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UKaid
from the British people

Low volume roads with neat sand bases

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11th TRB Low Volume Road Conference, Pittsburgh, USA 12th – 15th July 2015

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Introduction

- Follow up on previous paper at 10^{th} LVR in Orlando
- Looked at use of phi scale for PSD of sands

  $\Phi = -\log_2 d$ (d = particle size in mm)

- Now discuss additional work and investigations
- Including investigation of actual roads where neat sands appeared to be successful

Introduction

- One of the original conclusions was the importance of iron shown by red sands
- Experience had shown that red sands appeared to work best
- This was investigated specifically

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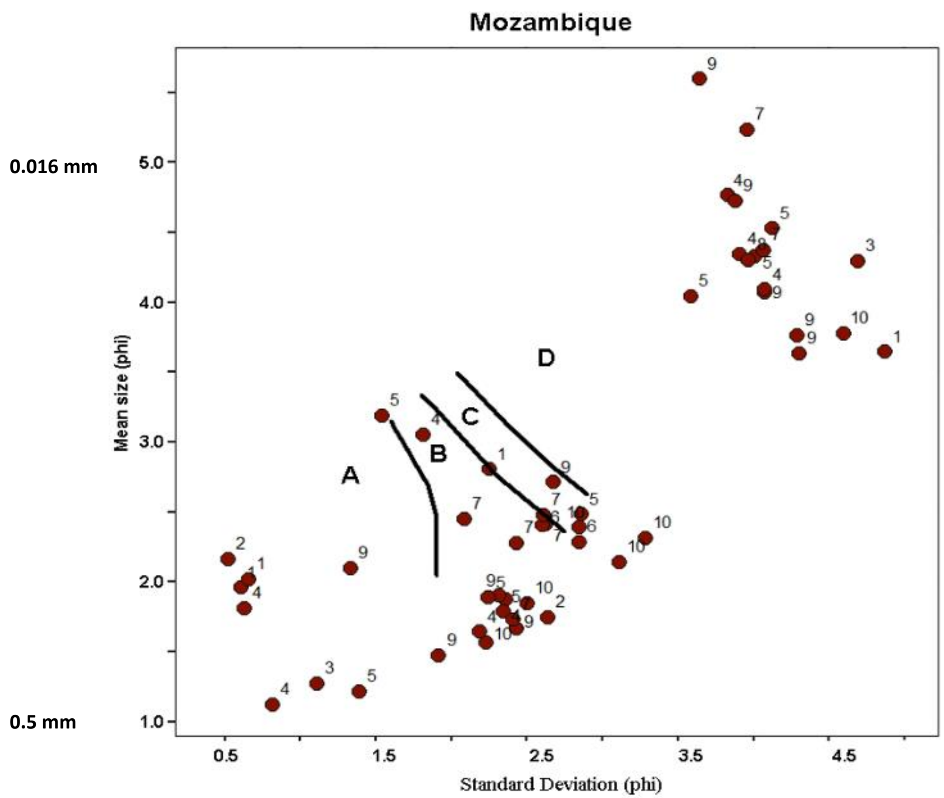
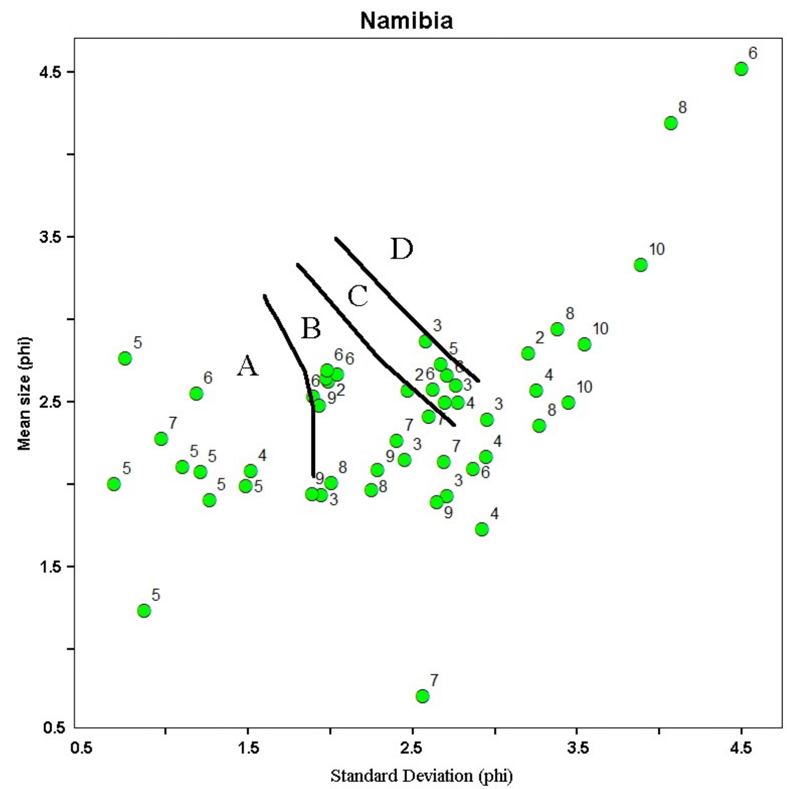
Background

