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# International Best Practices in the Design of Low Volume Roads

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# Outline of Presentation

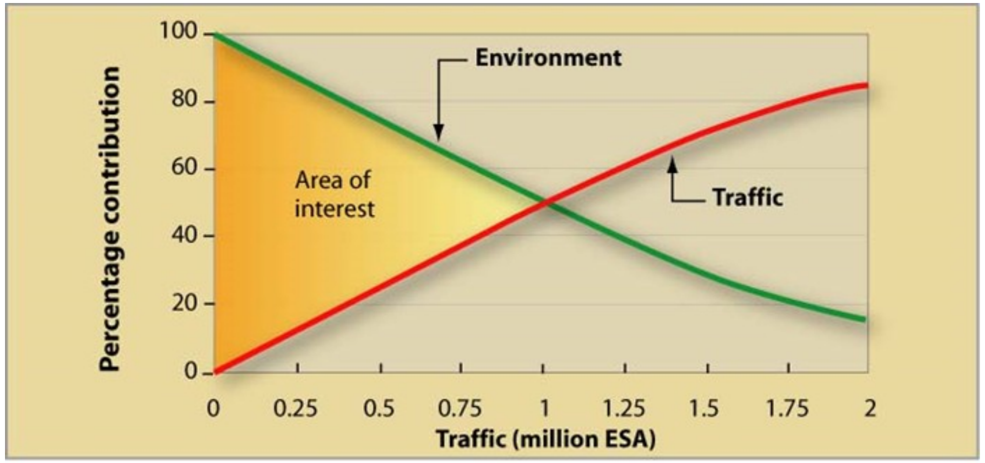
- General Introduction
- Characteristics of low volume roads
- Design philosophy
- Lessons Learned from research
- New approaches
- Summary

# Purpose of Presentation

- To engender a greater awareness of relatively recent, research-based developments in LVR provision.
- The new approaches provide the potential for providing LVRs more cost-effectively and sustainably than hitherto.

# Characteristics of Low Volume Roads

- Typically carry less than about 300 vpd or about 1 MESA over their design life.
- Constructed mostly from naturally-occurring, often “non-standard”, moisture-sensitive materials.
- Alignment may not necessarily have to be fully engineered.
- Variable traveling speeds seldom exceed 80 km/h
- Need to cater for significant amount of non-motorized traffic
- Pavement deterioration is driven primarily by environmental factors, particularly moisture, with traffic loading being a relatively lesser influential factor, and drainage being of paramount importance.



Traffic loading versus dominant mechanism of pavement distress (schematic)

# High Volume versus Low Volume Road Design

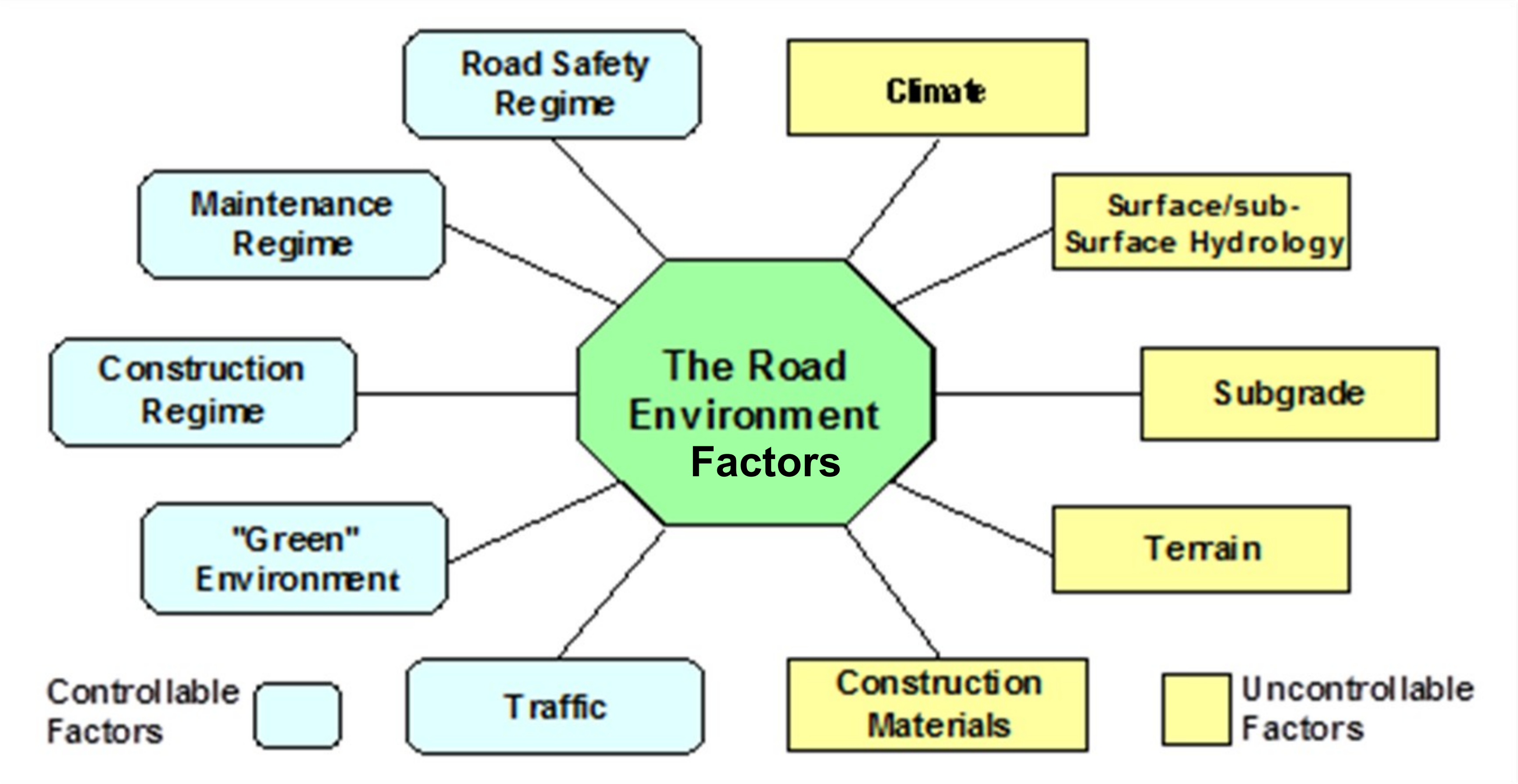
| High Volume Road Design | Low Volume Road Design |
|---|---|
| ▪ **Traffic** dominant in pavement deterioration | ▪ **Environment** dominant in pavement deterioration |
| ▪ Design reliability **high** (typically > 75%) | ▪ Design reliability **modest** (typically 50-75%) |
| ▪ Designed for **higher** speed (>80 km/h) | ▪ Designed for **lower** speed (< 40 - 60 km/h) |
| ▪ Main traffic composition: **motorized vehicles** | ▪ Traffic composition may include large %age of 2-3 wheel and **non-motorized vehicles** |
| ▪ Focus on **mobility** function (speed) | ▪ Focus on **access** function (reliability) |
| ▪ **Traditional** thinking related to road design (what should be done) | ▪ **Innovative and flexible** thinking and engineering judgment (what can be done with the resources available?) |
| ▪ Designed by **experienced** Consultants | ▪ Designed by **local** consultants or in-house by the client with limited means |
| ▪ Implemented by **experienced** and well-equipped contractors | ▪ Implemented by **local** contractors using intermediate equipment and labour |
| ▪ Use of **traditional** materials (crushed stone, cement stabilized, hot mix AC) | ▪ Use of **non-traditional** materials (e.g. pedogenic gravels, cold mix asphalt, emulsion based seals) |

