



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

Inception Report

RPN 2277

August 2012

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	Introduction	4
2	Project Objectives	4
3	Scope of Services	5
4	Project team	5
5	Roles and Responsibilities	6
6	Proposed Methodology	6
7	Indicative Milestones	9
8	Outputs and Deliverables	10
9	Activities to Date	10
10	Literature Survey	11
11	Comments on the Terms of Reference	11
12	Activity Schedule	12

1 Introduction

The project is part of the Africa Community Access Programme (AFCAP) which is a research programme supported by the Department for International Development (DFID) of the Government of the UK.

AFCAP has been approached by the Mozambique National Road Administration (ANE) to support a research consultancy for the mapping of calcrete deposits in Inhambane province, preparation of a classification system for Mozambique calcretes and specifications for the use of calcrete in road construction.

Road-building materials meeting conventional specifications are scarce along the coastal areas of Mozambique, and in particular in Inhambane Province. The non-availability of good natural gravels for the construction of wearing course on unpaved roads has resulted in high maintenance costs for these roads in the province. As the road network expands, there is a need for locally available materials such as calcretes to be exploited for the construction of sealed roads. Therefore, the innovative use of locally available materials, which are considered marginal or rejected by traditional specifications needs to be investigated for use in the construction of roads in the province.

Calcretes are already widely used in road construction in other countries, where the different forms have been classified and specifications have been derived for their use in road construction as a gravel wearing-course material, as a base course on paved roads and also for surfacing. Recent experience on projects implemented by ANE in Inhambane has also shown that, depending on their properties, calcretes can be used in the construction of road pavements. Materials characteristics vary significantly between the different forms of calcrete and the derivation of specifications for their use in road pavements offers considerable cost savings over conventional design approaches for paved roads in the province.

The purpose of the project is to build on existing experience in the use of calcrete in road construction in the SADC region. Deposits of calcrete will be identified and mapped using geological and soils mapping, satellite imagery and field investigations. Technical specifications will be developed for its use in road construction and a GIS database of calcrete deposits will also be developed.

This report gives details of the Inception Phase of the project and the preparatory work that has been undertaken, together with issues arising from initial discussions with ANE, and other activities to date. An outline of the project is given together with the planned activities and an approximate schedule of activities.

2 Project Objectives

The objectives of the project, as defined in the Terms of Reference are:

- a) To provide guidance to ANE and the Inhambane provincial authorities on the location of calcrete deposits in the province
- (b) To develop a classification system for calcretes as road building materials
- (c) To prepare technical specifications for the use of calcrete in road construction.

3 Scope of Services

(a) Technical Review

This will comprise a review of previous research, experience and studies in the use of calcrete in road construction along with any existing guidelines, standards and specifications. Particular relevance will be placed on research carried out in neighbouring and other countries in Southern Africa where deposits of calcareous materials may be similar to those in Mozambique. A provisional list of technical papers is included in this report. Any other relevant documentation identified later will be included in the Technical Review.

(b) Development of a Calcrete Classification System

This will initially be based on an evaluation of the suitability of existing systems to classify the Inhambane calcretes. Information from existing laboratory test data together with the results obtained from additional testing during the course of the project will give an indication of the applicability of these systems to Mozambique.

The task of the **development of technical specifications** for the use of calcretes in the construction of roads in Inhambane will be based on any available existing technical information in Mozambique together with regional information on materials properties and road performance data from elsewhere.

(c) Identification and Mapping of Calcrete Deposits

This will be based on a range of exploration techniques including prospecting methods currently being applied in the province together with an investigation of the applicability of remote sensing techniques such as aerial photography and satellite imagery.

A GIS database of calcrete deposits will be developed and will include:

- The location of probable deposits identified through the desk study, field investigations, aerial photos and satellite imagery;
- Proven deposits confirmed through field investigations, sampling and laboratory testing.