- Originally one hundred samples were collected in Mozambique and Namibia
- Colour "coded" on "Wylde charts"





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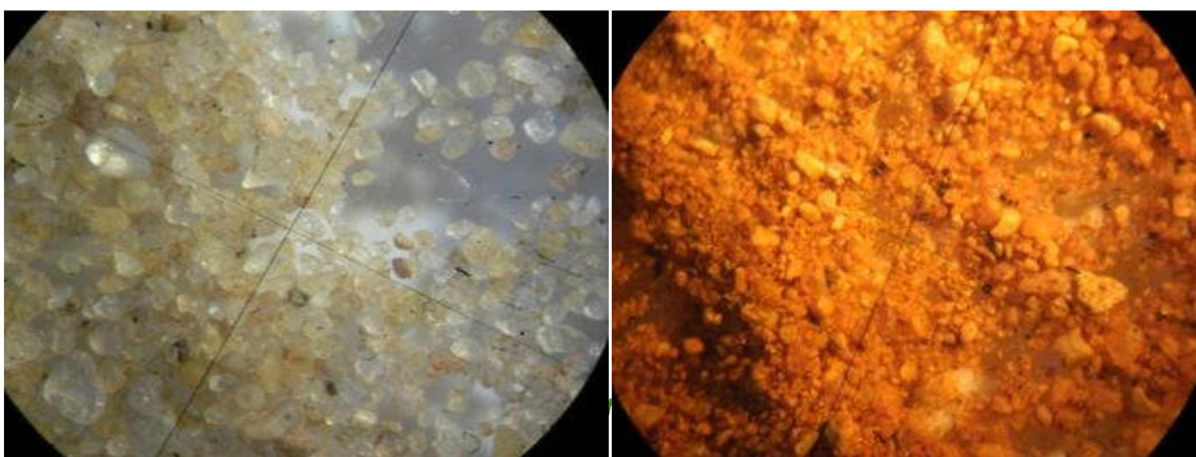
Background

- Noticed poor correlation between expected performance and colour
- Also between origin (Namibia mostly Aeolian and Mozambique mostly fluvial/coastal)
- And particle shape



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Sampling and testing

- Sampled 10 roads known to have neat sand layers and performing well
- Mozambique, Botswana, Malawi, South Africa
- Some more than 30 years old

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Sampling and testing

- Various assessments
  - Density, DCP, visuals, self-stabilisation, roughness, moisture contents, etc