# Design Philosophy

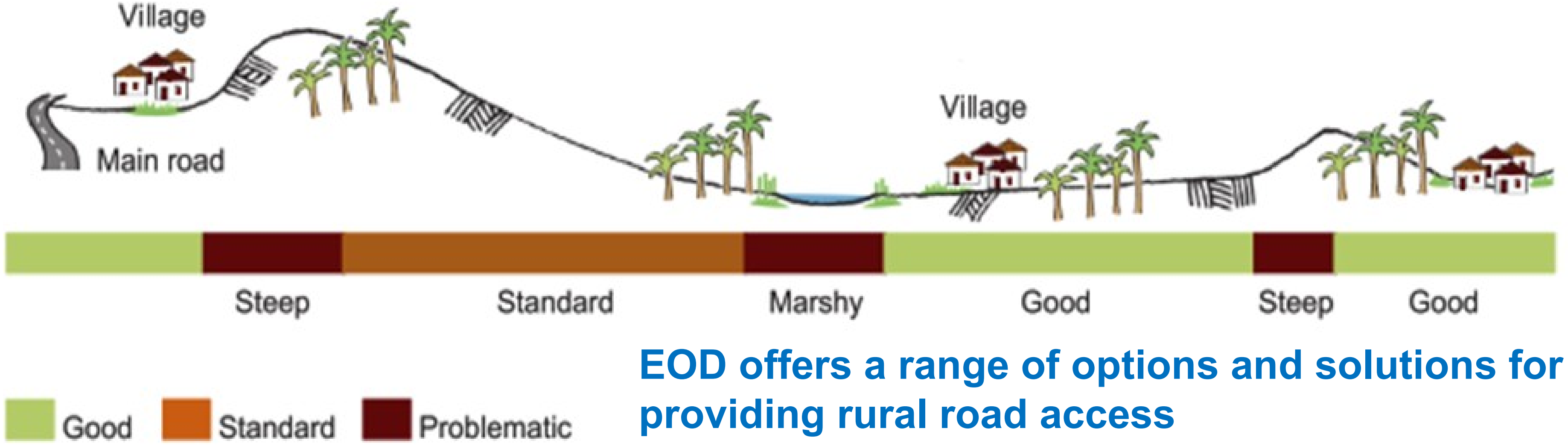
Need to appreciate several differences from the traditional methods adopted for HVRs.

- Complete understanding by design engineer of the local environment.
- Ability to work within the local environment demands
- Innovative and flexible thinking not tied to traditional approaches
- Client who is open and responsive to innovation
- Adopting an environmentally optimized design approach
- Ensuring funding for routine and periodic maintenance
- Recognizing and managing risk

# Environmental Impact Factors



# Environmentally Optimised Design



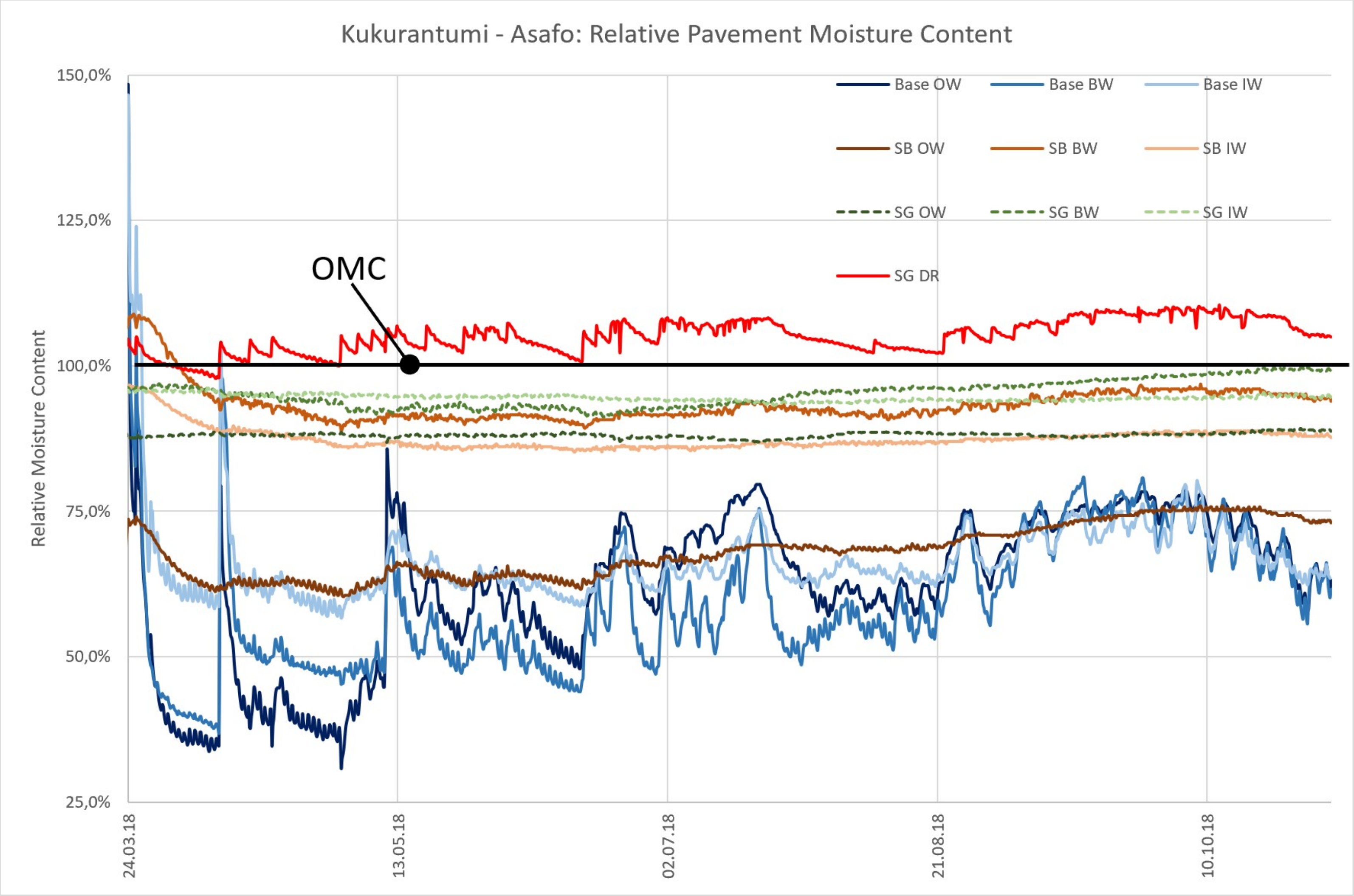
**EOD offers a range of options and solutions for providing rural road access**

