ALTERNATIVE SURFACING FOR STEEP HILL SECTIONS IN GHANA- PHASE I

Inception Report

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Cover Photo: *Road Map of Ghana*

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ABSTRACT

The African Community Access Programme (AfCAP) is promoting safe and sustainable rural access roads in Africa through research and knowledge sharing between participating countries and the wider community. The AfCAP programme is managed under the overall umbrella of the Research in Community Access Partnership (ReCAP). Feeder road rehabilitation and maintenance is seen as a crucial part of Ghana's efforts in agricultural development and in its strategies for economic recovery and growth, poverty alleviation and food security. Hence the identification of appropriate design options for higher risk sections (e.g. steep hills) of low-volume rural roads is seen as an important component of Ghana's strategy for improving sustainable all-season rural access.

The Council for Scientific and Industrial Research (CSIR) in South Africa, in partnership with the Building and Road Research Institute (BRRI) of Ghana, has been appointed by Cardno Emerging Markets (UK) Ltd to undertake a study on alternative surfacing for steep slopes in Ghana. The main objective of the current study is to provide practical information on the suitability of alternative road surfacings and paving techniques that are cost-effective, and offer sustainable solutions for road surfaces on steep gradients.

Although the preliminary review of available information indicates that conventional bituminous or concrete surfacings are the most extensively used surfacings for grades in excess of 12 per cent, the application of cost-effective locally available materials will be paramount in this study. The conventional surfacings will, therefore, serve as control to compare with three identified groups of candidate cost-effective alternative surfacings, i.e.

1. bituminous surfacings focusing on naturally occurring materials (e.g. lateritic gravels, sand) and locally available bituminous binders, as well as non-traditional construction materials (demolition concrete, and steel slag),
2. concrete surfacings (e.g. concrete paving blocks, ultra-thin reinforced concrete, roller compacted concrete, and
3. stone setts and cobblestones (e.g. granite, quartzite or sandstone).

It is projected that the selected cost-effective surfacings will be constructed on subbase/base layers made of naturally occurring lateritic gravels mixed with emulsions, cement and lime stabilisations or mechanically modified.

This inception report provides the overall framework for the study including the background, scope and methodology. In addition, minutes of project meetings are provided. A detailed implementation plan for the first phase of the study is provided in this report with recommendations to guide the project team on how to effectively execute the project to meet the needs of the client.

Key words

Low-Volume Roads, Bituminous Surfacing, Concrete Surfacing, Steep Gradient, Laterite

AFRICA COMMUNITY ACCESS PARTNERSHIP (AfCAP)

Safe and sustainable transport for rural communities

AfCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa. The AfCAP partnership supports knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. AfCAP is brought together with the Asia Community Access Partnership (AsCAP) under the Research for Community Access Partnership (ReCAP), managed by Cardno Emerging Markets (UK) Ltd.

See www.afcap.org

Acronyms

AfCAP	:	Africa Community Access Programme
BRRI	:	Building and Road Research Institute
CSIR	:	Council for Scientific and Industrial Research
DFID	:	Department for International Development (UK)
DFR	:	Department of Feeder Roads
MRH	:	Ministry of Roads and Highways
RCC	:	Roller compacted concrete
ReCAP	:	Research for Community Access Partnership
R&D	:	Research and Development
TOR	:	Terms of Reference
vpd	:	Vehicles per day

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1. EXECUTIVE SUMMARY

The African Community Access Programme (AfCAP) is promoting safe and sustainable rural access roads in Africa through research and knowledge sharing between participating countries and the wider community. The AfCAP programme is managed under the overall umbrella of the Research in Community Access Partnership (ReCAP). Feeder road rehabilitation and maintenance is seen as a crucial part of Ghana's efforts in agricultural development and in its strategies for economic recovery and growth, poverty alleviation and food security. Hence the identification of appropriate design options for higher risk sections (e.g. steep hills) of low-volume rural roads is seen as an important component of Ghana’s strategy for improving sustainable all-season rural access.

The Council for Scientific and Industrial Research (CSIR) in South Africa, in partnership with the Building and Road Research Institute (BRRI) of Ghana, has been appointed by Cardno Emerging Markets (UK) Ltd to undertake a study on alternative surfacing for steep slopes in Ghana. The main objective of the current study is to provide practical information on the suitability of alternative road surfacings and paving techniques that are cost-effective, and offer sustainable solutions for road surfaces on steep gradients. The key objectives are to:

i. identify the factors impacting on steep sections of rural road
ii. identify options for mitigating these factors in terms of pavement surfacing and/or effective drainage that can provide an acceptable level of service
iii. propose a programme to demonstrate and try a suitable range of the identified pavement surfacing and drainage options on steep hill sections of the road

Although the preliminary review of available information indicates that conventional bituminous or concrete surfacings are the most extensively used surfacings for grades in excess of 12 per cent, the application of cost-effective locally available materials will be paramount in this study. The conventional surfacings will, therefore, serve as control to compare with three identified groups of candidate cost-effective alternative surfacings, i.e.