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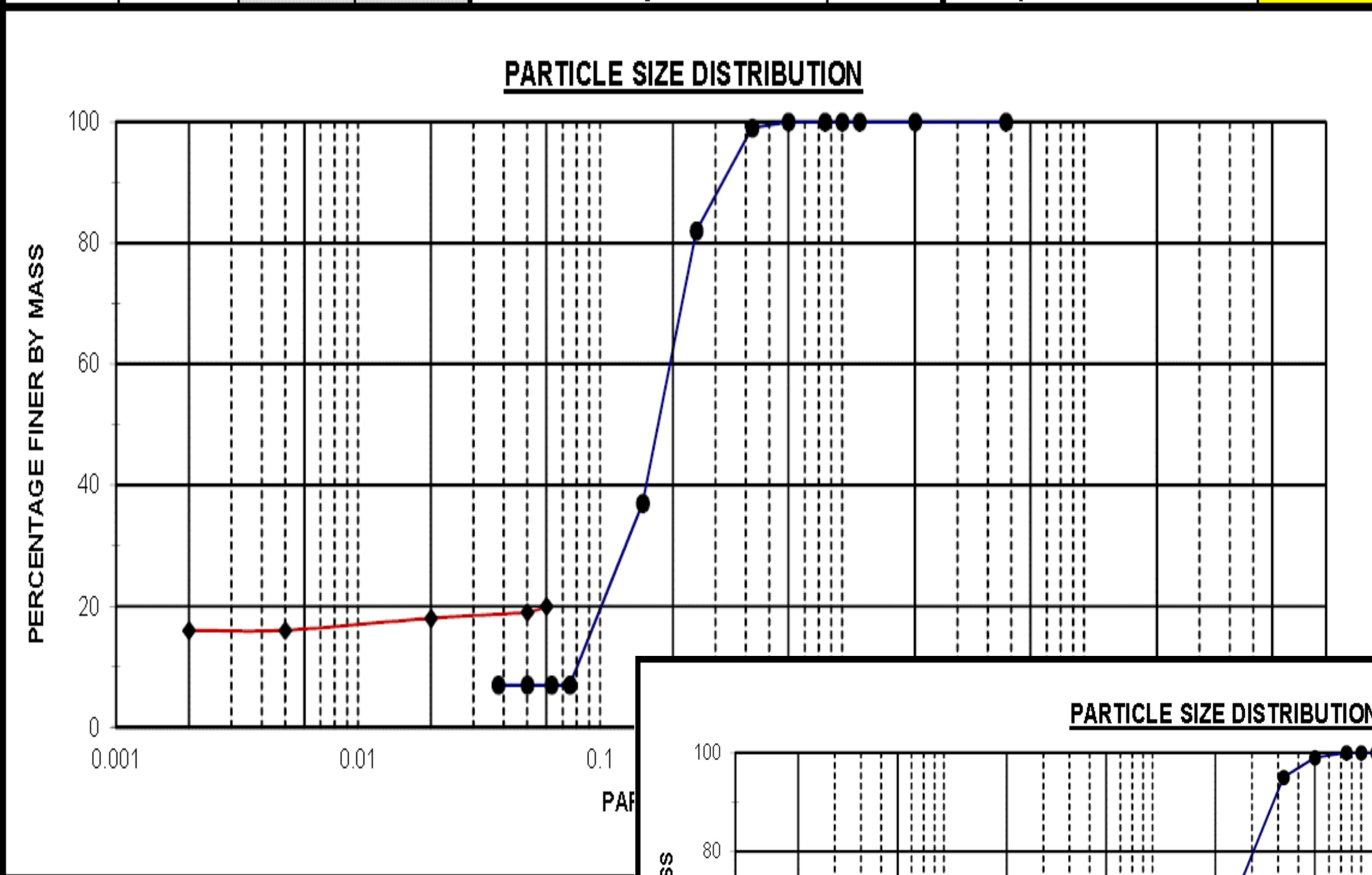