- Overall aim is to ensure that each section of a road is provided with the most suitable pavement type for the specific circumstances prevailing along the road.
- Need to consider broad spectrum of solutions to improve different road sections, depending on their requirements, ranging from engineered natural surfaces to paved roads

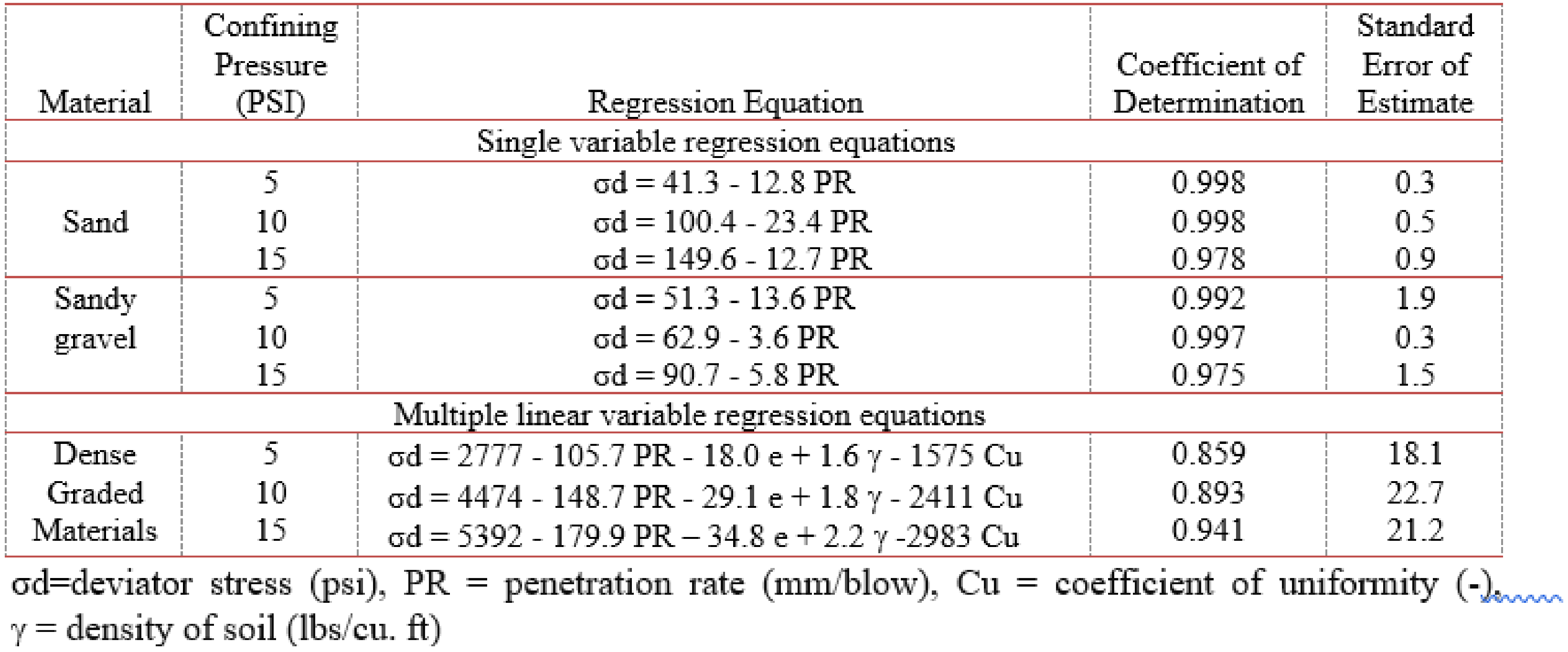
# Lessons Learned From Research

- Most pavement failures caused by failures of surfacing and are non-structural
- Structural Number (SN) (=Bearing capacity) of good-performing roads below design SNs obtained using traditional design methods
- Almost no correlation between measured CBR and soil indicator properties (e.g. Plasticity Index, Grading Modulus)
- Wide range of particle size distributions well outside typically specified grading envelopes
- Drainage is a significant performance factor influenced by crown height and type of shoulders (sealed/unsealed)
- Given adequate drainage, moisture content in subgrade tends to equilibrate at +/- OMC and below OMC in pavement layers.

