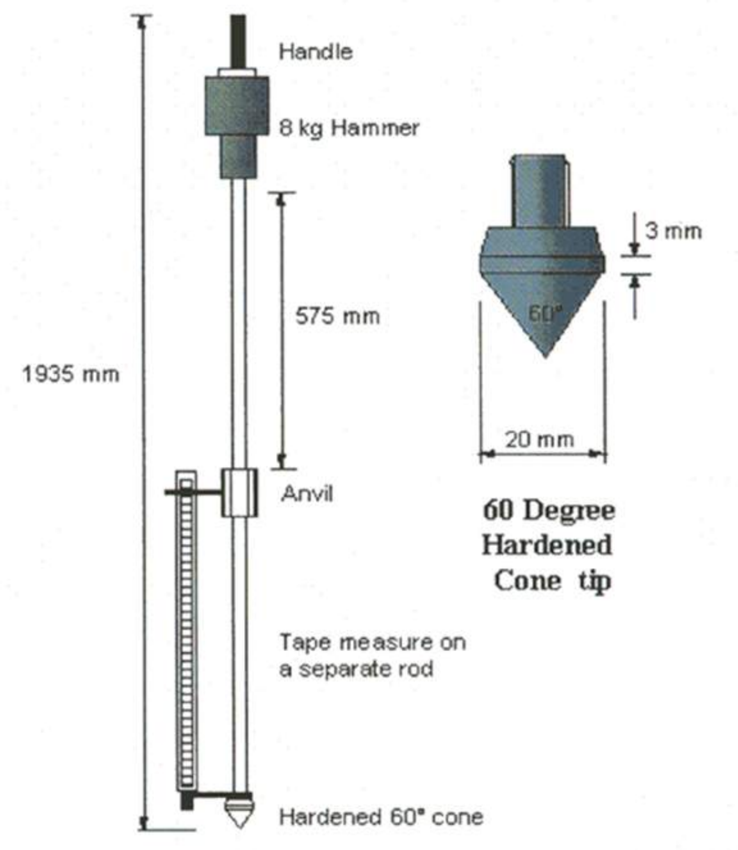
Background

- Approximately 1 million km of unsealed roads on the African continent
- Increasingly difficult to maintain:
  - Constraints: financial, logistical, and technical coupled with limited renewable natural resources
  - Consequence: lack of access to basic socio-economic amenities
- Solution: upgrading unpaved roads to a sealed standard, by optimized use of residual strength of existing road and use of "fit for purpose" specification

DCP Outline Details

- DCP method of design developed in South Africa
- DCP measures in situ shear strength which is a function of material moisture, density, grading and plasticity at time of testing.
- Test entails dropping an 8 kg mass from 575 mm height, recording the penetration of the cone in the material per number of blows and evaluatinge the weighted average of the rate of penetration in mm/ blow (DN value)
- DCP structure number: number of DCP blows required to penetrate a pavement structure or layer, e.g. DSN_{800} = number of blows to penetrate 800mm of pavement



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DCP Design Principles

Philosophy: to achieve a balanced pavement design whilst optimizing the utilization of the in situ material strength:

- Determining design strength profile needed
- Integrating strength profile with in situ strength profile

