Identification and Mapping of Calcrete Deposits in Inhambane Province and Preparation of a Calcrete Classification System and Specifications for the Use of Calcrete in Road Construction in Mozambique

AFCAP/MOZ/091

FINAL REPORT
Report No. RPN 2551

TRL Limited, UK, in Association with InfraAfrica (Pty) Ltd, Botswana and Hearn Geoserve Ltd

March 2013
This project was funded by the Africa Community Access Programme (AFCAP) which promotes safe and sustainable access to markets, healthcare, education, employment and social and political networks for rural communities in Africa.

Launched in June 2008 and managed by Crown Agents, the five year-long, UK government (DFID) funded project, supports research and knowledge sharing between participating countries to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources.

The programme is currently active in Ethiopia, Kenya, Ghana, Malawi, Mozambique, Tanzania, Zambia, South Africa, Democratic Republic of Congo and South Sudan and is developing relationships with a number of other countries and regional organisations across Africa.

This material has been funded by UKaid from the Department for International Development, however the views expressed do not necessarily reflect the department’s or the managing agent’s official policies.

For further information visit https://www.afcap.org
Contents
1 Background .................................................................................................................. 5
2 Purpose of this report .................................................................................................. 5
3 Workshop objectives and activities ............................................................................. 5
4 Topics covered ............................................................................................................. 6
  4.1 Project objectives ................................................................................................. 6
  4.2 Project activities .................................................................................................... 6
  4.3 Remote sensing, field prospecting, GIS and database ......................................... 7
  4.4 Trial test pitting and sampling ............................................................................. 8
  4.5 Materials testing and specifications ..................................................................... 8
  4.6 Road research projects using calcrete ................................................................. 8
5 Issues and questions raised in discussions ............................................................... 8
6 Conclusions, Recommendations and Way forward ................................................. 10
  6.1 Conclusions ....................................................................................................... 10
  6.2 Recommendations and way forward ................................................................. 11
7 Field visit .................................................................................................................... 11
APPENDIX A ................................................................................................................ 12
APPENDIX B ................................................................................................................ 14
1 Background

Road-building materials meeting conventional specifications are scarce along much of the coastal and inland areas of Mozambique and, in particular, in Inhambane Province. The non-availability of good natural gravels for the construction of wearing courses has resulted in high maintenance costs for unpaved roads and expensive options such as chemical and bituminous stabilisation of sand for the construction of sealed roads in the province. The main locally available gravel material is calcrete, which in the past was considered as marginal because it frequently does not meet traditional specifications for road construction. However, calcrete has been used successfully elsewhere in the region in similar situations where good roadbuilding materials are scarce. If calcrete deposits in the province can be relatively easily located and appropriate specifications derived for their use, then this will lead to more appropriate and extensive use of this material for road construction.

TRL, in collaboration with the Aministracao Nacionale de Estrades (ANE) and assisted by Hearn Geoserve Ltd and Infra Africa was commissioned to undertake a study under the DFID/ANE-funded Africa Community Access Programme (AFCAP). The main purposes of the project were to provide guidance to ANE and the Inhambane provincial authorities on locating calcrete deposits and to assess their properties in relation to existing technical specifications for their use in road construction.

2 Purpose of this report

This report contains a summary of the objectives, presentations, discussions and outputs from the workshop and associated field visit.

The workshop programme is given in Appendix A.

3 Workshop objectives and activities

The workshop described in this report was held to present the objectives, methodology and outcomes of the project to practitioners in the road sector and to provide participants with an opportunity to contribute to discussions on the project outputs and recommendations for future work.

ANE staff from the four provinces (Inhambane, Sofala, Maputo, Zambezia and Gaza), where significant deposits of calcrete occur attended the workshop, together with representatives from the ANE and LEM materials testing laboratories.
Presentations were made by the various members involved in the project and included a presentation on the current use of calcretes in research projects in Mozambique, with opportunities provided for questions and discussion.

The workshop activities also included a field visit to selected locations where calcretes had been located.

An early draft of the project report was also distributed to the workshop participants.

4 Topics covered

A brief summary of the content of the presentations are given in this section of the report. The workshop presentations are given in Appendix B and covered each of the main project areas as well as providing an oversight of existing research projects in the road sector using calcareous materials.

The presentations covered the following main theme areas of the project:

- Project objectives
- Remote sensing using aerial photography and satellite imagery
- Field prospecting
- Mapping of potential deposits
- Trial pitting and material sampling
- GIS and database
- Materials testing and specifications
- Current road research projects in Mozambique using calcrete.

4.1 Project objectives

The project objectives can be summarised as follows:

- Location (prospecting for) road-building material (calcretes) in Mozambique (Inhambane province)
- Testing and classification
- Specifications for the use of calcretes in roadbuilding

Full details of the objectives and project deliverables are given in the Final Project Report.

4.2 Project activities

The main activities undertaken included:

- Review of existing published information
• Examination of aerial photographs and geological, topographical and soil maps of the province
• Review of available information use satellite imaging (LANDSAT, SPOT, ASTER)
• Survey of prospective sites using a calcrete probe and augering
• Test pitting in prioritised areas
• Sampling of materials
• Testing of samples
• Comparison of results with existing specifications
• Revised maps showing possible sources of calcrete
• Development of GIS and database
• Reporting

The presentation on the objectives of the project also included an introduction to the various types of calcretes and a brief reference to their mode of formation and occurrence in the region.

4.3 Remote sensing, field prospecting, GIS and database

These activities together comprised a major component of the project and were covered by two presentations in the workshop.

The first of these presentations covered background information on the formation of calcrete and experience from previous remote sensing studies undertaken in Southern Africa, particularly in Botswana and the typical field investigations used to locate calcareous materials. Photographs of the typical types of calcrete were given and of the vegetation associated with these deposits of calcareous. Not all calcareous material found in Inhambane is calcrete.

In the second presentation, details were given of the methodology used to detect deposits of calcrete in Inhambane province. This began with a survey of existing calcrete borrow pits and relating these to the indicators derived from aerial photographs and satellite imagery. The main difference from the Botswana model is that in Inhambane, deposits of calcrete are not found in ‘pan’ areas, although they are often primarily associated with general low-lying areas, which can be identified by examination of stereo pairs of aerial photographs and satellite imagery. Investigations with a calcrete probe and an auger were used to detect the presence of calcrete.

Also presented was the outcome of the various phases of remote sensing and field surveys, which enabled a geomorphological map to be prepared which also shows probable sources of calcrete together with the identification of priority sites for further field investigations. The use of ASTER data was a critical factor in identifying future areas to be investigated.