# Equilibrium Moisture Content in Pavements



# Lessons Learned from Research–DN/Shear Strength Correlation



| Material | Confining Pressure (PSI) | Regression Equation | Coefficient of Determination | Standard Error of Estimate |
|---|---|---|---|---|
| Single variable regression equations | | | | |
| Sand | 5 | σd = 41.3 - 12.8 PR | 0.998 | 0.3 |
| | 10 | σd = 100.4 - 23.4 PR | 0.998 | 0.5 |
| | 15 | σd = 149.6 - 12.7 PR | 0.978 | 0.9 |
| Sandy gravel | 5 | σd = 51.3 - 13.6 PR | 0.992 | 1.9 |
| | 10 | σd = 62.9 - 3.6 PR | 0.997 | 0.3 |
| | 15 | σd = 90.7 - 5.8 PR | 0.975 | 1.5 |
| Multiple linear variable regression equations | | | | |
| Dense Graded Materials | 5 | σd = 2777 - 105.7 PR - 18.0 e + 1.6 γ - 1575 Cu | 0.859 | 18.1 |
| | 10 | σd = 4474 - 148.7 PR - 29.1 e + 1.8 γ - 2411 Cu | 0.893 | 22.7 |
| | 15 | σd = 5392 - 179.9 PR – 34.8 e + 2.2 γ -2983 Cu | 0.941 | 21.2 |

σd=deviator stress (psi), PR = penetration rate (mm/blow), Cu = coefficient of uniformity (-), γ = density of soil (lbs/cu. ft)

Ayers et al, 1989: Rapid Shear Strength Evaluation of In Situ Granular Materials (http://onlinepubs.trb.org/Onlinepubs/trr/1989/1227/1227-014.pdf
)

**Conclusions drawn from study:**

- DCP test may be used to estimate shear strength of a variety of granular materials using the prediction equations.
- Factors such as moisture and density are implicitly accounted for in the single variable equations because a direct, inverse linear relationship exists between the penetration rate and shear strength.
- Detailed characteristics, such as gradation, maximum aggregate size, density, and void ratio, are not required to predict shear strength from DCP data, although they improve prediction accuracy.
- The use of a DCP device in the manner described in the paper is a viable alternative to detailed in situ test pit investigations based on CBR tests; in contrast, DCP tests are rapidly conducted and inexpensive.

# New Approaches to the Provision of LVRs Based on the Outcome of Recent Research Findings

# Geometric Design

”Fit-for-purpose” alignment engineered for fulfilling access function

- Most of existing alignment retained except in problem areas where any safety issues need to be addressed by sound engineering solutions.

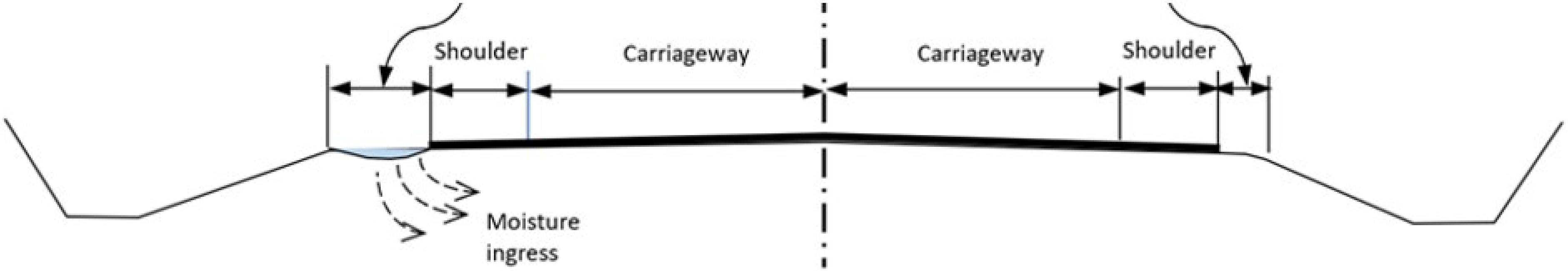
- This approach means that “the existing alignment fixes the travel speed”.
  - Will result in variable cross section widths and travel speeds but will not incur significant earthworks costs.

- Used where road is unlikely to change function over its design life; road used mostly by local people.

# Pavement Cross Section

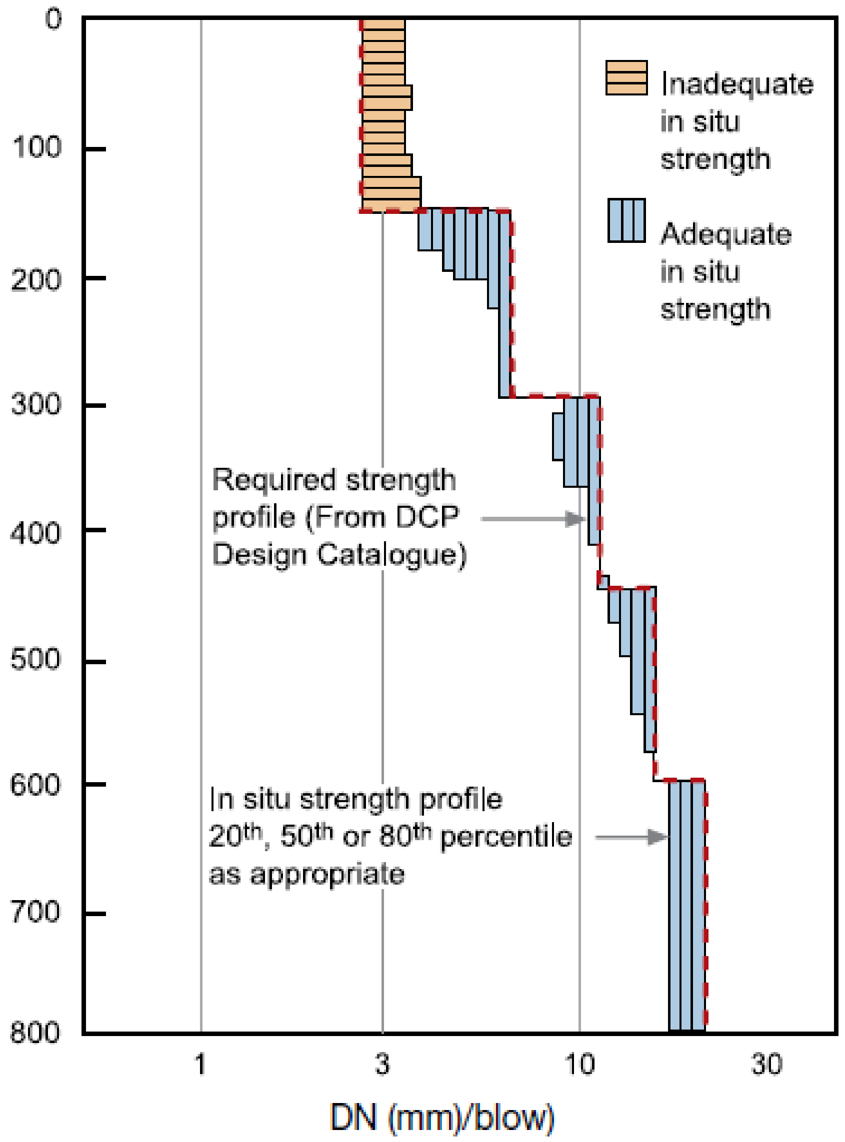
Gravel strip outside sealed shoulder used as footpath. Will develop depressions, trap water and result in moisture ingress to outer wheel path.