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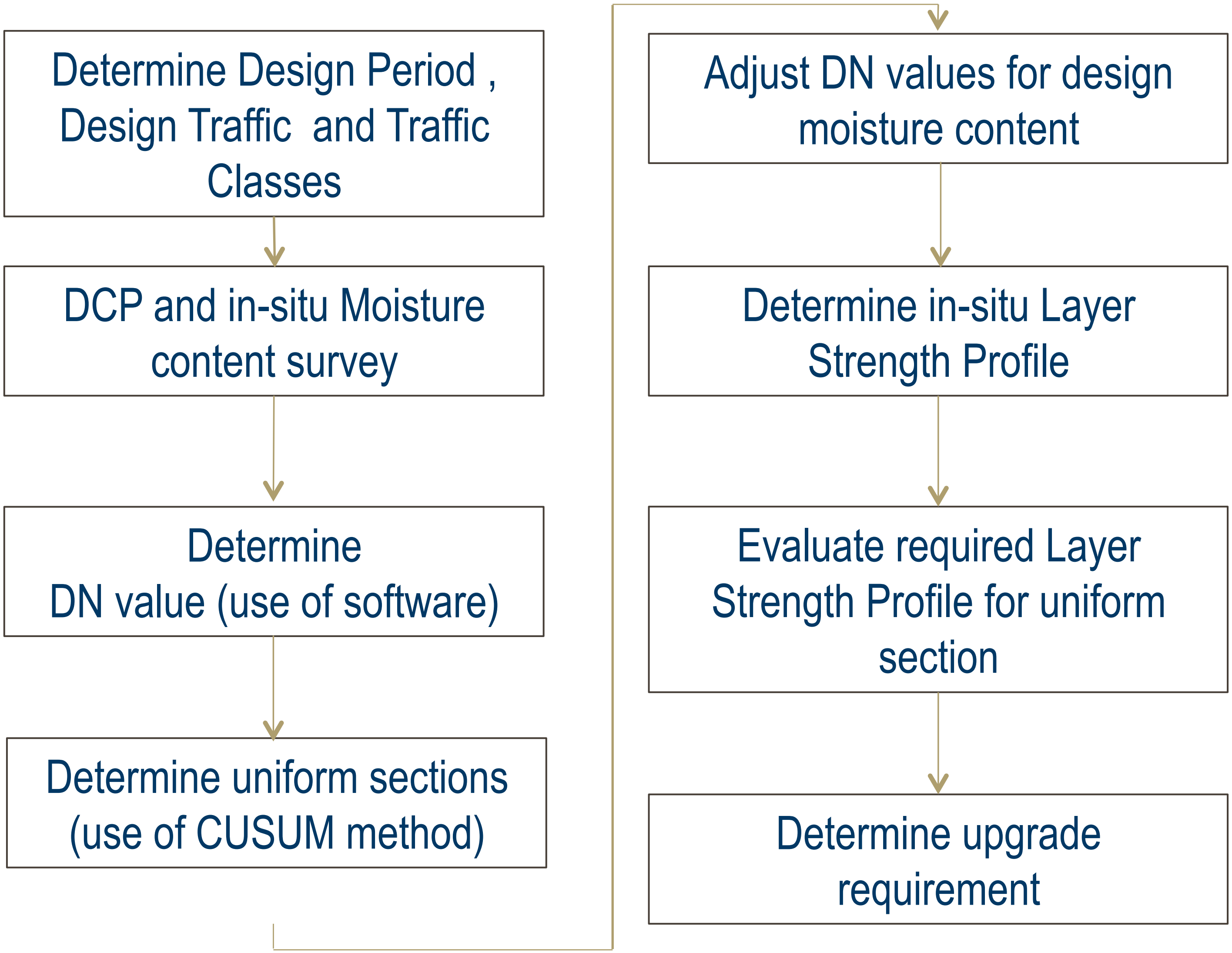