The GIS and database components of the project were also included in this presentation. The GIS links the layers of the various location and other data for the deposits investigated and can be linked to additional sources of information. The live link ensures that the latest data is available. Potential, active and exhausted sites are included together with discounted sites that can be excluded from future prospecting on the basis that no calcrete was located. Provision for the location of individual
trial pits within a potential deposit is also included. Various material tests are included in the database with a provision for additional tests to be added.

4.4 Trial test pitting and sampling
Two presentations covered the methodology used in testing pitting and sampling, which was organised and supervised by ANE. Test pitting was done by labour which is a time-consuming exercise with limitations on the depth of material that can be excavated safely. Due to time constraints, it was possible to excavate just one pit at each of the priority areas identified from the remote sensing activities. Samples of material were taken according to a previously agreed methodology. The approximate lateral extent of the deposit was investigated up to an area of 200m by 200m and to a depth of approximately 1.8m using the calcrete probe. Samples were bagged and transported to the ANE and LEM laboratories for testing.

Photographs of the types of vegetation that occur on calcareous soils were presented and samples of the plants circulated amongst the workshop participants.

4.5 Materials testing and specifications
This presentation covered the results of the material testing programme and existing specifications for the use of calcrete in road construction. Three ‘identical’ samples of material were prepared from each trial pit and one sample each dispatched to the LEM laboratory at Maputo, and the ANE laboratories at Maxixe and Maputo. The quality of materials in calcrete borrow pits varies significantly both laterally and with depth. Therefore, the results of tests from just one pit are unreliable and additional pitting, sampling and testing is required for these locations. There were additional problems related to the calibration of testing equipment and the different test methods being used that further complicated interpretation of the test results. The results of the limited testing undertaken were presented and discussed in relation to existing specifications together with outline recommendations for their possible use in Mozambique. An example of a road construction project in Botswana was also presented in which calcareous materials that did not meet conventional specifications had been used for the construction of 300kms of sealed road crossing the Kalahari to Namibia.

4.6 Road research projects using calcrete
Examples of ongoing research projects involving the use of calcareous materials in Mozambique were presented. The presentation reiterated the lack of good quality materials in Inhambane that meet conventional specifications materials. The research projects include the blending of sand with calcrete, using calcrete for armouring of road base, the use of calcrete as a surfacing aggregate in Otta seals and highlighted the need for long-term monitoring.

5 Issues and questions raised in discussions
The outcome of the discussions which ensued during and subsequent to the presentations and responses to questions raised are summarised below:

- The difference between the different forms of calcium carbonate-bearing materials, particularly limestone and calcrete was clearly an issue. In the context of calcrete formation,
tertiary limestone was formed under the sea millions of year ago and provides a source of the calcium carbonate which, in solution, indurates and precipitates in the host soil to form calcrete.

- The limestone and harder forms of calcrete were not tested in this project but these materials have been used as roadbuilding material elsewhere and can provide a source.

- Testing with dilute hydrochloric acid is used to detect calcium carbonate with which it reacts (with obvious effervescence) to produce carbon dioxide. Commercially available swimming pool acid from a local supermarket was used on site.

- On the subject of vegetation that occurs in calcrete-bearing soils, the thorny plants found can also amongst other vegetation but they are more abundant in calcareous soils.

- The measurable thickness of the deposits found in this preliminary prospecting exercise was limited to approximately 1.8 metres using the calcrete probe and augering and to 2 metres in the trial pitting. This included the depth of overburden. The average depth of the calcrete investigated was approximately one metre but the full depth (i.e. lower limit) of the calcrete seams was not determined. The approximate minimum area of the deposit was determined up to a maximum area of 200m x 200m using the probe. Subsequent trial pitting, sampling and testing will be required in the usual prescribed way to determine the full extent, depth and quality of the materials present.

- The hardpan calcrete is usually found as hard layer in the upper layers of calcrete deposits which, in Inhambane, are often associated with grey sand but an observation was made from a presentation that a hard deposit was found at depth in an area of red sand. This could be a limestone deposit or an older deposit of calcrete.

- The GIS was still being developed at the time of the workshop but it was explained that the development of the associated database will continue with the facility for additional data being added by ANE.

- The outcome of materials testing component of the project was clearly of some concern. Within the time and resource constraints of the project, it was possible to sample from only one trial pit in each of the areas which had been identified from the remote sensing and surface surveys for priority investigation.

- Material in calcrete borrow pits tend to vary in quality both in extent and with depth due the mode of formation and a single sample can provide only a limited indication of the material available. However, the results did raise questions about sampling sizes for testing, the test methods being used and the calibration of testing equipment.

- Specifications developed for the use of calcretes in the region were presented. It is clear that the above issues with respect to testing will have important implications in deciding which specifications should be used pending development of specifications for calcretes in Mozambique. These are important issues that need to be resolved.

- The final presentation was on ongoing research by ANE in Mozambique using calcareous material. Of particular interest were the use of sand/calcretes blended material and the use of calcretes as aggregate in Otta seals.
6 Conclusions, Recommendations and Way forward

The results of the prospecting together with conclusions and recommendations are included in the Final Project Report but are also presented here as information for the workshop participants who may be involved in further prospecting activities in Inhambane or other provinces in Mozambique.

6.1 Conclusions

- Comparing ground and environmental conditions found at existing calcrete borrow areas in Inhambane Province from stereo aerial photography and satellite imagery provides an indication of similar conditions elsewhere.
- The landform indicators used in Botswana were not generally applicable in Inhambane Province.
- Vegetation types associated with calcrete in other parts of Southern Africa also indicated a presence of calcrete in Inhambane Province.
- The calcrete probe and a hand auger were useful tools in confirming (or otherwise) the presence of calcrete at the predicted locations.
- Examination of satellite imagery using the known calcrete locations as control can be used to identify common visual and spectral signatures to extrapolate the same conditions to other areas for prospecting purposes.
- The ASTER data was helpful in mapping low-lying areas with which calcrete deposits are associated and can be extrapolated to other areas for prospecting purposes.
- A preliminary Geomorphological and Calcareous Materials Map for Inhambane Province at 1:250,000 scale was produced.
- A list of 48 calcareous locations (additional to the existing calcrete borrow areas) where either remote sensing, surface probing investigations or outcrop gave rise to the identification of calcareous materials.
- 16 sites were considered likely to be in situ Tertiary limestone, Tertiary calcareous sandstone or Quaternary coralline materials (i.e. definitely not calcrete)
- 8 sites were considered likely to be calcrete based on the probe results, but were not investigated with trial pits
- 5 sites were considered to be lacustrine limestone based on probe results and the published outcrop pattern, but were not investigated with trial pits
- 6 sites were considered likely to be either calcrete or lacustrine limestone, based on surface evidence, i.e. ‘outcrop’, but were not investigated by trial pits;