(d) Workshop

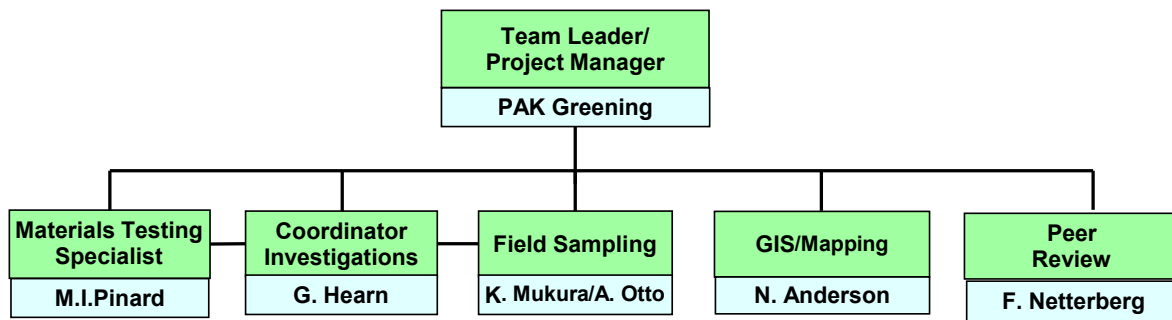
A workshop will be convened to review the draft recommendations and outputs of the study.

(e) Guidelines

A Final Report in the form of a Guideline will be prepared, which will include a calcrete classification system, specifications for the use of the calcretes and a GIS database.

4 Project team

It is proposed that the project team identified in the contract should be supplemented as shown below:



Kenneth Mukura is the Manager of the TRL office in Maputo and he and Andrew Otto are managing other AFCAP projects in Mozambique. TRL intend to use their presence to assist with overseeing the laboratory testing programme and local administrative tasks.

Dr Frank Netterberg is an acknowledged materials expert with particular expertise in calcretes and will carry out an independent peer review of the calcrete classification system and specifications.

5 Roles and Responsibilities

Name of Staff	Role	Responsibility
Tony Greening	Team Leader	Interaction with ANE, co-ordination of the project team activities, deliverables and dissemination workshop. Responsibility for delivery of project outputs.
Michael Pinard	Materials Testing Specialist	Primary responsibility for laboratory testing programme and technical review with inputs to other activities – classification, technical recommendations and reporting.
Dr Gareth Hearn	Coordinator – Investigations	Primary responsibility for field investigations with inputs to other activities – technical review, prospecting and mapping materials, technical recommendations and reporting.
Neil Anderson	GIS Specialist	Development of GIS/mapping system with inputs to other technical and reporting activities.
Kenneth Mukura/Andrew Otto	Senior Researcher	Assistance with overseeing laboratory testing in Mozambique and other logistical support.
Dr Frank Netterberg	Peer Reviewer	General advice and external peer review of calcrete classification and specification guidelines.

6 Proposed Methodology

Literature review

An extensive review of existing documentation on the use of calcretes will be carried out including calcrete classification systems and specifications developed by the Council for Scientific and Industrial Research (CSIR), TRL and by the road authorities in Botswana and Zimbabwe. The review will include experience from the recent use of calcretes in

Mozambique.

Technical Review – The literature review of previous research, experience and studies in the use of calcrete in road construction in the region along with any existing guidelines, standards and specifications is an essential component of the technical review and will provide guidance on the activities to be undertaken. The consultant will also visit road sections in Inhambane that have been constructed using calcrete, including sections constructed under the ANE Targeted Interventions Programme, ANE/KfW Regional Roads and the Sasol Road Programme for providing access to gas-well drilling sites.

Calcrete Classification System and technical specifications

The consultant recognises that the calcrete classification systems developed principally in Botswana may not adequately cover the range of calcrete materials found in Inhambane. A review of the laboratory test results already available with ANE, consultants and contractors in the provinces will be conducted in order to give an early indication of the properties of calcretes in past and current use. Sampling and testing of an additional 30 samples will be carried out and the results of these tests will provide additional information on their properties. The suitability of existing systems to classify the Inhambane calcretes will then be evaluated.