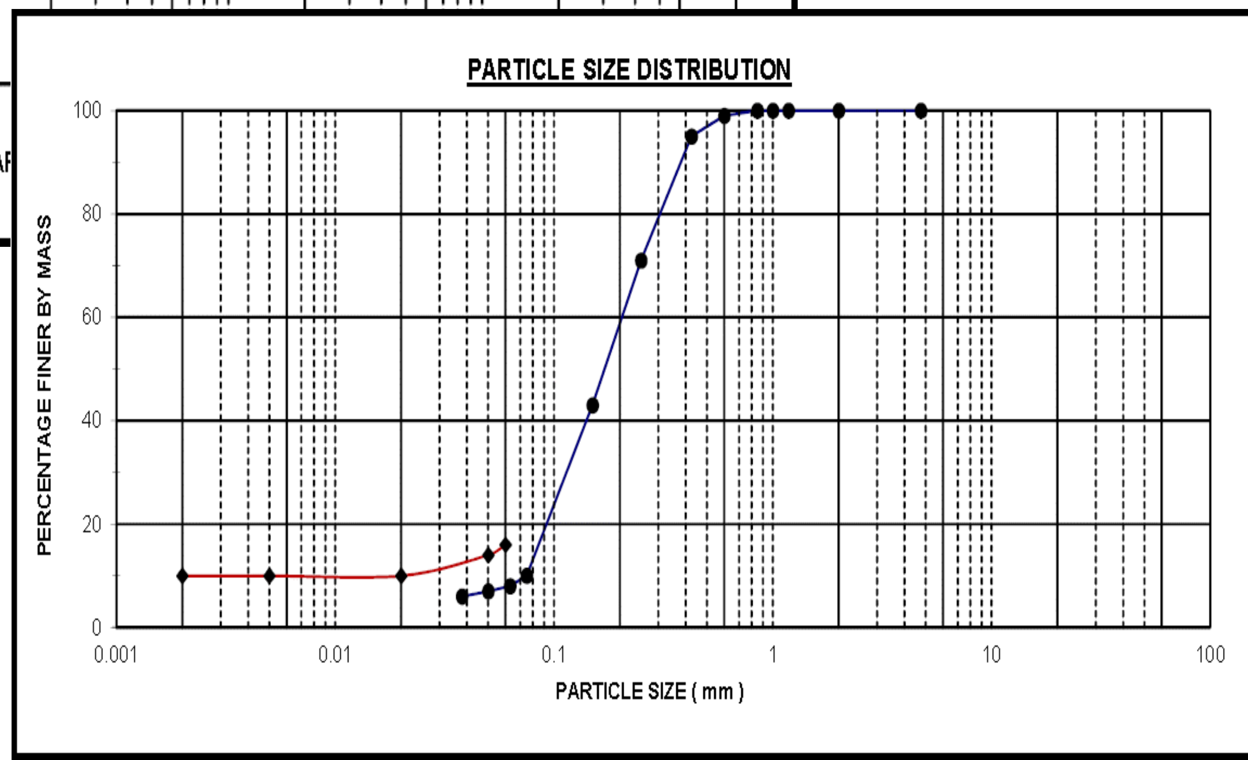
Sampling and testing