1. bituminous surfacings focusing on naturally occurring materials (e.g. lateritic gravels, sand) and locally available bituminous binders, as well as non-traditional construction materials (demolition concrete, and steel slag),
2. concrete surfacings (e.g. concrete paving blocks, ultra-thin reinforced concrete, roller compacted concrete, and
3. stone setts and cobblestones (e.g. granite, quartzite or sandstone).

It is projected that the selected cost-effective surfacings will be constructed on subbase/base layers made of naturally occurring lateritic gravels mixed with emulsions, cement and lime stabilisations or mechanically modified.

This inception report provides the overall framework for the study including the background, scope and methodology. In addition, minutes of project meetings are provided. A detailed implementation plan for the first phase of the study is provided in this report with recommendations to guide the project team on how to effectively execute the project to meet the needs of the client.

2. INTRODUCTION

2.1 Background

The CSIR was requested by Cardno Emerging Markets (UK) Ltd to submit a proposal for a study on alternative surfacings for steep slopes in Ghana on 15 January 2016. The project proposal was accepted on 25 January 2016, and the contract was signed into effect on 29 January 2016 with a start date of 1 February 2016 and a completion date of 31 May 2016. The project Team Leader visited Ghana from 4 February 2016 to 14 February 2016. The goal of the visit was to conduct meetings and site visits with the Department of Feeder Roads.

The programme partners for this project are the UK Government through the Department for International Development (DFID); the Ghana Ministry of Roads and Highway (MRH), represented by the Department of Feeder Roads (DFR).

The overall study is aimed at identifying, defining and demonstrating appropriate surfacing options as alternatives to the current gravel wearing courses on selected low-volume rural road sections (i.e. feeder roads) in Ghana, specifically focussing on roads in steep terrains (higher risk sections). This inception phase of the study was undertaken to formulate the detailed study, and to determine how the objective of the project will be met. A project initiation meeting, project site visits and a preliminary desk study were the major activities undertaken during Inception.

As part of the study, the project team will engage fully with assigned counterpart staff within the Department of Feeder Roads (DFR) to ensure that the knowledge acquired throughout the project is transferred and entrenched within DFR. When completed, it is expected that DFR will feel more confident in taking a lead role in promoting the use of the identified surfacing options and techniques for improving all-weather passability on steep sections of their feeder road network. A desk study and site evaluation programme were pursued at the inception phase of the project with the main goal of identifying cost-effective and sustainable surfacing types that could be used as alternatives for the current gravel surfaces used on steep hilly terrains.

Detailed background to this project is provided in the Terms of Reference.

2.2 Rural Access Roads and Alternative Surfacing

Sustainable roads in rural areas play vital role in the socio-economic development of the more remote areas of a country in terms of access to markets, schools, health facilities and employment opportunities. AfCAP is promoting safe and sustainable rural access roads in Africa through research and knowledge sharing between participating countries and the wider community. AfCAP is managed under the overall umbrella of the Research in Community Access Partnership (ReCAP).

AfCAP is building on the programmes of the high quality research under AfCAP Phase I and takes this forward to sustainable future in which the research results are adopted in practice and influence future policies of member countries. AfCAP is managed by Cardno Emerging Markets (UK) Ltd, and operates in the eastern, western and southern African countries.

In Africa, unsealed and low-volume sealed roads provide access to both urban and rural communities for socio-economic opportunities.. Low-volume roads are typically either unpaved (i.e.

earth or gravel road) or paved with a thin bituminous surfacing. Unpaved roads form the bulk of the rural road networks in African countries on account of their low construction cost (i.e. affordability). Such roads require regular maintenance, more so than paved roads, in order to maintain minimum standards of accessibility. However, maintenance is often delayed or is hampered by budget and other constraints. Furthermore, unpaved roads tend to deteriorate rapidly under the effects of traffic and weather conditions, especially on steep slopes (hilly terrains). Often, more durable alternatives such as bituminous surfacings or concrete have been selected for use on steep (high risk) sections of roads that are subjected to harsh environmental conditions such as high rainfall. Apart from providing a more durable pavement structure, bituminous and concrete surfacings also have the added advantage of providing good riding quality, a safer solution for road users travelling on steep roads (i.e. better skid resistance and better visibility by elimination of dust pollution) and all weather access. It is the preferred option for communities although it has a relatively high initial construction cost.