Additional testing will be organised by the Consultant in liaison with ANE and the provincial authorities using the standard test methods normally used for the testing of road building materials in Mozambique. A sampling and testing matrix will be developed and relevant tests conducted in line with the recommended classification system. It is expected that most of the testing will be carried out in Mozambique, although provision is made in the contract for any specialized tests that may need to be undertaken outside the country.

It has been agreed that ANE will assist in transporting samples to the laboratory. The Consultant will manage and coordinate the testing and will analyse the test results.

Following the Technical Review and additional sampling and testing of calcrete materials, a draft classification system for calcrete materials found in Inhambane and technical specifications of their use will be developed. It should be noted that specifications developed elsewhere are based on extensive laboratory testing programmes and the evaluation of results obtained from long-term monitoring of the performance of road pavements constructed with calcrete.

It is anticipated that similar long-term monitoring data is unlikely to be generally available in Mozambique for a range of calcretes. In these circumstances, any classification will inevitably need to be based on information from outside the country until such time as similar research projects are undertaken in Mozambique. However, recommendations will be developed to include each layer of the road pavement from sub-grade to its use as a wearing course and in bituminous surfacings.

Blending of materials in order to achieve a composite with the desirable properties is widely used and previous research has included projects that have investigated the blending of calcrete with sand. The draft specifications will cover both the use of naturally occurring calcrete in road construction and the use of calcrete blended with locally occurring sands. The use of natural gravel material for road building is not normally sensitive to the technology used and the recommendations for calcretes are expected to apply equally to equipment-based and labour-based technology. The specifications will be in a form that will be suitable for inclusion as part of standard tender documentation used by ANE and provincial authorities.

Identification and Mapping of Calcrete Deposits – Calcretes generally occur as relatively small localised and scattered deposits. They are usually overlain by a cover of soil and vegetation that makes them difficult to locate.

The Consultant will employ a range of exploration techniques to ensure that available deposits are located as efficiently as possible. The techniques will include:

- Geological and soils information from existing maps and reports;
- Landscape and vegetation information from topographic maps, aerial photos and satellite images;
- Exploitation of local knowledge regarding the occurrence of calcretes
- Field investigations using pit evaluation and laboratory testing.

The location of proven deposits previously identified by ANE, together with those identified under the project will be used to assess the feasibility of using remote sensing techniques to locate calcareous deposits.

A field survey and pit evaluation will be carried out on potential deposits identified within one kilometre either side of an existing classified road (primary, secondary, tertiary and vicinal). The output of the calcrete identification mapping exercise will be a GIS database of calcrete deposits indicating probable deposits identified through the desk study, aerial photos and satellite imagery.

Proven deposits will be confirmed through field investigations. For these deposits, the database will include detailed information on the classification of material found in the deposit as well as an estimate of the quantity of material available.