- Various laboratory tests carried out
  - Grading (sieve and hydrometer), Atterberg limits, strength (CBR and DCP DN), Fe and Al contents
- Number of problems highlighted

Sampling and testing

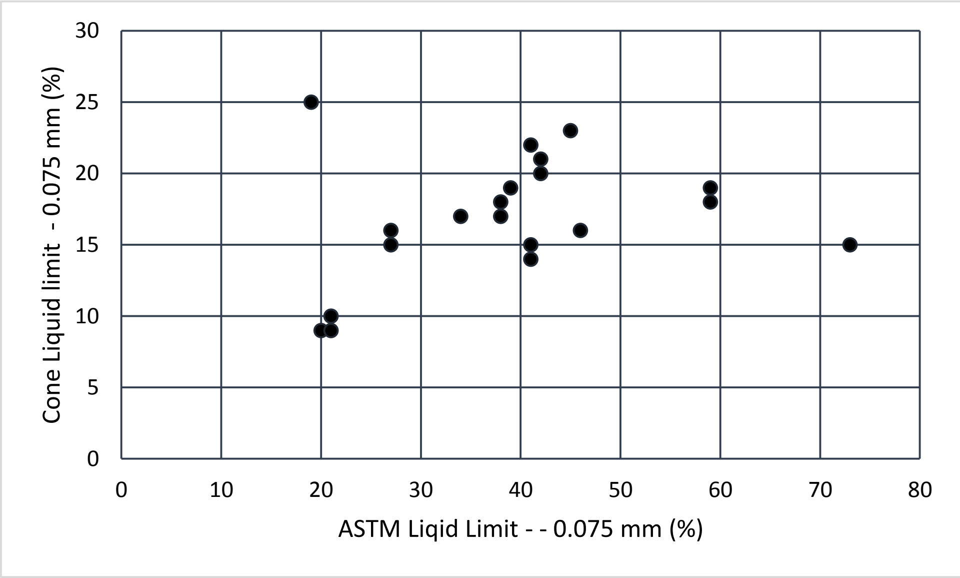
- Hydrometer
  - Need this to get higher percentiles of mass retained
  - Wide variation between laboratories
  - Dispersants, times of readings, assumed SGs, gap between sieve and hydrometer, etc
- Looked for alternatives
  - Sand equivalent, field moisture equivalent, cone liquid limit on the fine fractions, particle angularity tests, etc
  - None suitable


PARTICLE SIZE DISTRIBUTION
PERCENTAGE FINER BY MASS
100
80
60
40
20
0
0.001
0.01
0.1


PARTICLE SIZE DISTRIBUTION
PERCENTAGE FINER BY MASS
100
80
60
40
20
0
0.001
0.01
0.1
1
10
100
PARTICLE SIZE (mm)

Sampling and testing

- Atterberg limits
  - Standard test – all non- to slightly-plastic
  - Must be done on minus 0.075 mm fraction
  - All then have a PI (6 – 32%)
  - BS Cone LL (9 -25%)



Sampling and testing

- Iron and Aluminium content
  - Free iron oxide/hydroxides were considered to be important (red colour)
  - A minimum free iron and aluminium oxide/hydroxide content (i.e. the sesquioxide content) has been specified for the use of sands in Western Australia
  - Some of the potentially useful sands were grey and light brown - perhaps the free aluminium oxide/ hydroxide content may be as important as the free iron oxide/hydroxide content

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Sampling and testing

- Iron and Aluminium content
  - Free iron and aluminium oxide/hydroxide contents were determined using various techniques.
  - It should be borne in mind that only the *available* iron (or aluminium) can take part in such chemical activity
  - Iron and aluminium components "tied up" in minerals such as feldspars are not available for reaction.
  - The CBD (citrate bicarbonate dithionite) method dissolves only the free iron and aluminium oxides/hydroxides was thus used
  - Testing by two laboratories gave widely varying results

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Sampling and testing

- Iron and Aluminium content
  - X-ray fluorescence (XRF) analyses give *total* iron and aluminium
  - X-ray diffraction (XRD) analyses identify specific minerals that may contain iron or aluminium
  - The relation between the various concentrations of these two components gave a semi-quantitative indication of the available iron and aluminium contents.