It is generally believed that on steep slopes, especially where the gradients are more than 12 per cent, thin bituminous surfacing seals are unlikely to perform well. They are usually affected by the flow of surface running water and are prone to deterioration or shoving under wheel loads leading to loss of bond with the base and stripping. These constraints could, however, be addressed by, for instance, the provision of a coarse and stable base that would be able to “anchor” the surfacing seals and, most importantly, the provision of adequate drainage systems to protect the pavement structure. Asphalt or concrete surfacings are reported to be the most suitable surfacings for grades in excess of 12 per cent. In comparison, concrete surfacings could provide a very valuable solution for steep sections of low-volume roads as they offer a very good resistance to wheel loads and generally require less maintenance, compared to bituminous surfacings. There is also a reduced risk of major deterioration in the form of slippage cracks, permanent deformation and potholes that could impair the safety of especially motorcycle and bicycle users. Stone setts and cobles obtained from local areas or within the vicinity of the road sections are viable surfacing options to both bituminous and concrete surfacings for the steep sections. Major advantages of these materials include inexpensive equipment for construction, low maintenance, erosion resistant, suitable for construction by small and medium scale contractors and unskilled labour.

For the past two decades, the provision of all-weather access to rural communities has become the priority of DFID in support of poverty alleviation and stimulation of economic growth in Africa and other countries of the world. DFID has, therefore, funded research and knowledge transfer projects in developing countries through ReCAP. The outcomes of this successful research include innovative and unconventional approaches that can provide beneficial and cost-effective solutions for low-volume rural roads in ReCAP partner countries, through the use of alternative road surfacings.

The successful provision of low volume roads requires the selection of appropriate materials, including the use of locally available materials, in an optimal and environmentally sustainable manner (SATCC, 2003). Low-volume roads in many developing countries, including Ghana, consist of mainly earth and gravel roads. However, in recent years, research has shown that most earth and gravel roads are generally uneconomical and practically not sustainable (Cook et al., 2008). Gravel is a finite, non-renewable resource and is not sustainable in the medium to long term. The cost of reshaping a road with gravel is often too high for the economy of most developing countries. These concerns have prompted a need for considering the use of alternative interventions which would be more cost-effective to use than routinely re-gravelling of low-volume roads in an unsustainable manner.

2.3 Ghana

Road transport is significant to Ghana's economy as it is the most widely available form of transport in the country; it links agricultural production areas with local, regional and national markets, and carries in excess of 95 per cent of all passenger and freight traffic in Ghana (Logistics Infrastructure, 2013). Ghana has a total road network of approximately 68,124 km, out of which 42,210 km, representing 62 per cent, are feeder roads (earth or gravel roads). Only five per cent of the total feeder road network in Ghana is reported to have bituminous surfacings. The remaining 95 per cent are either earth or gravel roads. Traffic on most unpaved feeder roads in Ghana seldom exceeds 100 vpd and rarely exceeds 200 vpd on all feeder roads. An unpaved feeder road becomes a candidate for upgrading to paved standards when traffic exceeds the threshold of 100 vpd. However, in many cases, an unpaved road is upgraded to paved standards for reasons other than traffic. These include: a growing sentiment that gravel roads passing through settlements should be converted to bituminous surfaced roads as a dust control measure, irrespective of traffic levels; and, for political reasons. The use of cost-effective concrete or bituminous surfacings for these feeder roads is viewed as an appropriate, resource conserving and sustainable solution for many rural roads in Ghana.

The Department of Feeder Roads (DFR) is responsible for the administration, planning, control, development and maintenance of feeder roads in Ghana. Rehabilitation and maintenance of feeder roads is seen as a crucial part of Ghana's efforts to support and strengthen agricultural development and to implement its strategies for economic recovery and growth, poverty alleviation and food security. Hence, the identification of appropriate design options for higher risk sections on low-volume roads is seen as an important component of Ghana's strategy for ensuring sustainable all-season rural access.

Lateritic gravels in Ghana have been used extensively in road construction for both paved and unpaved roads. Lateritic gravels with CBR values in excess of 60 per cent have been used as either a fill or subbase material for both paved and unpaved roads. In situation where the lateritic gravels have CBR values in excess of 80 per cent, these materials have been used as a fill or base materials for gravel roads. Although they are abundant and hence a sustainable source of material for road construction, further assessment of these materials in terms of their engineering properties (i.e. resilient modulus, shear strength, plastic strain, etc.) should be done to better understand the potential for use of these lateritic gravels.