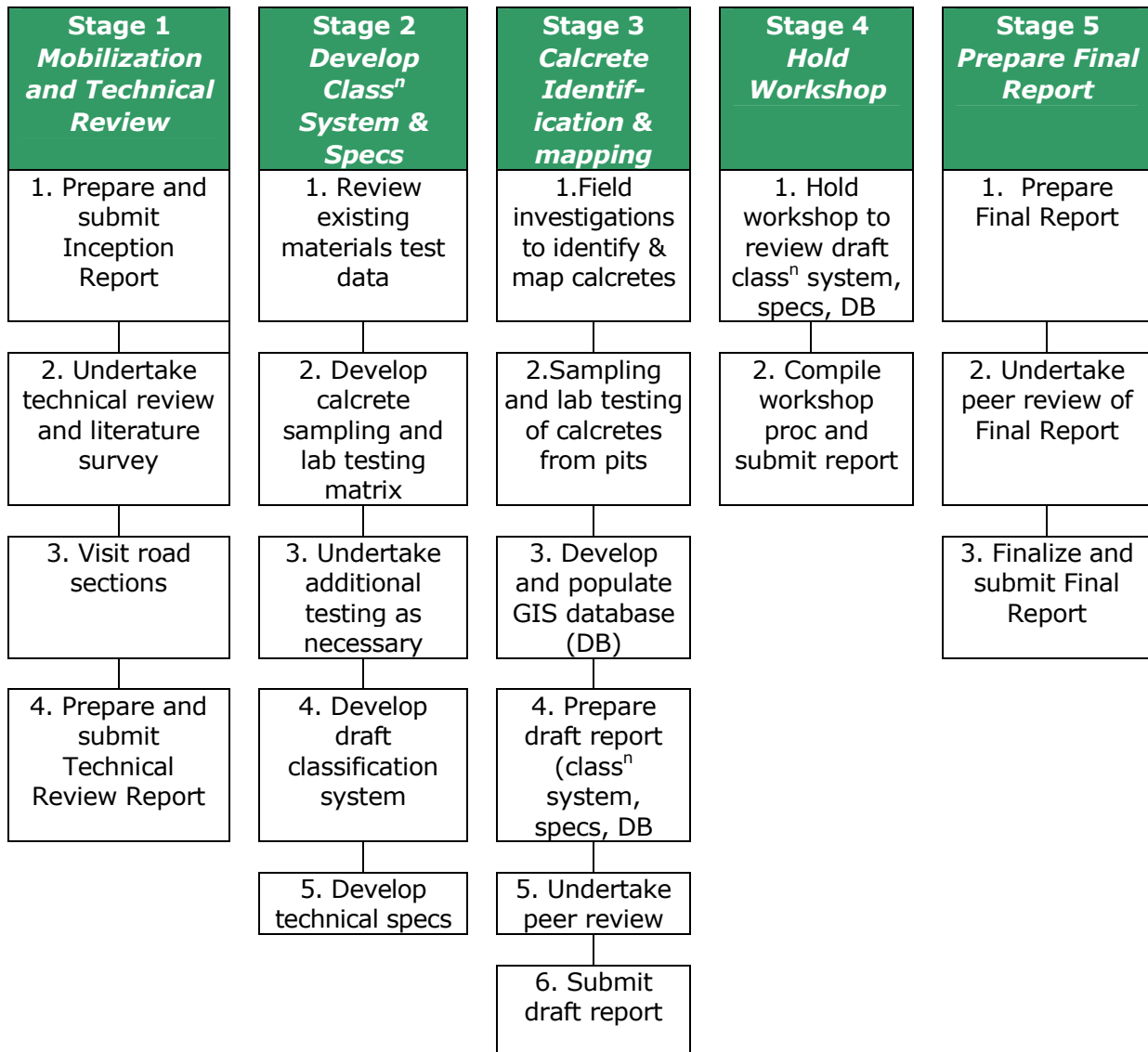
GIS System

The GIS database will be in a standard format which has been approved by ANE and which will be compatible with their existing IT systems. It will use the ArcGIS system for the display of data, linked to a Microsoft Access database storing detailed information on the calcrete deposits. The structure of this database will be designed to allow for easy transfer to TRL's Materials Database Inventory System (MDIS) if further functionality is required in the future. This approach will provide a system that can easily be further developed, whilst meeting the requirements of the current project.

Stakeholder Workshop – A 2-day workshop will be organised by the Consultant and ANE to review the draft recommendations and outputs of the study as stipulated in the TOR.

Finalisation of Guidelines – The draft classification system, specifications and GIS database will be finalised for approval and adoption by ANE based on the comments and feedback from the workshop.

Methodology Summary



7 Indicative Milestones

The total duration of the project is 8 months. The following key milestones are shown in the activity schedule.

- Preparation of draft Inception Report - Month 1.
- Submission of Technical Review of existing literature - Month 3.
- Preliminary identification of calcrete deposits and development of GIS database - Month 3.
- Sampling and testing of calcrete materials from inspection pits - Month 5.
- Submission of a Draft Report including the draft classification system, technical specifications and populated GIS database by - Month 6.

- Workshop to discuss the draft outputs - Month 7. Workshop report to be submitted within 2 weeks of the workshop.
- Submission of final classification system, technical specifications and GIS database - Month 8.