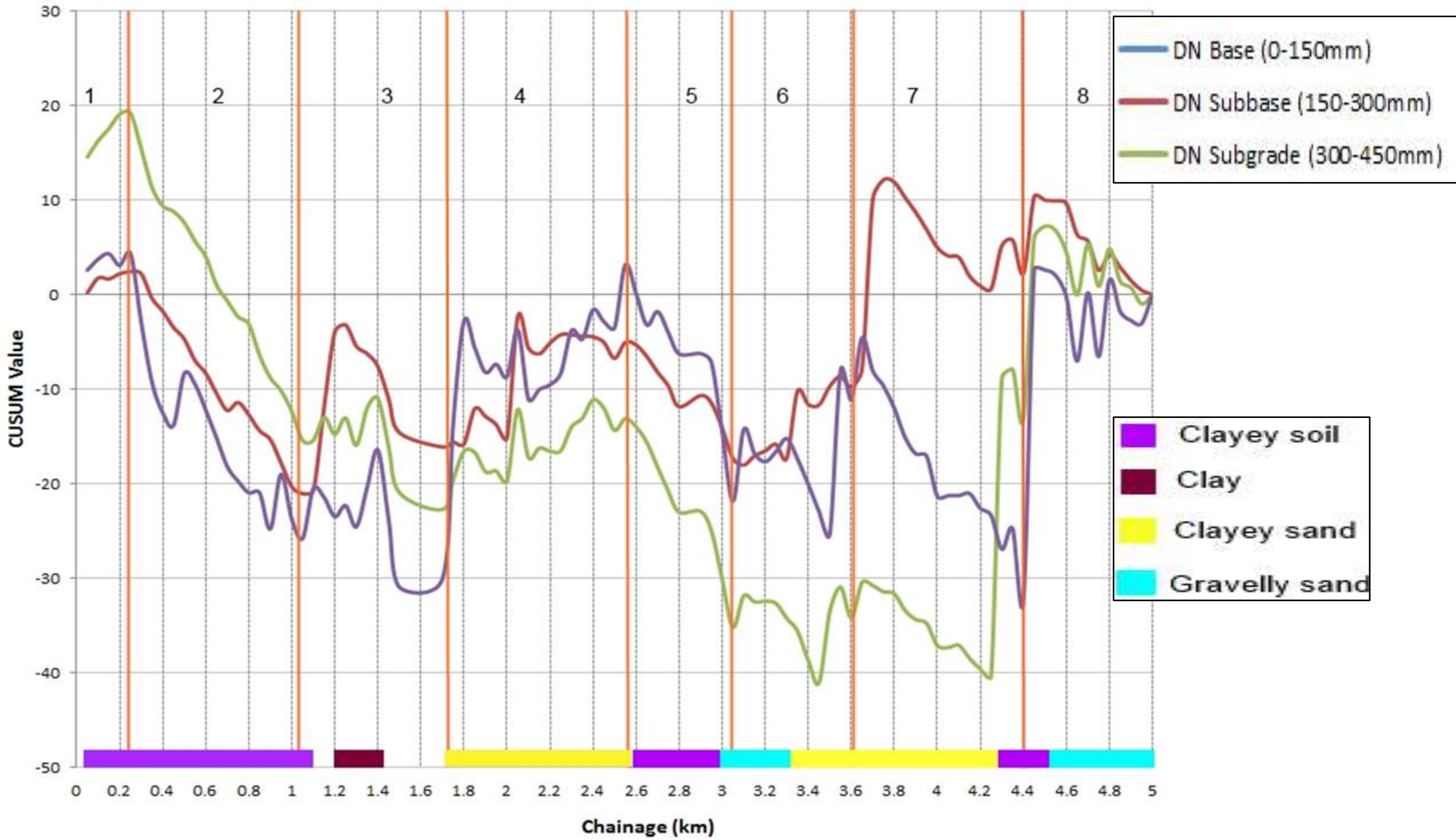
Outline DCP Design Procedure