Of the 13 sites investigated by trial pits:
  a) 10 yielded calcrete
  b) 1 yielded what is considered to be Tertiary limestone, and
  c) 2 yielded sand only.
6.2 Recommendations and way forward

It is recommended that the following actions are taken in relation to the outcome of this study:

- Investigate further the proven calcrete deposits (i.e. the 8 out of the 10 positive trial pitting investigations undertaken during this study). This will require the use of a back hoe to excavate a greater number of pits at each location to a greater depth in order to determine the quality and variability of the material in each case.
- Collect samples at each of these additional trial pits and carry out the tests previously scheduled.
- Take samples from some of the borrow areas in the mapped Lacustrine Limestone between Mabote and Tome and carry out the same tests on these for comparison.
- Undertake a trial pit investigate of the remaining 8 suspected calcrete locations and collect samples for testing.
- Carry out a probing investigation of the 36 additional potential calcrete locations identified from the Google Earth imagery and listed in the Final project Report.
- Use the ASTER imagery to assist in future campaigns for calcrete prospecting.
- Extend the methodology applied in this study to other Provinces where there is a potential presence of calcrete. According to the rainfall map of Mozambique this would include Gaza, Maputo and Tete Provinces.

7 Field visit

An important component of the workshop activities was a field visit that enabled workshop participants to relate the remote sensing, prospecting and sampling techniques presented at the workshop to the field conditions where calcrete had been located.

Activities in the field included demonstrations and hands-on use of the calcrete probe and augering techniques as well as an opportunity to observe typical plants that occur in areas with calcareous soils.

It was also an opportunity to observe and handle samples of typical calcareous materials.
APPENDIX A

Workshop Programme
# CALCRETE PROJECT WORKSHOP

**Outline Programme**

**Thursday/Friday 14/15th March 2013**  
Vilanculos, Mozambique

<table>
<thead>
<tr>
<th>Time</th>
<th>Subject</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>08.00 - 08.30</td>
<td>Arrivals/Registration</td>
<td></td>
</tr>
</tbody>
</table>
| 08.45     | Opening                                           | Albino Novela  
Provincial Director of Public Works and Housing                         |
| 09.00     | AFCAP                                             | Nkululeko Leta                                                            |
| 09.15     | Background to project                            | Tony Greening                                                             |
| 09.30     | Introduction to remote sensing techniques        | Gareth Hearn                                                              |
| 10.00     | Coffee / Tea break                               |                                                                           |
| 10.45     | Remote sensing for calcretes in Inhambane province| Gareth Hearn                                                              |
| 11.15     | On-site surveying                                 | Joana Guiulele Francisco Menheche                                         |
| 11.45     | Test results and specifications                  | Tony Greening                                                             |
| 12.15     | Discussion                                       |                                                                           |
| 12.30     | Lunch                                            |                                                                           |
| 14.00     | Research on use of calcrete in Inhambane          | Kenneth Mukura                                                            |
| 15.00     | Coffee / Tea                                     |                                                                           |
| 15.30     | Summary                                          | Tony Greening  
Gareth Hearn                                                                |
| 16.00     | Closure                                           | Eng Fernando Dabo  
(ANE Delegado – Inhambane Province)                                      |
| Friday 14 March 08.00 – 16.00 | Site visit                                      | Workshop Participants                                                   |
APPENDIX B

Workshop Presentations
The Africa Community Access Programme
by Nkululeko Leta
THE AFRICA COMMUNITY ACCESS PROGRAMME

Identification and Mapping of Calcareous Deposits in
Inhambane Province and the Preparation of a Calcareous
Classification System and Specifications for the Use of
Calcite in Road Construction in Mozambique

14th - 15th March 2013
Agua Negra Hotel,
Vilanculos, Mozambique

AFCAP
Calcrete as a roadbuilding material
by Tony Greening
AFCAP

Project Objectives

- Location (prospecting for) road-building material (calcretes) in Mozambique (Inhambane province)
- Testing and classification
- Specifications of the use of calcretes

AFCAP

PROJECT ACTIVITIES

- Review of existing published information
- Examination of aerial photographs and various maps of the province
- Review of the use satellite imaging available images
- Survey of prospective sites with a calcrete probe
- Test pitting in prioritised areas
- Sampling of materials
- Testing of samples
- Comparison of results with existing specifications
- Revised maps showing possible sources of calcrete
- Preparation draft report
**AFCAP**  
**IMPORTANCE OF MATERIALS IN ROAD CONSTRUCTION**
- Materials typically make up to 70% of total cost of road
- 90% of problems occurring on low-volume roads are materials related
- Large benefits from knowledge about use of local materials

**AFCAP**  
**ROAD BUILDING MATERIALS**
- Road building materials mostly derived from weathering and pedogenesis
- Each group has a characteristic range of properties and potential problems which should be taken into account by test methods and specs
- Conventional specs often unnecessarily restrictive and can result in costly failures as well as over-conservative, uneconomic designs
- Specs tied directly to test methods used in carrying out research work — dangerous to mix.

**AFCAP**  
**FORMATION OF CALCARE**
- Calcareous materials are formed by pedogenesis.
- In times of high rainfall calcium (and magnesium) carbonates dissolve and the resulting solution indurates existing soils.
- Carbonates are precipitated out of solution and replace the host material.
- Repeated action over long periods lead to deposits of calcare.
- Other pedogenic materials are formed in similar process — silcrete (with silica) and laterite (mainly with oxides of iron).
- The materials harden in time to the various forms of calcare: calcified sand (rarely other host material), powder, nodule, boulder/hardpan calcare.