8 Outputs and Deliverables

- **Inception Report** — including a summary of tasks undertaken during the mobilisation of the consultant's team, a summary of discussions with key stakeholders, a list of key literature identified for the Technical Review, proposals for the GIS database format, and a detailed work plan for the remainder of the assignment.
- **Technical Review** — based on the review of existing research reports, recommendations of the use of calcrete in road works, technical specifications, etc. from Mozambique, the SADC region and internationally.
- **Draft Final Report** — Including recommendations on the classification system, technical specifications and GIS database.
- **Workshop Report** — Including a summary of the workshop proceedings, discussions, recommendations and participant details.
- **Final Report** — The final report should be updated and finalised based on feedback from the workshop and comments received from ANE and other stakeholders.

Output	Timing (Months after commencement) *
Progress Reports	Monthly
Inception Report	1
Technical Review Report	3
Draft Final Report	6
Workshop Report	7.5
Final Guideline	8

In addition to the above, monthly progress reports will be submitted to the Technical Manager of AFCAP and ANE.

9 Activities to Date

- Initial meetings by the team leader with the Director of the Maintenance Department (DIMAN) and other personnel at ANE in Maputo.
- Assessment of transport requirements for the project and procurement of project vehicle
- Meeting and telephone conference with members of project team
- Assignment of roles and responsibilities of team members
- Outline planning for field visits
- Administrative tasks including request for letters of visas
- Correspondence with ANE to determine format of database and GIS that will be compatible with existing ANE systems
- Initial literature survey

10 Literature Survey

A list of references obtained from the initial literature search is given in Appendix A.

11 Comments on the Terms of Reference

As indicated in Section 3, supervision of laboratory testing will be assisted by TRL staff based in Mozambique. It should also be noted that some samples may be submitted to an independent laboratory for confirmatory testing.

We shall work with ANE in preparing for the dissemination workshop, but suggest that this may only require one day to demonstrate the GIS system and database and present findings from the project to key stakeholders.

12 Activity Schedule

ACTIVITY	Month												
	July	August	September	October	November	December	January	February					
1. Project Management													
1.1. Client Liaison													
1.2. Overall planning, programming & management													
1.3 Monthly Progress Reports		★		★		★		★		★		★	
2. Mobilization and Technical Review													
2.1 Inception Report		◆											
2.2 Technical Review & Literature Survey													
2.3 Visit road sections													
2.4 Prepare and submit Technical Review Report						◆							
3. Develop Classification System & Technical Specs													
3.1 Review existing materials test data													
3.2 Develop calcrete sampling and lab testing matrix													
3.3 Undertake additional lab testing, as necessary			?????	?????									
3.4 Develop draft classification system													
3.5. Develop technical specs													
4. Identify & Map Calcrete Deposits & Prepare Draft Report													
4.1 Undertake field investigations to identify and map calcretes													
4.2 Undertake sampling and lab testing of calcrete samples													
4.3 Develop and populate GIS database													
4.4 Prepare draft report (classification system, specs, DB)													
4.5 Undertake peer review of draft report													
4.6 Finalize and submit draft report											◆		
5. Hold Workshop (Organised by ANE)													
5.1 Hold Workshop													
5.2 Prepare workshop proceedings and submit report													◆
6. Prepare Final Guideline													
6.1 Prepare final guideline													
6.2 Undertake peer review of final guideline													
6.3 Finalize and submit final guideline													◆

★ Monthly progress reports

◆ Report submission

■ Intermittent activity

Appendix A

List of References

BEAUMONT, T E. (1979). Remote sensing for the location and mapping of engineering construction materials in developing countries. Quarterly Journal of Engineering Technology. Vol 12. Geological Society. United Kingdom

BULMAN, N and C LAWRENCE. (1980). The use of satellite imagery in highway engineering in Africa. 4th IRF Highway Engineering Conference. Nairobi Kenya

GREENING, PAK and ROLT, J. (1996). Calcrete in roadbases in the Kalahari region of southern Africa. RPN 1390, Wokingham, UK: TRL Limited

HUGO, F. Et al (1982) Four asphalt case studies using a mechanistic approach. Proceedings of the 5th International Conference on the structural design of asphalt pavements. Delft University of Technology. Vol 1 and Vol 2. Netherlands

LAWRANCE, C.J. and TOOLE, T. (1984). The location, selection and use of calcrete for bituminous road construction in Botswana. TRRL Lab. Rep. 112, Crowthorne.