Determine Uniform Sections



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Adjust DN Values for Design Moisture Content

Adjust DN Values for Design moisture Content considering anticipated long-term in-service moisture content in pavement

Drier than at the time of DCP Survey	20th percentile of DN
Same as at the time of DCP Survey	50th percentile of DN
Wetter than at the time of DCP Survey	80th percentile of DN

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Required Layer-Strength Profile (DCP Design catalogue)

Traffic Class	LE 0.01	LE 0.03	LE 0.1	LE 0.3	LE 0.7	LE 1.0
E80 x 10^6	0.003 - 0.010	0.010 - 0.030	0.030 - 0.100	0.100 - 0.300	0.300 - 0.700	0.700 - 1.0
	Max. DN					
0 - 150mm Base ≥ 98% Mod. AASHTO	8	5.9	4	3.2	2.6	2.5
150-300 mm Subbase ≥ 95% Mod AASHTO	19	14	9	6	4.6	4
300-450 mm Subgrade ≥ 95% Mod AASHTO	33	25	19	12	8	6
450-600 mm in situ material	40	33	25	19	14	13
600-800 mm in situ material	50	40	39	25	24	23

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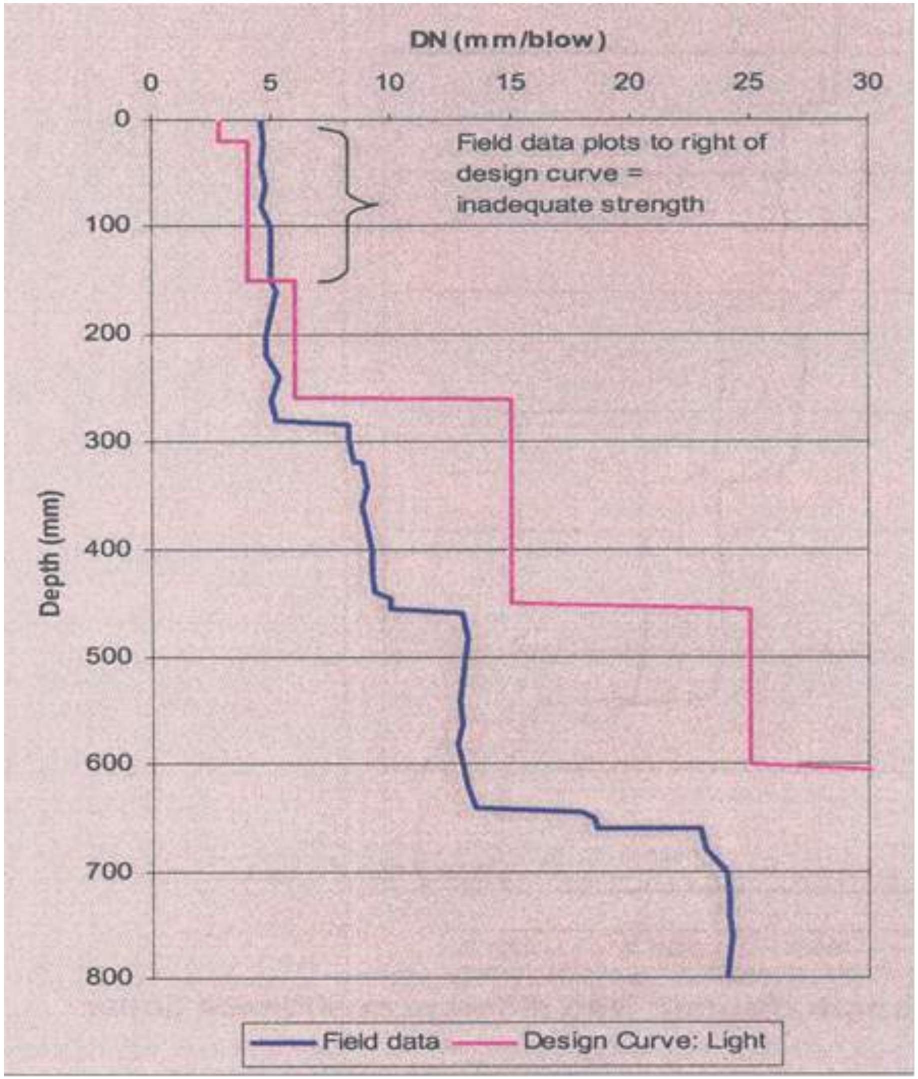
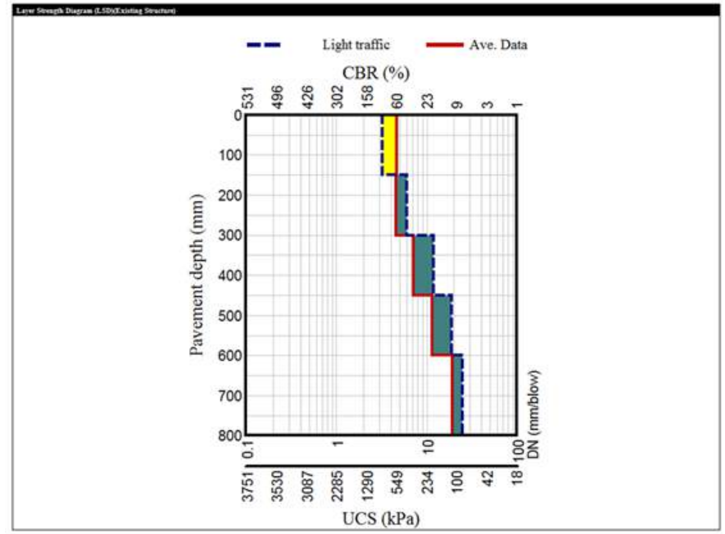
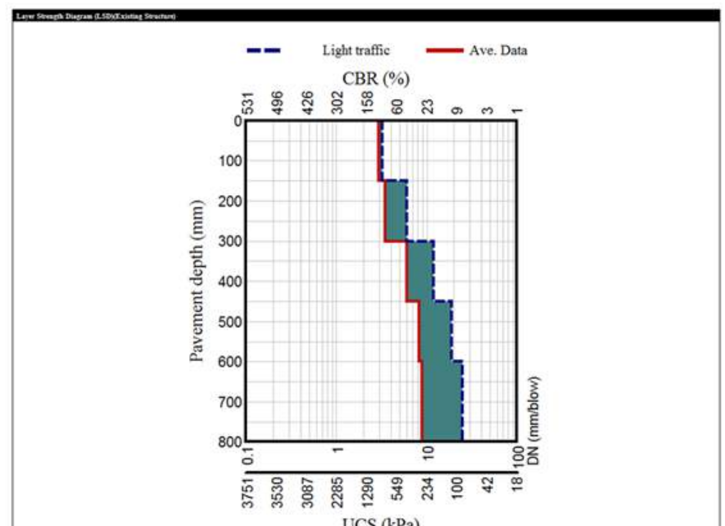
Evaluate In Situ Layer-Strength Profile for Uniform Sections