Edge of shoulder rounded off into side lope. Facilitates water shedding to drain.



# Pavement Design – DCP-DN Method

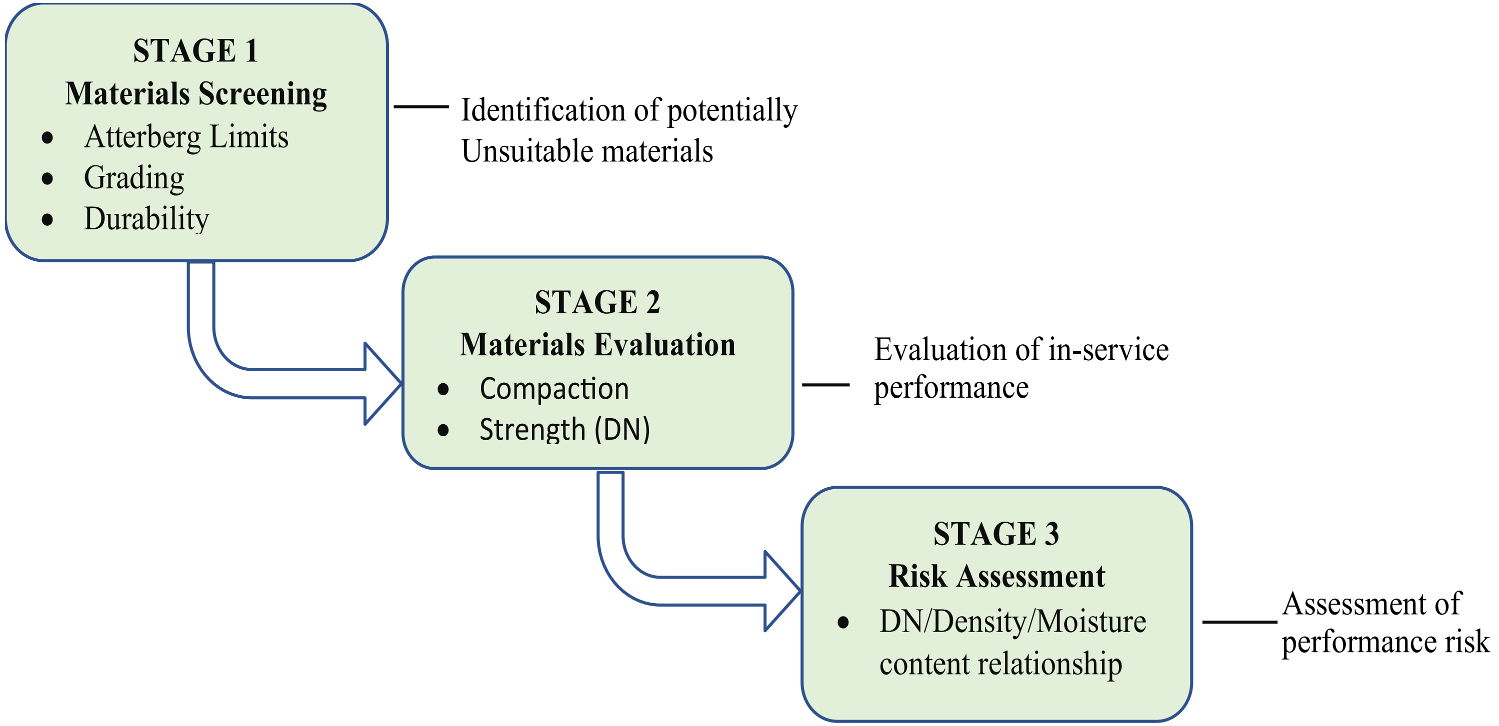
- Determining the design strength profile needed for a particular traffic loading (from a DCP design catalogue)
- Comparing design strength profile with in situ strength profile at the anticipated, in-service moisture condition.
- determining upgrading requirements for each uniform section.



# Why the DCP-DN Pavement Design Method

- Relatively low cost, robust apparatus that is quick and simple to use allowing comprehensive characterization of the in situ road conditions.
- DCP measurements provide improved precision limits compared with the more traditional CBR test.
- 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.
- Simplicity of the test allows repeated testing to minimize errors and also to account for temporal effects.
- Determination of uniform sections based on a cumulative sum analysis of DN values for the upper layers, as well as the full depth (to 800 mm) of the existing pavement. This allows section-specific pavement designs to be developed.
- Method is as good as or better than any other method in taking into account variations in moisture content and provides data quickly for analysis.

# Materials Evaluation Framework



**STAGE 1**
**Materials Screening**

- Atterberg Limits
- Grading
- Durability

Identification of potentially Unsuitable materials

**STAGE 2**
**Materials Evaluation**

- Compaction
- Strength (DN)