LIONJANGA, A.V., TOOLE, T. and Newill, D. (1987). The development of specifications for the use of low-grade calcretes in lightly trafficked roads in Botswana. Trans. Res. Record 1106, 1, 281-304.

LIONJANGA, AV, TOOLE, T and GREENING, PAK. (1987) The use of calcrete in paved roads in Botswana. Proc. 9th Reg. Conf. Africa Soil Mech. Fndn Eng., Lagos, 1 Sept. 1987. (TRL Paper PA1185/87).

MOUNTAIN, MJ (1967). The location of pedogenic materials, using aerial photographs, with some examples from South Africa. Proc. 4th Reg. Conf. Africa Soil Mech. Fndn Engng, Cape Town, 1, 35-40.

MOTSWAGOLE, K R et al. Mellowing and curing of marginal road construction materials treated with lime. Unbound Aggregates in roads 4th International Symposium (UNBAR4). University of Nottingham. UK

NETTERBERG, F and OVERBY, C. (1983). Rapid materials reconnaissance for a calcrete road in Botswana. Proc. 7th Reg. Conf. Africa Soil Mech. Fndn Engng, Accra, 1980, 2, 765-768. (CSIR Reprint RR 340).

NETTERBERG, F and C. CAIGER. (1986). The geotechnical classification of calcretes and other pedocretes. National Institute of Transport and Road Research. Pretoria south Africa

NETTERBERG, F. (1967). Some roadmaking properties of South African calcretes. Proc. 4th Reg. Conf. Africa Soil Mech. Fndn Engng, Cape Town, 1, 77-81. (CSIR Reprint RR 91).

NETTERBERG, F. (1969). Pedogenic materials in road construction. Nat. Inst. Road Res. Bit. Surfacing Lecture Course, NIRRR Rep. RS/10/69, CSIR, Pretoria, 13 pp.

NETTERBERG, F. (1969). The geology and engineering properties of South African calcretes. CSIR Monograph, Pretoria, Ph.D. thesis, Univ. Witwatersrand, Johannesburg, 4 vols, 75 plates, 106 figs, 172 tables, 12 maps, 1070 pp.

NETTERBERG, F. (1969). The interpretation of some basic calcrete types. Proc. 1st S. Afr. Quat. Conf., Cape Town. In: S. Afr. Archaeol Bull., 24, Parts 3 & 4 (95 & 96), 117-122. (CSIR Reprint RR 104).

NETTERBERG, F. (1971). Calcrete in road construction. CSIR Res. Rep. 286, NIRR Bull, 10, Pretoria, 73 pp. (Received 1975 Holdredge Award of the Assoc. Engng Geols, USA).

NETTERBERG, F. (1976). Experimental Calcrete Bases and Subbases. CSIR Tech. Note. TS/18/75.

NETTERBERG, F. (1978). Calcrete wearing courses for unpaved roads. Civil Engr S. Afr., 20, (6), 129-138. (CSIR Reprint RR 228). (Received 1978 Jennings Award from the Geotechnical Division and two Best Paper Awards from the S. Afr. Instn Civil Engrs.)

NETTERBERG, F. (1978). Prospecting for calcrete road materials in South and South West Africa. Civil Engr S. Afr., 20, (1), 3-10. (CSIR Reprint RR 227). (Received 1978 Jennings Award from the Geotechnical Division of the S. Afr. Instn Civil Engrs.)

NETTERBERG, F. (1979). Effect of drying temperature on the index properties of calcretes. Trans. Research Record 675, 24-32. (CSIR Reprint RR 279).