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Sampling and testing

- Strength
  - The performance of a sand is directly related to its strength (or stiffness)
  - At the in service moisture.
  - Main selection criterion - a difficult property to characterize consistently.
  - Sands can be difficult to compact in the laboratory
  - Unusual behavior detected in many of the standard tests and procedures.
  - Many of the current testing procedures are not appropriate for use with sands
  - Highly variable results

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Sampling and testing

- Strength
  - Testing should concentrate on the strength of the compacted sand that can be mobilized at different density and moisture conditions expected in-service.
  - Look at the actual strength mobilized under the in situ density and moisture conditions
  - Dynamic Cone Penetrometer (DCP) penetration rate has proved to be a useful indicator

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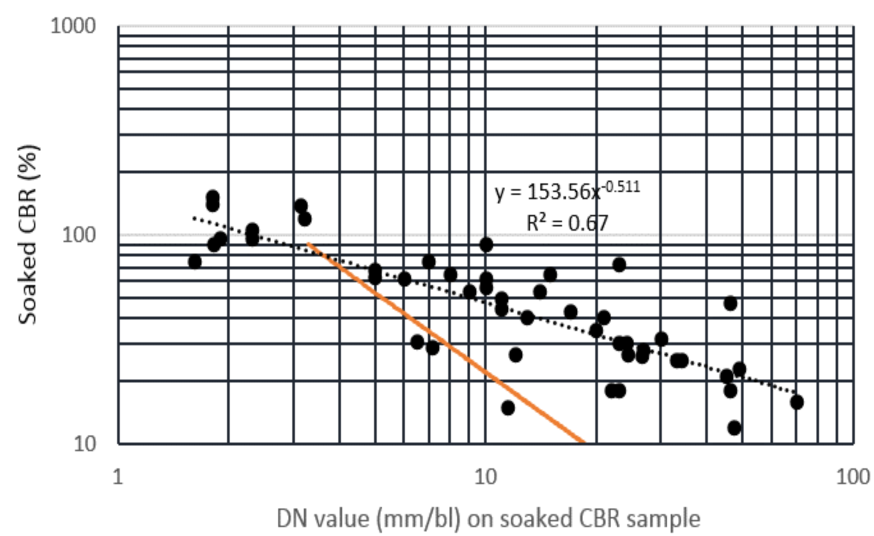
Sampling and testing

- Strength
  - Common correlations with CBR are inaccurate for sands.
  - Higher penetration rates are usually found in the laboratory than in the field under similar conditions (confinement?).
  - Preliminary evaluation of the relationship between the CBR and DCP has been developed ($r^2 = 0.67$)
  - $CBR = 153.6\ DN^{-0.511}$
  - Traditional South African model
  - $CBR = 410\ DN^{-1.27}$
  - Requires new test protocol



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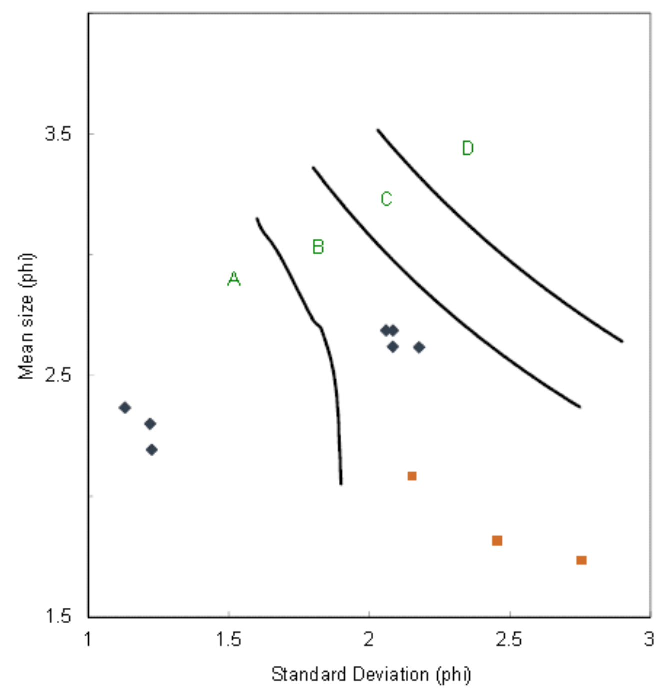
Specifications

- Proposed specification of sands

1. The material should be graded - mean and standard deviation of the particle size distribution compared with the current Wylde Chart. Materials falling within Zone B should be investigated further.
2. Marginal materials close to this zone can also be considered for further investigation if no other materials are available.
3. Ensure that there is a minimum plasticity index of 10% on the minus 0.075 mm fraction.