**AFCAP**  
**Types of calcare**
- Boulder
- Hardpan
- Nodular
- Powder
- Calcified (sand)

**AFCAP**  
**EXAMPLES OF TYPICAL TYPES OF CALCARE USED IN ROAD**

**AFCAP**  
**USE OF CALCARES IN ROAD CONSTRUCTION**
- **BOULDER/HARDPAN** - Surfacing aggregate (CRUSHED)
- **NODULAR** - gravel wearing course
  - natural (uncrushed) as base course in sealed roads
- **POWDER** - gravel wearing course
  - base course (USFR's)
  - sub-base
- **CALCIFIED (sand)** - sub-base (USFR's)
Calcirete borrow pit

THANK YOU
Introduction to calcrete sources: Inhambane in a South African context

By Gareth Hearn
Definitions

- Pedocretes:
  - Materials that have formed in place, either at or below the surface as a result of weathering, cementation or replacement of existing soil particles by minerals precipitated from soil water or groundwater
  - What used to be called:
    - Surface limonite is now referred to as calcrete
    - Surface ironstone as ferricrete
    - Surface quartzite as silcrete

Different types of calcrete

Climate and Calcrete Development

The correlation between the distribution of calcretes and climate is marked. In Southern Africa well-developed calcretes...
Soils and Calcrite Development

- Only when the soil profile is residual or the thickness of the transported cover is reasonably thin, does the soil-geology determine whether or not calcrite will form. In such profiles, calcrite is likely over calcareous rocks, such as limestone, dolomite, calcareous shale and mudstone. Calcrites also sometimes mark faults, probably in many cases largely due to shallow water-table conditions.
- A thickness of soil cover within certain limits appears necessary for significant calcrite formation. If the soil is too thin, little rainwater can be retained and calcrite formation is limited. If it is too thick and the water-table is deep, the soil will absorb all the water and prevent dissolution of the underlying rock.

Vegetation and Calcrite Development

Calcium/calcrite tolerant plants (Botswana MWTC)

<table>
<thead>
<tr>
<th>Botanical Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia tortilis</td>
<td>Veld thorn</td>
</tr>
<tr>
<td>Acacia nilotica</td>
<td>Dingo thorn</td>
</tr>
<tr>
<td>Acacia nilotica</td>
<td>Hook thorn</td>
</tr>
<tr>
<td>Acacia nilotica</td>
<td>Water thorn</td>
</tr>
<tr>
<td>Acacia nilotica</td>
<td>Water thorn</td>
</tr>
<tr>
<td>Calotropis alexandrin</td>
<td>Trumpet thorn</td>
</tr>
<tr>
<td>Combretum imberbe</td>
<td>Leadwood</td>
</tr>
<tr>
<td>Dichrostachys cinerea</td>
<td>Shikra bush</td>
</tr>
<tr>
<td>Ericea leucantha</td>
<td>Snow bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>False brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>False brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
<tr>
<td>Erica herbacea</td>
<td>Brassy bush</td>
</tr>
</tbody>
</table>

Experience Mapping Calcrites Elsewhere in Southern Africa

Techniques
- Satellite and airborne remote sensing, using multi-spectral analysis and other sensors
- Characteristic landform mapping from aerial photograph interpretation and field mapping
- Field reconnaissance and detailed survey
Remote Sensing Options for Calcrite Prospecting

Selected studies
- Colour and black and white aerial photography proved highly useful in Botswana, for direct visual recognition of characteristic landforms.
- SLAR – proved useful for calcrite mapping in Nigeria, especially useful where vegetation is more dense.
- Multispectral (including infra-red) analysis of satellite imagery: from Botswana false colour composites using Bands 4 (red), 5 (green) and 7 (blue) proved successful.
- Landsat MS – unsuccessful in Namibia.

Botswana: Pan morphology and calcrite occurrence

- Pans support very circular depressions of the relative relief greater than equal to 50m in diameter with a well-developed pattern of intercalations are almost certain to yield large quantities of valuable quality calcrite in the pattern and in the scattered, lower quality calcrite material in the pan.
- Pans greater than 500m in diameter with a well-developed pattern of intercalations are less certain to yield large quantities of valuable quality calcrite in the pattern, but usually of quantities high enough.
- Pans less than 500m with a pattern may yield good quality calcrite in the pattern, but usually of quantities high enough.
- Pans less than 500m without a pattern may yield calcrite of considerable quality.
- Depressions are usually identified only by the quality calcrite, as gases grow in the Tef or concave floor of the depression to the exclusion of mineral growth on the surrounding plains.
- Grey sands occur without topographical expression and may contain poor quality calcrite in areas where no pans or depressions exist. They are usually cored by 1.5m or horizontal.

Idealised section across calcrite-forming depression (from Netterberg 1969)

Typical Field Investigations

<table>
<thead>
<tr>
<th>Reconnaissance survey</th>
<th>Detailed Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose is to obtain an overview of the area of interest, i.e. to identify specific sites.</td>
<td>Purpose is to make a detailed record of the most appropriate sources of material for the project, i.e. to investigate specific sites identified in the reconnaissance survey.</td>
</tr>
<tr>
<td>Large distances are covered quickly to obtain an overview of the area of interest.</td>
<td>The sites are covered methodically, in detail and in the context of the project.</td>
</tr>
<tr>
<td>Monitoring materials are taken, but a sampling plan is prepared.</td>
<td>Samples are taken as necessary to determine the nature and quality of the material in the context of the project.</td>
</tr>
</tbody>
</table>
Existing Calcere Bover Pits in Southern Inhambane Province

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Location</th>
<th>Area</th>
<th>Calcere Type</th>
<th>Calcium Carbonate</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-1</td>
<td>Coa &amp; Other</td>
<td>548k</td>
<td>22% Calcere</td>
<td>Large gravel &amp; crust of calcere</td>
<td>N/A</td>
</tr>
<tr>
<td>01-2</td>
<td>Coa &amp; Other</td>
<td>548k</td>
<td>22% Calcere</td>
<td>Large gravel &amp; crust of calcere</td>
<td>N/A</td>
</tr>
<tr>
<td>01-3</td>
<td>Coa &amp; Other</td>
<td>548k</td>
<td>22% Calcere</td>
<td>Large gravel &amp; crust of calcere</td>
<td>N/A</td>
</tr>
<tr>
<td>01-4</td>
<td>Coa &amp; Other</td>
<td>548k</td>
<td>22% Calcere</td>
<td>Large gravel &amp; crust of calcere</td>
<td>N/A</td>
</tr>
<tr>
<td>01-5</td>
<td>Coa &amp; Other</td>
<td>548k</td>
<td>22% Calcere</td>
<td>Large gravel &amp; crust of calcere</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Other Calcium Carbonate Materials (not calcere)

- Columnar Carbonate (Coral/Limecrete/Mammillae)
- Quartz Sandstones (Mica 7%, Mica 5%, Mica 4%)
- Quartz Sandstones (Mica 3%, Mica 2%, Mica 1%)
- Quartz Sandstones (Mica 1%, Mica 0.5%)

Images of the calcere and other calcium carbonate materials are shown in the document.
Calcereous Materials in Inhambane

- Tertiary Limestone
- Tertiary Calcereous Sandstone
- Quaternary Coralline Materials
- Quaternary Lagonidine Limestone
- Quaternary Calcreta

Thank you for your attention.