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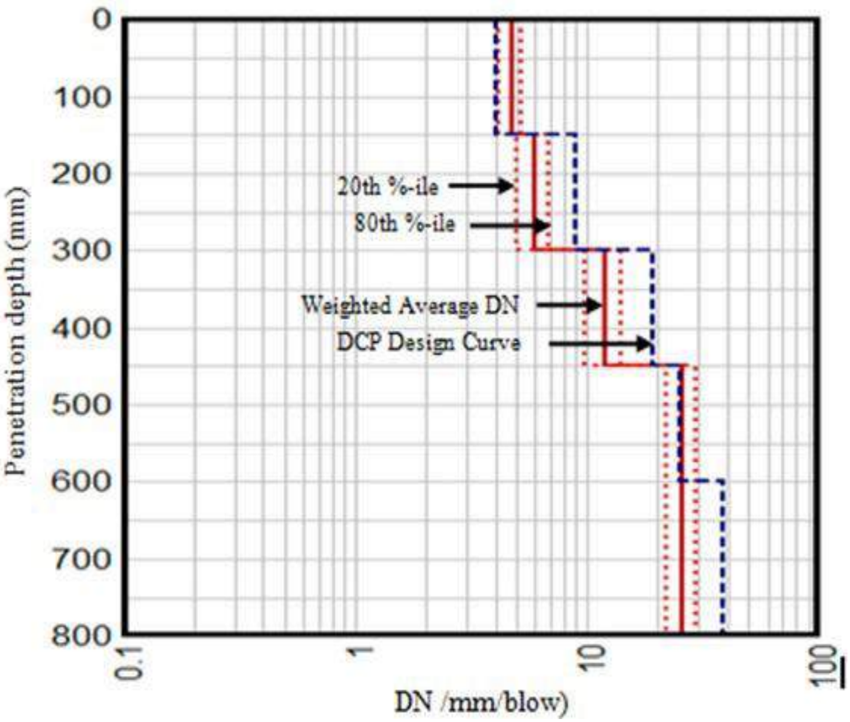
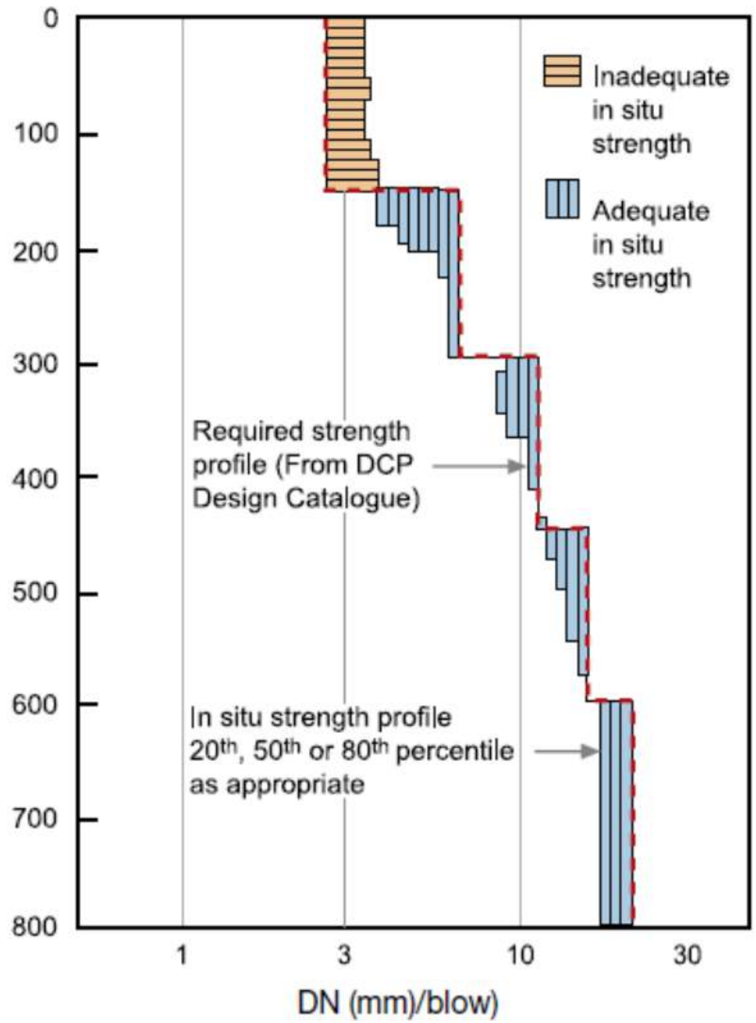
Layer-strength diagram for average analysis of uniform sections



Comparison of DCP design and in situ strength profiles



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Material Selection and Specification

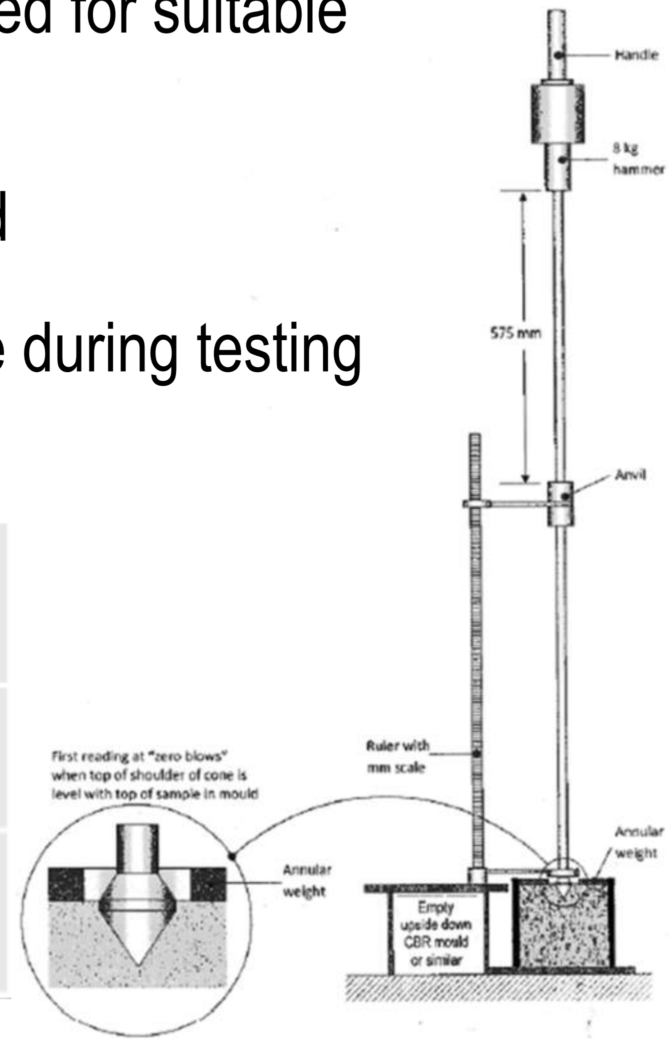
- DCP-DN Method provides composite measure of material properties that indirectly takes into account PI, grading, density and moisture