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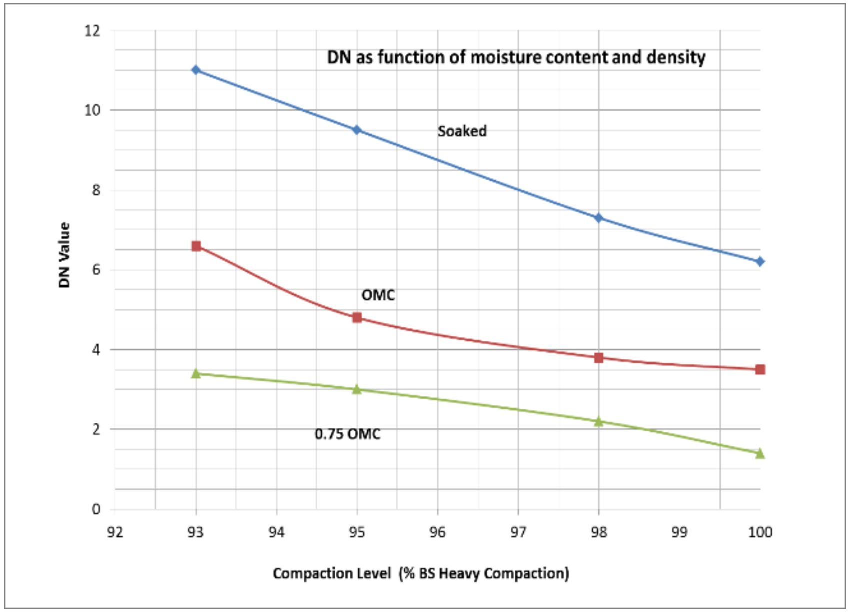
Specifications

- Proposed specification of sands

4. Investigate potentially useful materials in the laboratory be compacting them into CBR moulds (at the expected in-service moisture and density) and carrying out DCP testing
5. Determine the DCP penetration rate at a range of density and moisture contents.



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Analysis and discussion

- Definite evidence that neat sands can be used successfully
- Examples
  - Hoopstad - Constructed in 1962 using a neat (untreated) local aeolian sand as the base course.
  - 2013 annual daily traffic is about 850 vehicles per day (± 150 heavy vehicles per day)
  - estimated total of about 1.0 million equivalent standard axles (mesa) carried over 52 years that the road has been in service
  - only one reseal


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Analysis and discussion

- Examples
  - Orapa, Botswana - Constructed in 1989 using a neat Kalahari sand as the base course.
  - After 25 years the road has carried about 0.5 million equivalent standard axles and shows no notable distress.


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SAND SECTION
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Analysis and Discussion

- The state of the materials in the road is a major contributor to performance.
- Degree of densification, the in situ moisture content (related to effective drainage) and probably the effects of traffic moulding all contribute to successful performance of sands
- Construction techniques and quality also critical
- Still missing answers
- Require additional research and investigation

Conclusions

- Sands often provide the only economic source of construction materials for low volume roads in many countries
- Experience has shown that the correct sands and construction can provide effective structural layers for low volume roads.
- Conventional road testing needs to be augmented with sedimentological techniques (phi scale) to differentiate between the performance of sands
- The mean and standard deviation of the particle size and the Plasticity Index on the minus 0.075 mm fraction should be used as a screening test
- Direct strength testing using the DCP at different moisture and density conditions will identify the in service performance

Thank you

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