‘Who said its not calcrete!’
Calcrete prospecting in Inhambane province: Remote sensing and field Mapping
By Gareth Hearn
Methodology

- **Phase 1 Fieldwork:** determine site characteristics of existing borrow pits using field reconnaissance.
- Use remote sensing to identify:
  - a) where these characteristics can be found elsewhere.
  - b) if the typical landform conditions indicative of calcrete in Botswana occur in Inhambane and investigate these for calcrete.
- **Phase 2 Fieldwork:** based on the above use a calcrete probe and hand auger to test for calcrete from the remote sensing interpretations.
- **Phase 3 Fieldwork:** carry out trial pitting in priority areas where probing had proven successful.
- Use the results of the above to reassess the satellite imagery visually and digitally (using multi-spectral analysis) and based on a proven set of calcrete locations.
- Identify further sites for future prospectioning by ANE.

Contents of this Presentation

- Methodology
- Phase 1 Fieldwork – review of existing calcrete borrow pits
- Phase 2 Fieldwork – preliminary Remote Sensing – Visual Interpretation
- Phase 2 Fieldwork – surface probing
- Phase 3 Fieldwork – trial pitting
- Phase 2 Fieldwork – reassessment and analysis of remote sensing using the results of Phases 2 and 3 fieldwork
- Geomorphological and Calcareous Materials Map at 1:200,000 scale for Inhambane Province
- List of future prospects for calcrete probing and investigation

Phase 1 Fieldwork: Existing Calcrete Borrow Areas

| Borrow Pit | Field Noted
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Notes</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Phase</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

| Borrow Pit | Field Noted
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Notes</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Phase</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Remote Sensing Data Sources

- Black and white aerial photography for the entire Province at Cenacarla.
- LANDSAT 7 satellite imagery downloaded from the USGS Earthexplorer website.
- SPOT 5 available as on-screen view only on Google Earth.
- SPOT 5 for the eastern part of the Province as digital data at Cenacarla.
- ASTER DEM downloaded from NASA.

Note that the SPOT 5 at Cenacarla was not used as it only covered the eastern part of the Province.
Phase 1 Desk Study: Stereo aerial photograph interpretation

The stereo aerial photography was very good at identifying subtle drainage features, including pans and drainage lines such as these.

Outcome of the Stereo Aerial Photograph Interpretation

- The photographs were taken in the 1960s and are approximately 1:400,000 scale. However, even at this small scale, subtle differences in photograph tone and morphology could be picked out.
- They have been upsized into sets of individual runs to produce linear mosaics which can be positioned relative to one another to yield an overall mosaic of most of the Province at an approximate scale of 1:90,000.
- Identification of pans and, where present, pan platforms:
  - Very obvious recent pans and pan lakes close to the coast
  - More subtle pan features further inland.
- The terrain surrounding each of the existing borrow pits was examined to identify characteristic topography and drainage patterns.
- The interpretation allowed a terrain classification system to be developed.

Google Earth SPOT Image for Existing Borrow Pits 1 & 2

Visual Identification of Areas on Google Earth with Potentially the Same ‘Reflectance’ of the Existing Borrow Pits
Visual Identification of Areas on Google Earth with Potentially the Same ‘Reflectance’ of the Existing Burrow Dits

Phase 2 Fieldwork

Calculation probe (Netterberg 1998)

Probe Refusal vs Material Type (Netterberg, 1978)

<table>
<thead>
<tr>
<th>Material resistance</th>
<th>Slight appearance</th>
<th>Calcite type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose to firm</td>
<td>By deposit if little resistance, white to grey chalky or silty sandstone</td>
<td></td>
</tr>
<tr>
<td>Dense</td>
<td>Hard and infocompact</td>
<td>Calcite with mica and feldspar</td>
</tr>
<tr>
<td>Medium</td>
<td>White to pale pink</td>
<td>Calcium carbonate</td>
</tr>
<tr>
<td>High</td>
<td>White to pale pink</td>
<td>Calcium carbonate</td>
</tr>
<tr>
<td>Rough to flat</td>
<td>Fine white to grey</td>
<td>Calcium carbonate</td>
</tr>
<tr>
<td>Fine to very fine</td>
<td>Fine white to grey</td>
<td>Calcium carbonate</td>
</tr>
<tr>
<td>Coarse</td>
<td>White and grey to brown</td>
<td>Calcium carbonate</td>
</tr>
</tbody>
</table>

TRL Girls on the Mphikanhi-Mabone Road

Outcomes of the Phase 2 Fieldwork

Low lying areas, predominantly in the central part of the Province, with poor drainage, grey soils (predominantly sandy and sparse vegetation, especially thorn, become the typical locations for positive probing results.

Finding this thorn is not the problem – it usually finds you first!
Outcome of the Phase 2 Fieldwork

- A total of 46 locations were recorded (additional to the existing calcrete borrow areas) where either remote sensing, surface probing investigations or outcrop gave rise to the identification of calcareous materials.
- Of these:
  - 13 were considered likely to be in situ Tertiary Limestone
  - 7 were considered likely to be Lagostrine Limestone, according to the outcrop pattern
  - 1 calcareous sandstone
  - 2 calcareous material
  - 1 calcified sand
  - 1 embryonic calcrete
  - 23 calcrete

Prioritisation of Phase 3 Fieldwork

- Trial pitting to be carried out by ANR (as described by Joane later) was scheduled at 10 priority locations out of the 23 calcrete prospects. Priority was based on distance from an existing source, and anticipated extent.