Evaluation of in-service performance

**STAGE 3**
**Risk Assessment**

- DN/Density/Moisture content relationship

Assessment of performance risk

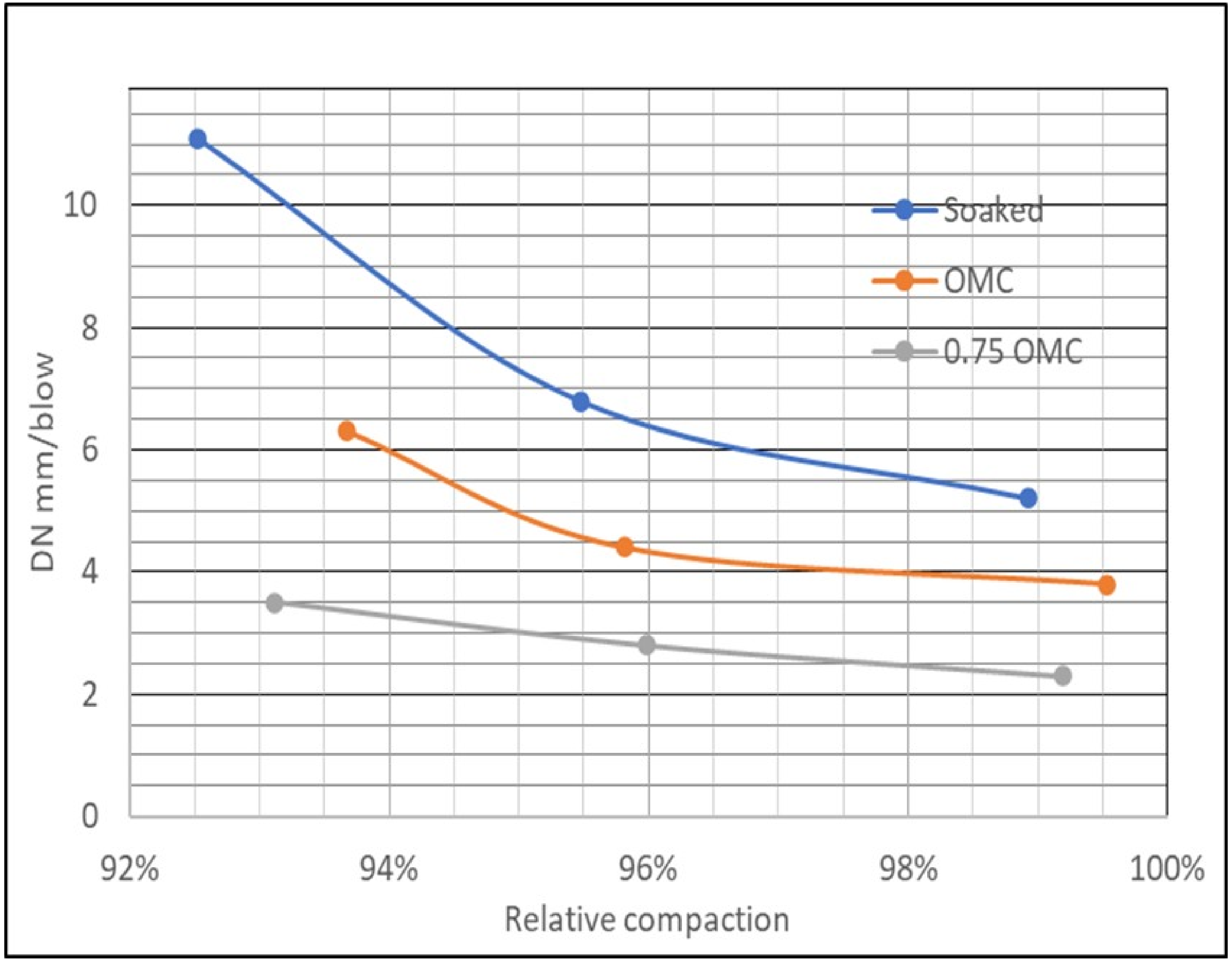
Three-stage evaluation procedure for selecting materials

**Stage 1** – **Materials screening**
Objective is to screen out, through appropriate testing, obviously unsuitable or problematic materials.

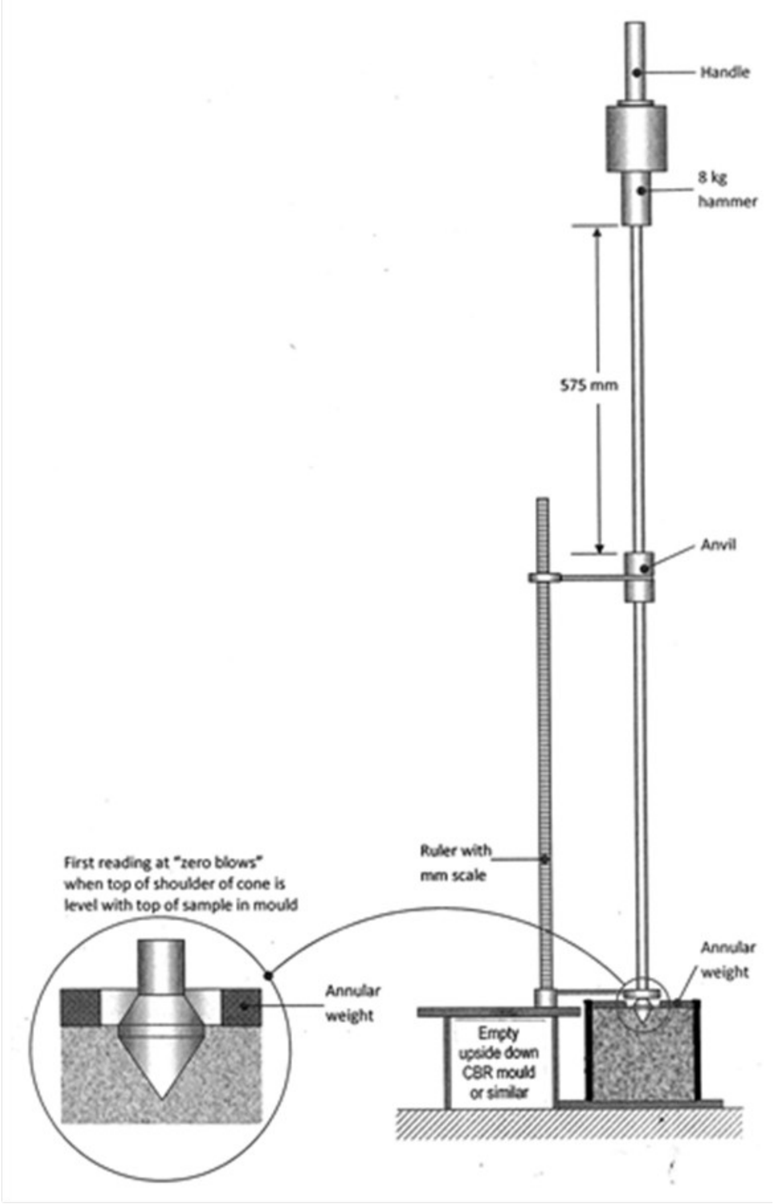
**Stage 2** – **Materials evaluation**
Objective is to evaluate the suitability of materials in terms of their strength, as related to various combinations of moisture and density, for comparison with the design requirement.

**Stage 3** – **Risk assessment**
Objective is to assess how the material responds to density and moisture content changes to evaluate the implications of such changes on the operational conditions in service.