- Criteria for selection of Material (Borrow pit investigation)
  - Strength: resistance to penetration (DN value) at specified moisture and density
  - Strength/density/moisture relationship
  - Grading modulus (GM)

Strength Measurement of lab DN value

- DN/moisture/density relationship required for suitable pavement material
- DCP used to penetrate the CBR mould
- Takes in account pore pressure release during testing

4 days soaked sample , sealed for 4 days in plastic bag	Soaked DN
Sample at OMC, sealed for 4 to 7 days in plastic bag	OMC DN
Oven sample (0.75OMC), sealed for 4 days in plastic bag	0.75 OMC DN



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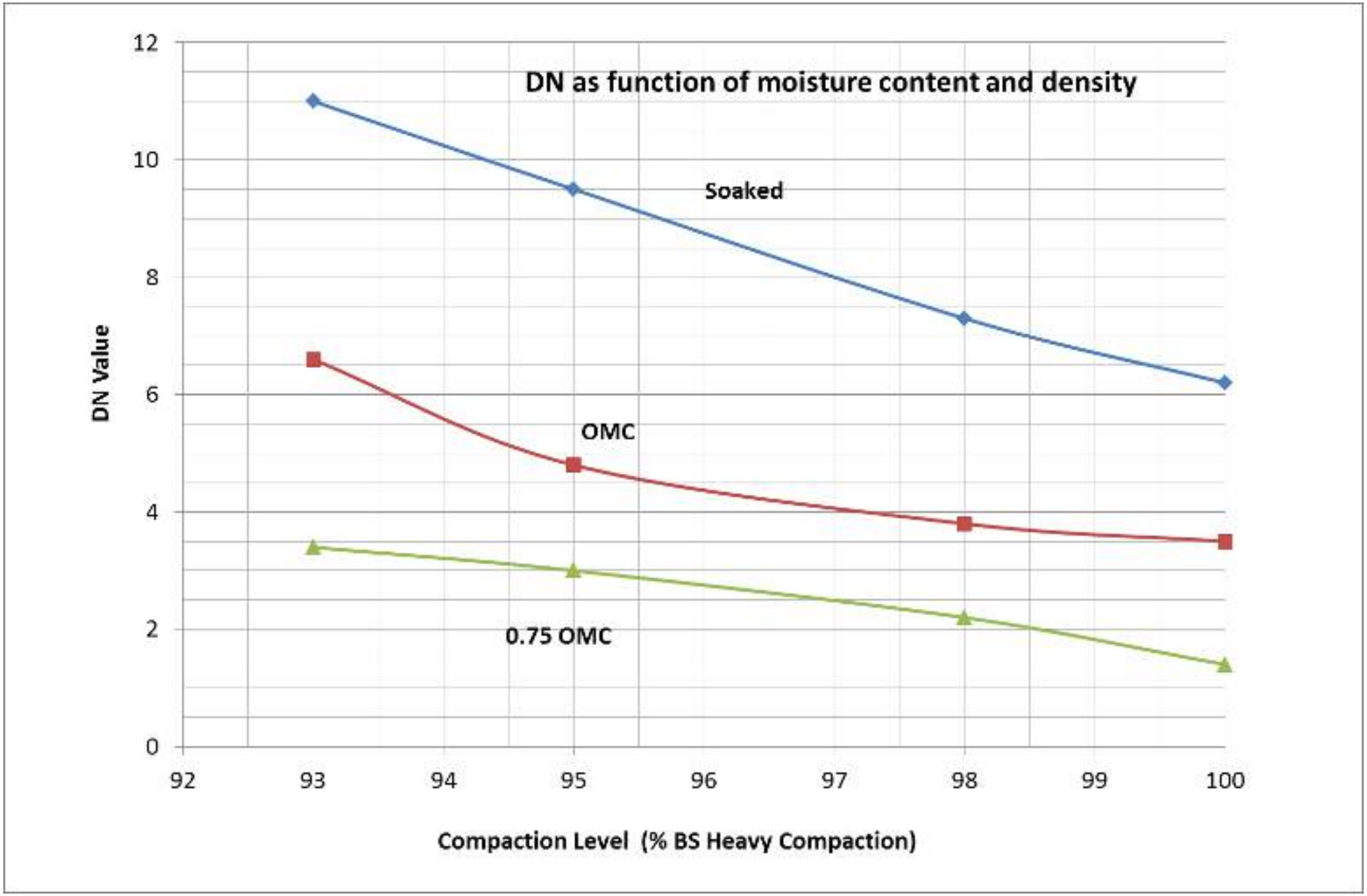
Strength/Density/Moisture Relationship