Phase 3 Fieldwork Results: Existing Calcrete Borrow Pits and Proven Prospects (See Geomorphological Map for Possible Explanation)

Phase 2 Desk Study

- This was designed to build on the success of the Phase 3 Fieldwork by utilising 24 existing/proven calcrete deposits as a benchmark for identifying similar locations from satellite imagery:
  - Visually (on screen) using Google Earth SPOT
  - Digitally using ASTER DEM
  - Digitally using multi-spectral analysis in LANDSAT
Use of Google Earth Spot to Visually Characterise Existing/Proven Calcrete Locations and Extrapolate to other Possible Areas

Further Prospects Identified for Probing Investigations

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Coordinates</th>
<th>Database</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site A</td>
<td>30°45'00&quot;S, 14°30'00&quot;E</td>
<td>Existing</td>
<td>High potential</td>
</tr>
<tr>
<td>2</td>
<td>Site B</td>
<td>30°30'00&quot;S, 14°45'00&quot;E</td>
<td>New</td>
<td>Medium potential</td>
</tr>
<tr>
<td>3</td>
<td>Site C</td>
<td>30°40'00&quot;S, 14°30'00&quot;E</td>
<td>New</td>
<td>Low potential</td>
</tr>
<tr>
<td>4</td>
<td>Site D</td>
<td>30°35'00&quot;S, 14°30'00&quot;E</td>
<td>Existing</td>
<td>High potential</td>
</tr>
</tbody>
</table>

LANDSAT 7 (MSS Analysis)

The aim of the Landsat analysis (30m spatial resolution) was to attempt to locate previously unknown calcrete deposits using the pattern of spectral wavebands recorded at existing deposits (borehole and from field investigations).
LANDSAT tiles

The Landsat 7 imagery tiles used in this study were downloaded from the USGS EarthExplorer website. These tiles are the latest available for 2001-2002 without cloud cover.

LANDSAT Spectral Bands

<table>
<thead>
<tr>
<th>Band 1</th>
<th>0.45-0.52 μm (blue-green)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 2</td>
<td>0.52-0.60 μm (green)</td>
</tr>
<tr>
<td>Band 3</td>
<td>0.63-0.69 μm (red)</td>
</tr>
<tr>
<td>Band 4</td>
<td>0.77-0.86 μm (near infrared)</td>
</tr>
<tr>
<td>Band 5</td>
<td>1.55-1.75 μm (thermal infrared)</td>
</tr>
<tr>
<td>Band 6</td>
<td>1.60-1.70 μm (thermal infrared)</td>
</tr>
<tr>
<td>Band 7</td>
<td>2.08-2.35 μm (middle infrared)</td>
</tr>
</tbody>
</table>

Spectral band response

Band Ratios

Conclusions from the LANDSAT Analysis

3:1 Band Ratio

There is no correlation between the band ratios and calculate locations. There is also no spectral response that can be used to distinguish the calcite locations and the other known geology units.

Colour composite Carbonates shown as magenta

Note that different LANDSAT tiles give different spectral signatures, compounding the difficulty.
GIS and Database Management

Location Details

The GIS links to the database, enabling the latest information to be displayed. Here the potential sites are shown colour coded by their priority score.

GIS data layers

- Geological units
- Aquifer boundaries
- Other groundwater recharge areas
- Groundwater characterised by low recovery rate
- Groundwater characterised by high recovery rate
- Land cover information
- Urban areas
- Natural areas
- Hydrological basins
- Natural drainage

GIS Layers

Being a standard ArcMap project, layers obtained from other sources can also be added to the GIS.

GIS Database Linking

The live link to the database means that the latest data for each site is always available.
Database Management

Database Design

Location

Position (selected or reviewed)

Sample

Test

Database

Location Details

Locations have a status assigned, which shows if they are potential or actual sites. Sites which have been exhausted or discounted are also included to allow them to be excluded from future investigations.

Database

Location Details

The history allows the previous status of the location to be easily checked.

Database

Positions

Within each location, a number of positions can be defined. These are the places where test samples have been collected.

Database

Positions

The individual samples collected and the tests which they have undergone are listed.

Database

Samples

Each sample can then have one or more tests carried out and the results recorded.
Trabalho de campo realizado no ambito do estudo
By Joana Guiuele
TRABALHO DE CAMPO REALIZADO NO ÂMBITO DO ESTUDO

1. Descrição do Trabalho de Campo Realizado

Foram efectuadas visitas às câmaras de empréstimo existentes (Inhassine, Chivalo e Mavuéla no Distrito de Pandé, Marumbe-Distrito de Funhalouro, Funhalouro sede-Distrito de Funhalouro, Manhuassau, Massalau, Chindjinguri, Mubalo e Domodomo no Distrito de Himoíne; Coa, Savi, Malevane e Jofane no Distrito de Govuro; Pambara no Distrito de Vilankulo).

Foi feita investigação das zonas de ocorrência do calcário ao longo de toda Província de Inhambane, principalmente nas estradas classificadas (prospecções, colecta e testagem do material).

A tabela de prioridades é conforme abaixo ilustrada.
2. Procedimentos para identificação do material

Foi usada um equipamento de sondagem de calcário “calcrete Probe” para determinar a profundidade do material existente em cada local de ocorrência de calcário.

3. Procedimentos para Colheita de Amostras

Foram feitas prospecções com uso do Probe de 25 em 25 m numa área de (100 x 100) m, conforme abaixo ilustrado.

3. Procedimentos para coleta de amostras - cont.

- Em cada área escavou-se um furo no centro com dimensões (1m Larg. x 2m Comp. x 2m <prof.>
- A amostra foi colhida de acordo com a dureza do material:
  - Colheita da camada dura do calcário “hard pan” – pode ser esmagada com um martelo
  - Colheita do Calcário nodular – pode ser esmagada com uma pressão firme dos dedos;
  - Colheita da camada do calcário em pó – facilmente esmagada com uma leve pressão dos dedos.

O material colhido era armazenado em sacos plásticos e selados para envio ao laboratório.

Prospeções feitas com o probe de 25 em 25 metros

4. Imagens de locais de ocorrência do calcário
5. Plantas Geralmente Encontradas nos Locais de Ocorrência de Calcário
OBRIGADO
Calcrete project: Trial pit investigations in Mozambique
By Francisco Manheche
**INTRODUCTION**

- Mozambique has serious shortage of road building materials, in particular in Inhambane.
- Materials for the construction of bases are very poor in most areas, e.g., fine coastal sands covering most of eastern Mozambique.
- It is even more difficult to find suitable aggregate in Inhambane.
- It is ABSOLUTELY necessary to develop alternative solutions using local materials such as calcrete, which is available in Inhambane Province. RIRF and the ARFACAP project is using calcrete for road construction.

**WHERE INHAMBANE IS SITUATED?**

Inhambane is a Province in Mozambique, a stretch of the South Eastern Africa, backing on the North with Tanzania, in the West with Mozambique, in the South with South Africa and in the South with the Indian Ocean.

**PURPOSE SCOPE OF PROJECT**

- Provide guidance to ANE on the location of calcrete deposits, as well as on the classification of road building material and find out the appropriate technical specification for using in road construction.
WHAT IS CALCRENTE?
- Calcrente can be regarded as a material formed by the in situ cementation and/or replacement of almost any pre-existing soil by calcium carbonate deposited from the soil or ground water.