# Laboratory Testing Output

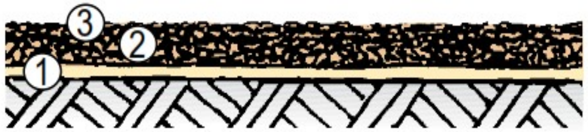


DN/density/moisture relationship

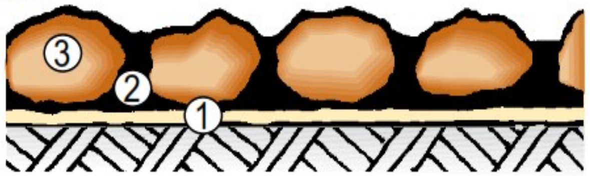


# Common types of bituminous surfacings

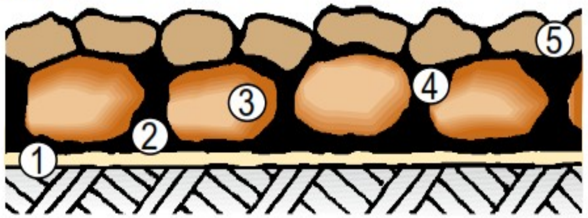
**SAND SEAL**
1 Prime
2 Binder
3 Sand



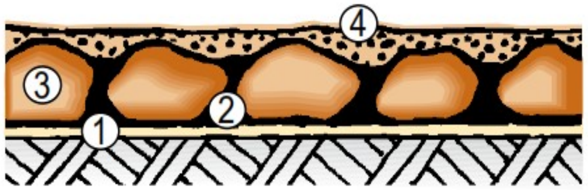
**SINGLE SURFACE DRESSING**
1 Prime
2 Binder
3 Stone



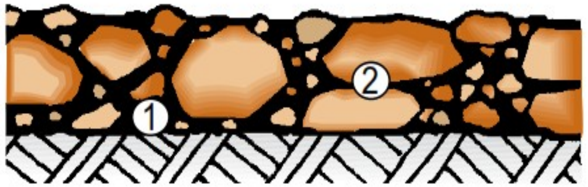
**DOUBLE SURFACE DRESSING**
1 Prime
2 Binder
3 Large Stone
4 Binder
5 Small Stone



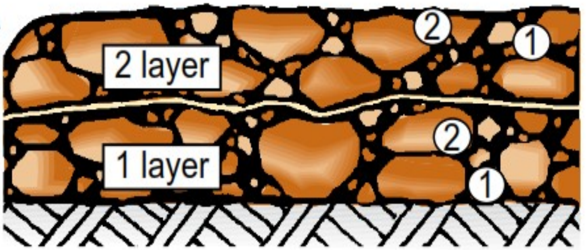
**CAPE SEAL**
1 Prime
2 Binder
3 Stone
4 Slurry



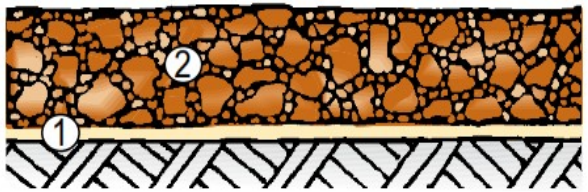
**SINGLE OTTA SEAL**
No Prime
1 Binder
2 Graded
aggregate



**DOUBLE OTTA SEAL**
No Prime
1 Binder
2 Graded
aggregate



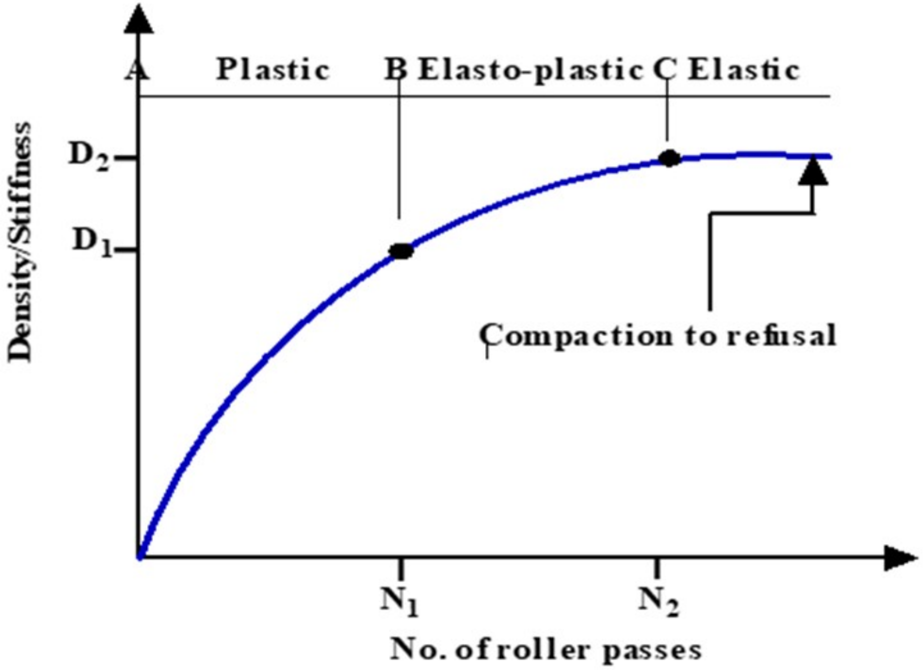
**COLD MIX ASPHALT**
1 Tack
2 Asphalt
Premix