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Grading Modulus (GM)

- $GM=300-(P\downarrow 2+P\downarrow 0.425+P\downarrow 0.075)/100$
  - where $P\downarrow x$ = percentage passing through sieve ofsize "x", x [mm]
  - GM: simplify classification of material in terms of : very fine, plastic soils or very coarsely/poorly graded gravels etc.
- GM range: The minimum GM (typically > 1.0) and maximum GM (typically < 2.25)

Critical Factors Affecting Long-term Performance of the Road

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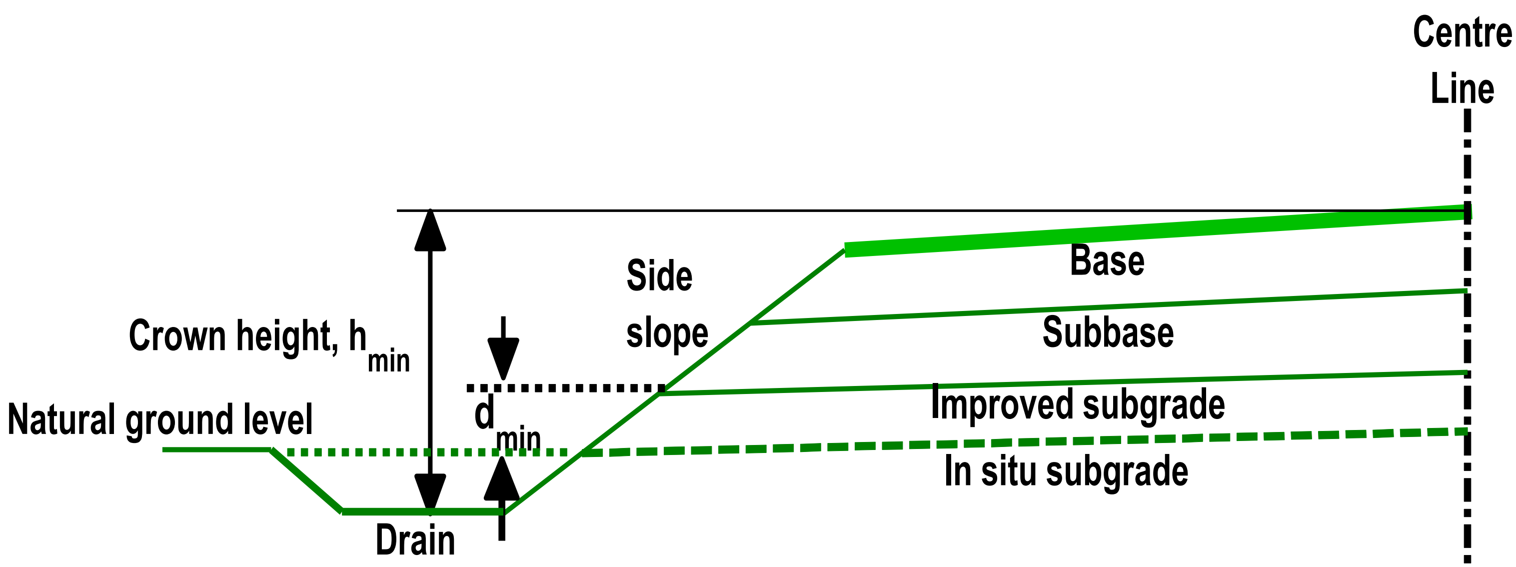
- Highest level density practicable ("compaction to refusal"): by heaviest rollers.
- Moisture content in outer wheel track of road, not above OMC: by drainage and drainage maintenance



Minimum drainage requirements: hmin = +/- 750mm, dmin = +/- 100mm

Compaction Quality Control Using DCP

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- Traditional methods (Sand Replacement, core cutter, rubber balloon and nuclear density gauge): slow, hazardous, uncertain accuracy, and impractical for variation of material along tested section.

- Alternative method of compaction quality control with DCP:
  - level and uniformity of compaction
  - relatively simple and low cost compared
  - procedure is based on the DN value criterion, used in the pavement design
  - assessing compaction compliance, field DN versus required DN value using strength/density/moisture relationship and adjustment factor for confinement effect of mould.