TRIAL PIT INVESTIGATION
- The criteria for selection of borrow area was made by:
  - Look for vegetation (botanical) and searching the existence of calcrente with an instrument similar to DCP equipment (PROBING DEVICE). Later add help to identify.
  - The borrow chosen was not be too close to the existing borrow areas.
  - Total of 3 borrow was be sampled for lab testing.
  - 3 test pit were dug per borrow area.

How we identify calcrente in the ground?

RAPID CALCRENTE PROBING DEVICE:
It is an instrument similar to a DCP equipment.

Identification of calcrente in the ground and Borrow pit
- BORROW PIT LAY OUT
  - I  II III IV
  - 1 X X X X
  - 2 X X X X
  - 3 X X X X
  - . 25m
  - 10X100 m

What kind of test is needed?
- Grading
- Atterberg limits
- Compaction/CBR
- Conductivity (P425) salt content needs to be determined
- 10% FACT on hardpan/boulder calcrente samples

WHERE WAS THE TEST CARRIED OUT?
- The test was carried out in ANE laboratories at Inhambane and Maputo.
- Another test was carried out in LEM (Laboratorio de Engenharia de Mozambique).
- Some of materials went to south Africa.
CONCLUSION & RECOMMENDATION
- The next presentation will show the result of laboratory test which demonstrate that calcere is a good material for road bases.
- With this project we can have high impact with small cost
- It is concluded that calcere is suitable as a road construction material for low volume traffic in the arid and semi-arid regions.
- It is recommended that further investigation or research on better use for bases can be carried out.

Thank You!
Calcretes in road construction
by Tony Greening
Calcrete in Road Construction

Tony Greening (TRL)

AFCAP workshop, Victoria, March 2013

Design Constraints

- Existing pavement design methods cater to relatively high volumes of traffic with damaging effect quantified in terms of sets. In contrast, main factors controlling deterioration are dominated by the local road environment and details of design (drainage), construction and maintenance practices.
- Local road building materials often “non-standard” compared with temperate climate materials. Dispensarily referred to as “marginal”, “low cost”, etc.

Change in design approach initiated by research

- Traditional specifications for base grays typically specify:
  - Sealed CBR @ 98% MASHO of 80%
  - PI of <6
  - Adherence to a tight grading envelope. Research has shown that additional factors such as drainage, pavement cross-section, environment etc enable significant relaxation in design with significant cost savings.

Design

Traffic and axle loading forecast

Subgrade classification and subgrade strength

Geotechnical information: field survey, materials properties

- Geotechnical factors N < 4
  - Sealed width = 650mm
  - Unsealed width = 650mm

Design Chart 1

Manhole location

- Materials classification increases limit on PU by 20%

Design Chart 2

Manhole location

- Materials classification increases limit on PU by 40%

Design Sections in Botswana Study

Borrow Pit Samples

Soil classification tests on calcrete subgrade materials borrow pit samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Liquid Limit (LL)</th>
<th>Plastic Limit (PL)</th>
<th>Plastic Index (PI)</th>
<th>A-Smoothed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Range</td>
<td>Mean Range</td>
<td>Mean Range</td>
<td>Mean Range</td>
</tr>
<tr>
<td>BGL 1A</td>
<td>14 27</td>
<td>12 29</td>
<td>20 27</td>
<td>12 29</td>
</tr>
<tr>
<td>BGL 1E</td>
<td>48 64,61</td>
<td>44 64,61</td>
<td>35 64,61</td>
<td>40 64,61</td>
</tr>
<tr>
<td>BGL 1F</td>
<td>58 76,63</td>
<td>54 76,63</td>
<td>34 76,63</td>
<td>55 76,63</td>
</tr>
<tr>
<td>BGL 1G</td>
<td>58 76,63</td>
<td>54 76,63</td>
<td>34 76,63</td>
<td>55 76,63</td>
</tr>
</tbody>
</table>
AFCAP

SAMPLES FROM THE ROAD (BOTSWANA TEST
SECtIONS)

<table>
<thead>
<tr>
<th>Material</th>
<th>Section</th>
<th>Average CBR*</th>
<th>Bake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-21</td>
<td>6</td>
<td>60 (24)</td>
<td>86 (7)</td>
</tr>
<tr>
<td>B-22</td>
<td>4</td>
<td>60 (6)</td>
<td>86 (7)</td>
</tr>
<tr>
<td>B-1-21</td>
<td>5</td>
<td>60 (6)</td>
<td>86 (7)</td>
</tr>
<tr>
<td>B-1-22</td>
<td>5</td>
<td>60 (6)</td>
<td>86 (7)</td>
</tr>
</tbody>
</table>

AFCAP

12 TEST SECTIONS IN BOTSWANA MONITORED FOR 12 YEARS

| No. | Section | Test FS | Test FS
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B-21</td>
<td>60 (24)</td>
<td>86 (7)</td>
</tr>
<tr>
<td>2</td>
<td>B-22</td>
<td>60 (6)</td>
<td>86 (7)</td>
</tr>
<tr>
<td>3</td>
<td>B-1-21</td>
<td>60 (6)</td>
<td>86 (7)</td>
</tr>
<tr>
<td>4</td>
<td>B-1-22</td>
<td>60 (6)</td>
<td>86 (7)</td>
</tr>
</tbody>
</table>

AFCAP

SPECIFICATIONS FOR CALCIATE BASES | GREENFIELD ROAD

<table>
<thead>
<tr>
<th>Property</th>
<th>Maximum (kg/m³)</th>
<th>Maximum (kg/m³)</th>
<th>Maximum (kg/m³)</th>
<th>Maximum (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum particle size (mm)</td>
<td>73</td>
<td>95</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Loss % passing 4.75mm sieve</td>
<td>60</td>
<td>95</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Minimum liquid limit</td>
<td>40</td>
<td>55</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Maximum plasticity index</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Maximum water absorption (%)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2.4% passing 0.425mm sieve</td>
<td>200</td>
<td>200</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>4% passing 0.075mm sieve</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Maximum liquid limit (%)</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

AFCAP

EXAMPLES OF TYPICAL TYPES OF CALCIATE USED IN ROAD (ALL SOMETIMES FOUND IN ONE LSP)

AFCAP

Materials Compliance

- It was only possible to undertake one series of tests per single sample from a test pit 2m deep in each borrow pit.
- The inherent variability of calcrete, coupled with the very poor reproducibility of the CBR test, make a single result unreliable.
- The lack of comparability of the calcrete specifications which were derived from BS test standards, and the actual laboratory testing which was carried out using South African TMH 1 test standards.
Test Results

- There is clearly a high degree of variability in some of the test results which make the comparison with existing specifications difficult.
- This is exacerbated by the use of different test methods (apples and oranges)
- The quality of calcrete deposits is highly variable both with depth and area. Single sample testing is highly unreliable.