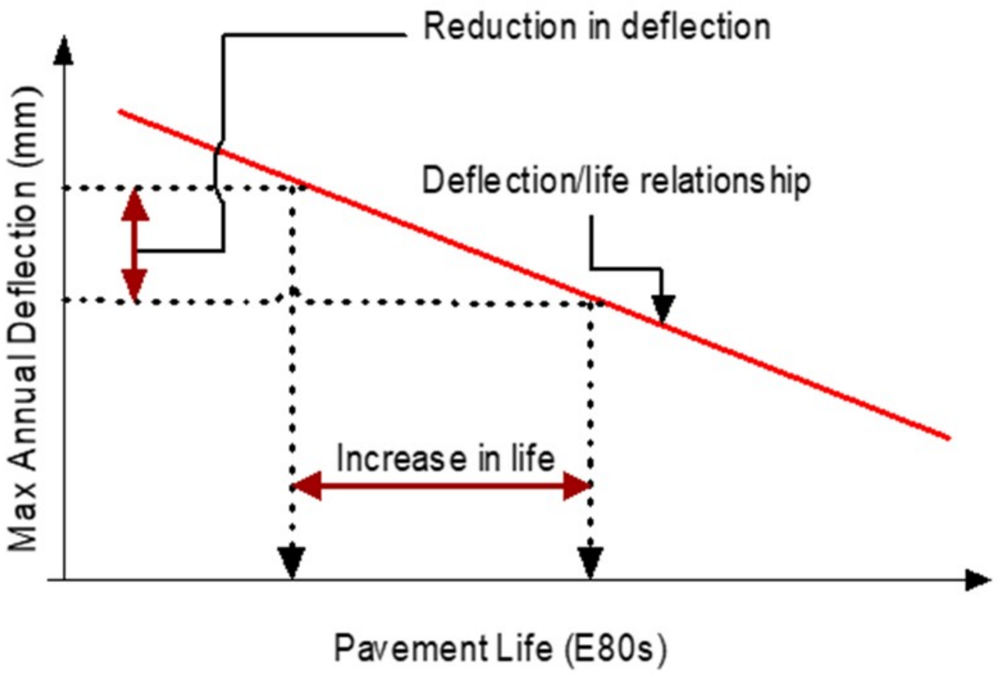
# Construction of bituminous surfacings – Cold Mix Asphalt

- A very labour-friendly sealing option
- Requires slow-setting cationic emulsion and well-graded aggregates with low fines content (≤ 7%)
- Requires only hand tools and light equipment

# Lessons Learned from Construction – Compaction to Refusal



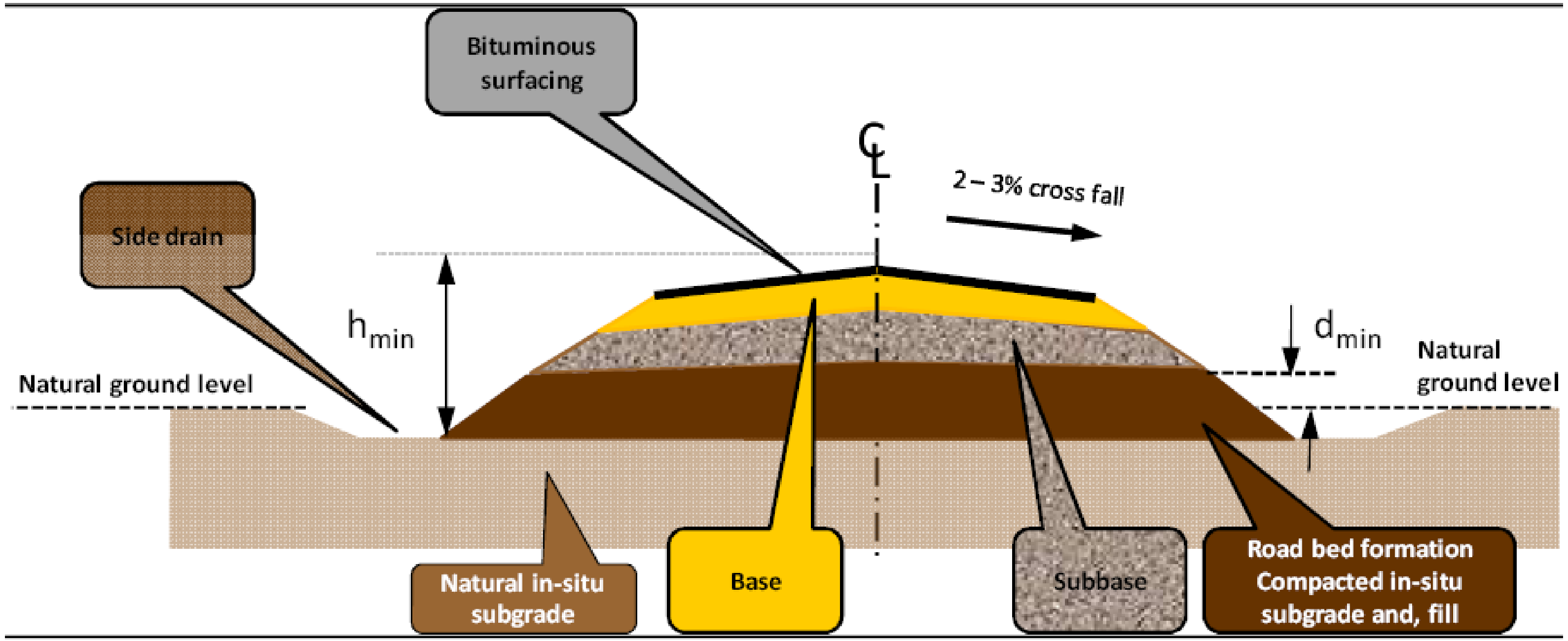
Compaction to “refusal”



Deflection/life relationship

**Level of compaction in pavement layers influences pavement life – increasing compactive effort is often economically justified**

# Ensuring Adequate Drainage – Crown Height



- $h_{min}$ > 750 mm
- $d_{min}$ > 150 mm

| Climate | Mean Annual Rainfall (mm) | Equilibrium Moisture Content | | |
|---|---|---|---|---|
| | | Subgrade | Subbase | Base |
| Dry | ≤ 500 | < OMC | 0.78 OMC | 0.63 OMC |
| Wet | > 500 | +/- OMC | | |

**Probable EMC if Crown Height Achieved**

# Design Risk Factors

Five main risks:

- Material quality (strength, durability, moisture sensitivity)
- Drainage (adequacy – crown height)
- Construction control (adequacy of compaction & layer thickness)
- Maintenance (surfacing, side drains, etc.)
- Traffic (overloading)

- Relax ONE and keep control of others. Risk increases BUT probably acceptable
- Relax TWO and risk probable failure

# Summary

- Urgent need to improve rural access in Asian and African countries
  - Attainment of this goal through the application of traditional methods of LVR provision would be prohibitively expensive

- There is now a wealth of invaluable research information now available that has provided practitioners with a better understanding of the performance mechanisms of LVRs.

- Flexibility in geometric design, low-cost improvements to drainage, adoption of appropriate road cross section, use of sealed shoulders, compaction to refusal, use of “non-standard” materials and alternative surfacing techniques have all been identified as potentially cost-effective measures for providing LVRs.

- Message is clear – the engineer needs to be more flexible in his/her approach to providing LVRs based on the outcome of valuable investigations and reserach undertaken in several Asian and African countries in the past several decades.

# Thank you