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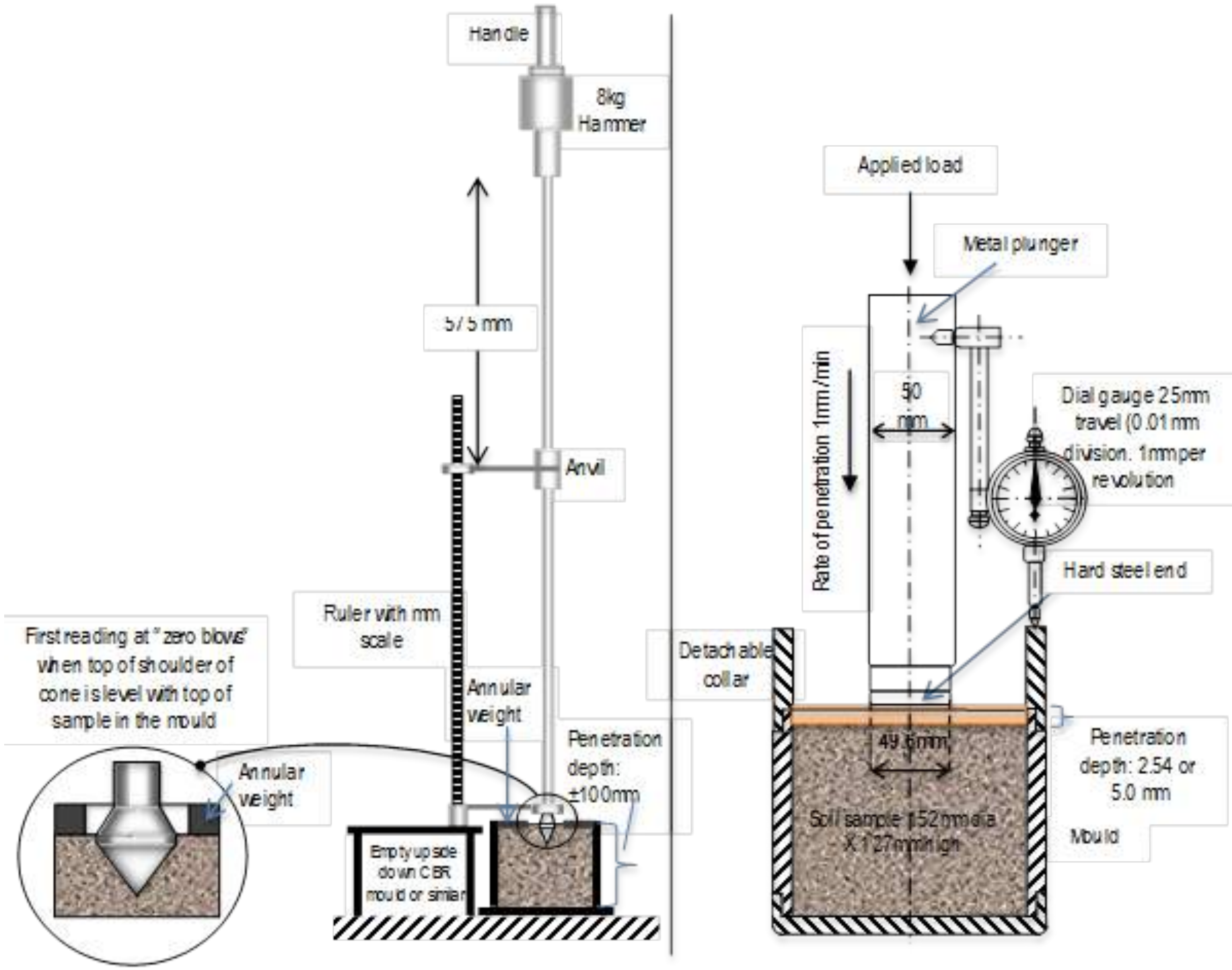
Strengths of the DCP Method

- **Strengths**
  - Relatively low cost, robust apparatus , quick and simple for comprehensive characterization of in situ road conditions (longitudinal and vertical direction)
  - Precise and accurate compared to CBR (laboratory DN value determined over 150mm depth vs. 25 – 50mm depth for CBR test)
  - Non-destructive test
  - Similar testing condition as performance condition (both in the field and laboratory)
  - The simplicity allows repeatability of testing to minimize errors and account for temporal effects.
  - Account for variations in moisture content

Limitations of the DCP Method

- **Limitations (Many are controllable)**
  - Use in very coarse granular or lightly stabilized materials
  - Very hard cemented layers in pavement structure
  - 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 associated bidding documents
  - Use outside the type of environment (materials, climate, traffic, etc.) in which it was developed

DCP vs. CBR Testing



Conclusions

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- Successful design of light pavement structures in the Southern African
- Simple and cost-effective design: Often resulting in the need to rip and re-compact or to import a single layer of appropriate material
- Possibility of economically upgrading a significantly greater length of road, with similar risk as conventional pavement design techniques.
- Allows the designer to use local knowledge and experience, in developing appropriate layer strength diagrams for different traffic classes and environmental conditions, to optimize pavement layer thicknesses and material strengths

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Africa…
Most of them are happy and proud, we need to give them hope for the future by improving their roads

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Thank you

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