NETTERBERG, F. (1980). Geology of southern African calcretes: 1. Terminology, description and classification. Trans. Geol. Soc. S. Afr., 83, (2), 255-283. (CSIR Reprint RR 301).

NETTERBERG, F. (1981). Geotechnical properties and behaviour of calcretes as flexible pavement materials in southern Africa. Nat. Inst. Transp. Road Res. Rep. RS/4/81, CSIR, Pretoria, 30 pp.

NETTERBERG, F. (1982). Behaviour of calcretes as flexible pavement materials in southern Africa. Proc. 11th ARRB Conf., Melbourne, 1982, 11, (3), 60-69. (CSIR Reprint RR 325).

NETTERBERG, F. (1982). Geotechnical properties and behaviour of calcretes in South and South West Africa. In: Geotechnical Properties, Behaviour, and Performance of Calcareous Soils.

NETTERBERG, F. (1985). Pedocretes. Chapter 10 in Brink, A.B.A. (Ed.), Engineering geology of southern Africa, 4, 286-307, Building Publications, Silverton. (CSIR Reprint RR 430).

NETTERBERG, F. (1987). Weathering, durability and pedocretes, 14-36 In: Buckle, L.J., Netterberg, F. and Oberholster, R.E. Some chemical aspects of road-building materials, Proc.

F NETTERBERG AND M I PINARD (1991). Interim Performance-Related Specifications for Coarsely Graded Plastic Calcrete Gravels. Tenth African Reg. Conf. on Soil Mech. and Fndn. Eng., Maseru, Lesotho, September.

NETTERBERG, F. (1994). Engineering geology of pedocretes and other residual soils. Proc. 7th Congr. Int. Assoc. Engng Geol., Lisbon, Keynote Address, Theme 4, V, XIX-XXXVIII.

NETTERBERG, F. (1996). Prospecting for pedocretes for use as road construction material; a review. Dept Transport Res. Rep. RR 90/277, Pretoria, 113 pp.

NETTERBERG, F. (1997). Use of calcretes and ferricretes for light to medium duty road pavements. Proc. AEG Sem. Role Eng. Env. Geol. Urban Plan. Dev., Cape Town, Aug 1997, 20 (extended abstract).

NETTERBERG, F. and CAIGER, J.H. (1983). A geotechnical classification of calcretes and other pedocretes. In: Residual deposits: Surface related weathering processes and materials, R.C.L. Wilson (Ed.), Geol. Soc. Spec. Pub. No. 11, Blackwell Sci. Pubs, London, 235-243. (CSIR Reprint RR 368).

OVERBY, C. (1983). The use of Low Quality calcrete Under a Bituminous Seal in the Kalahari Region. 26th World road Congress, Sydney.

SMITH, R B and G HAWKINS. (1982). Utilisation of calcretes for road pavement construction in the arid western region of New South Wales. Australian Road Research Board. Australia Road Research Vol 11.

STONE, R. J. (1989). Remote Sensing of Salt Damage to the Maun-Nata Road, Botswana. TRRL Working Paper No. 263, Overseas Unit, TRRL, Crowthorne, Berkshire.

STONE, R. J. (1991). Identification of Saline Areas Along the Maun-Nata Road, Botswana, from Remote Sensing Imagery. TRRL Working Paper No. 280, Overseas Unit, TRRL, Crowthorne, Berkshire.

THRISCUTT, A. (1977). Calcretes in Botswana. TRRL Working Paper No. 7, Overseas Unit, TRRL, Crowthorne, Berkshire.

TOOLE, T. (1984). Calcrete as Surfacing Aggregate. Joint Ministry of Works and TRRL Research Project in Botswana.

TOOLE, T. (1986). The Use of calcrete in Paved Roads. TRRL Overseas Unit Working paper No. 211. Overseas Unit, TRRL, Crowthorne, Berkshire.

UPPAL, H L. et al (1968). Survey of hidden calcrete in alluvial plains in India by airphoto interpretation. Australian Road Research Board.