Summary of test results

- Some of the borrow pits located, namely Marumbe (LMM 07-V), Marabba (LMM 09-V) and Ibo (LMM 04-V) contain calcrete that appears to be potentially suitable for use as base course, subbase and selected fill of low volume roads carrying less than 0.5 million ESUs.
- The remaining borrow pits contain calcrete that appears to be suitable for subbase and selected fill for low volume roads carrying less than 0.5 million ESUs.
- The hard pan calcrete appears to be suitable for use as surfacing aggregate or as crushed stone base course.
- Salinity does not appear to be a problem.

Suitability of calcrete for road construction in Inhambane

- The terms of reference require an evaluation of the suitability of existing systems to classify the Inhambane calcretes based on a review of existing test data.
- The inconclusive nature of the results make such an evaluation impossible.
- The current calcrete classification system has been developed on the basis of many years of research work.
- It will require a comprehensive investigation of calcretes in Inhambane province to provide the data necessary to evaluate the suitability of the current calcrete classification system.

Conclusions

- On the basis of the limited samples tested to date and the specification adopted:
  - All of the materials tested would be suitable for gravel wearing course and subbase.
  - At least 3 samples would be suitable for roadbase in an LVR (sealed shoulders)?
  - At least one sample collected appeared to be (hard) and thus possibly suitable for use in C56 seals or other surface options.

Using local materials

The art of the roads engineer consists for a good part in utilizing specifications that will make possible the use of materials he finds in the vicinity of the road works.

Unfortunately, force of habit, inadequate specifications and lack of initiative have suppressed the use of local materials and innovative construction technologies:

- Consider materials “fitness for purpose”
- Make use of local materials rather than materials fit specification
- This approach needs to be supported by research

Performance of low-volume roads

Many low-volume roads have performed better than expected. Is this due to:
- Overdesign (too conservative)?
- Environmental factors?
- Timely maintenance?
- The actual traffic damage is less than forecasted?
- (i.e., the exponent of 4.0 is inappropriate)
- Good construction practice?
- All of these and more?
- New laboratory tests and specifications for sand as sub-base material
- Use of "marginal" materials for road base
- Provision of sealed shoulders enabling use of weaker materials
- Revised specifications and techniques allowing use of weaker aggregates for surfacing

RINGS × US$20 million

THANK YOU
Mozambique AFCAP/RRIP research on use of calcrete in Inhambane province
by Kenneth Mukura
Introduction
- Mozambique is a large country with a relatively small road network
- More than 70% of the network is unsealed
- Good road construction materials are scare (e.g. haul distances of surfacing aggregate may exceed 400km)
- Vast areas are covered in coastal sands
- Previous research carried out by TRL and ANE showed an average rate of gravel loss on unpaved roads exceeding 50mm/year (maintenance demand is high)

Issues relating to Inhambane
- **Shortage of materials**
  - Natural local material that can be used for base and surfacing is calcareous
  - Red and grey sands are abundant but usually used for construction of cement stabilised bases (CTB)
- **High costs**
  - Expensive to build roads, especially Low Volume Roads
  - Use of locally available calcereous will reduce costs significantly

Research work under AFCAP/RRIP
- ANE initiated the Rural Road Investment Programme (RRIP) supported technically by AFCAP: Phase 1 from 2008, Phase 2 from 2009, Phase 3 from mid-2011.
- More than 50km have been built and Otto seals constitute the bulk of the sections
- Designs also include concrete slabs and stone paving with concrete screed on steep ramps, emulsion treated bases, armoured bases, slurry seals, sand seals, penetration macadam, untreated sand bases, etc
- Designs were carried out by TRL and provincial consultants (Mango in Inhambane). Construction is carried out mostly by local contractors
- ASDI (SIDA) provided funding for construction works and DFID is providing funding for technical support

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unpaved (6km)</td>
<td>Blended wearing course 50:50 calcareous and sand, performance based specifications developed by TRL were used</td>
</tr>
<tr>
<td>2 and 3</td>
<td>Blended base 50:50 calcareous and sand with Otto seal</td>
<td>Resultant base with CBR = 40%, calcereous graded aggregate with nominal size of 15mm ACV = 25-40, Binder rate 1.2, 1.5, 1.6, 1.8, 2.0, 2.4 L/m2</td>
</tr>
<tr>
<td>4</td>
<td>Armoured base with sand seal</td>
<td>100 - 120mm neat sand base + layer of aggregate 20-40mm (50mm max)</td>
</tr>
<tr>
<td>5</td>
<td>Neat sand base with penetration macadam surfacing</td>
<td>Red sand (CBR = 25-36), penetration macadam 1st layer (20-40mm) second layer of 5-13mm or sand</td>
</tr>
</tbody>
</table>

Cumbana Chacane Road – Blending Before and after intervention
Challenges

- The calcrite had too much powder (dust) and the dust was covering the binder before the aggregate landed.
- The binder distributor was brand new but it was spraying badly – recommended for it to be converted into a water bowser.
- ACV was good < 26 but there a small percent of weak aggregate
- Due to low traffic volumes extended rolling of the Otta seal was required (compensatory rolling) to aid curing of the surfacing
- The contractor did not correct the construction defects during the defects liability period
Cumbana Chacane – Ph3: Construction of armoured base

Cumbana Chacane – Ph3: Completed armoured base

Cumbana Chacane – Ph3: Completed armoured base

Cumbana Chacane – Ph3: Sand seal over armoured base

Cumbana Chacane – Ph3: Sand seal over armoured base

Cumbana Chacane – Ph3: ‘Amalgamated surfacing’
Challenges
- Distributing the aggregate evenly on the full width of carriageway
- Getting adequate compaction
- Ensuring that the aggregate protrude above the fine material
- Construction was too slow – too long before second layer of sand was applied

Zambezia: Zero Mopeia Road

Recommendations
- Blended and armoured bases are viable solutions. Minimum requirements for the soaked CBR for low volume roads (CBR > 40?)
- Otta seals cured very well for the finer aggregate even at low traffic volumes
- The blended wearing course has performed very well (no maintenance grading for 2 years and very low rate of gravel layer) – the performance based specifications are key to good practice
- Need to improve quality of construction
- Need for long term monitoring
- Need to minimise construction and LC costs

OBRIGADO