In Ghana, a two-stage construction process is followed for the upgrading of roads: the *first stage* consists of the construction of a gravel wearing course, followed by the *second stage* where a bituminous surfacing is provided on top of the existing gravel road. Prior to the second stage, the practice in Ghana is to scarify, top up (where necessary) and re-compact the top 100 mm of the sub-base layer, followed by the application of 100 mm to 200 mm of selected gravel base material with a minimum CBR of 60 per cent, a fines content of between 5 and 22 per cent, and a plasticity index not exceeding 12. For the bituminous surfacing, a layer of bituminous binder (usually bitumen emulsion) is sprayed over the compacted and lightly watered base layer. This is followed by the spreading of 14 mm diameter aggregates, pre-coated with a mixture of diesel and bitumen, and compacting the layer to form a prime seal or single seal. It is a common practice that after having opened the road to traffic for 10 days, a second layer of bituminous binder is sprayed and a layer of pre-coated 10 mm diameter (instead of 7 mm size) aggregates is spread and compacted to form a second seal and thus to create the double bituminous seal surfacing. The cost items thus include the reworking of the gravel wearing course, the application of a gravel base course and the placement of the double seal.

A study by Addison (2008) indicated that it is increasingly becoming difficult to find suitable gravel material in Ghana that meets specifications (i.e. scarce and marginal). Thus, the need for a study to define cost-effective and sustainable alternative surfacing techniques, as well as related erosion control methods for steeper slopes (> 12%) for low volume roads in Ghana is justifiable and prudent.

2.4 Objectives of Phase I

The main objective of this phase of the project is to provide practical information on the suitability of alternative road surfacing and paving techniques that offer relatively low cost sustainable solutions, for climate strengthening road surfaces on steep gradients. The key objectives are to:

i. identify the factors impacting on steep sections of rural road;

ii. identify options for mitigating these factors in terms of pavement surfacings and /or effective drainage that can provide an acceptable level of service; and

iii. propose a programme to demonstrate and try suitable range of the identified pavement surfacing and drainage options on steep hill sections of the road.

2.5 Approach and Methodology

The detailed approach and methodology for the study are presented in the project proposal. The methodology for the study is grouped under five main tasks as summarised below:

- Task 1: Inception phase including site visit, and gathering of information and publications on a wide range of surfacings options (e.g. concrete strips; concrete paving blocks; concrete slabs; roller compacted concrete; single, double, Otta, slurry seals, asphalt, stone setts and cobbles) for low volume rural roads

- Task 2: Review and analysis of all available national and international guidelines and standards to provide a means of grouping and identifying the expected behaviour of soil, water management, drainage measures, erosion control techniques used in low-volume roads, design, construction, and maintenance interventions

- Task 3: Expansion of the information gained from the site visit and literature review (under Task 1) to prepare a Draft Scoping Report

- Task 4: Workshop to present the findings, recommendations and suggested solutions, including proposals for follow-up research in Phase II

- Task 5: Final Report indicating the proposed surfacing options for steep slopes on low volume roads and a matrix for further research

Technology transfer and capacity building are an integral part of AfCAP's activities, and form a core aspect of this project. To this end, mentorship interventions are incorporated in all tasks. Details of each task and assigned deliverables are presented in Annex 2 of the contract.

2.6 Comments on the TOR

The terms of reference for the assignment were well understood. However, it was suggested that a project of this kind would require an internal technical reviewer of the output reports. The recommendation for the Consultant to be included as Non-Key personnel in the project team was approved.

2.7 Scope of the Report

The report covers four main areas. These are:

- A summary of the project background, objective, scope of work, methodology, and the deliverables agreed upon for the study is provided.
- Available information is summarised to provide an indication of the different surfacing techniques as well as design and construction guidelines that have been used for low-volume roads. Excerpts from selected publications are provided for different techniques. Brief descriptions of the main surfacing types are grouped according to their dominant constituents, and a summary of various surfacings and alternative treatments for sealed and unsealed roads are provided.
- Site visit and proposed sites for the study. An arrangement was made at the DFR regional Head Office in the Eastern Region. The region's entire feeder road system is discussed with particular emphasis on the visit with the DFR technical team of the region. The potential road sections for experimental trials to be carried out in Phase II are provided.
- A set of planned activities and implementation recommendations to be adopted for the study are provided. Aspects of this report will be used together with the outcomes of the other tasks to provide inputs into the Scoping Report of this study.

2.8 Project Team

The project team consists of two key personnel (the Team Leader, and one Civil Engineer from Ghana) and a technical reviewer. The key technical experts have both previously carried out investigations in Ghana and elsewhere in Africa. The project team will consult widely with prominent civil engineers and scientists in the road sector of Ghana, particularly with DFR staff, and other international experts during the course of the project.

2.9 Main Deliverables

The main deliverable for Phase I is a Scoping Report for Phase II. Tangible deliverables are:

1. Inception Report setting out the approach for the implementation of the activities relating to the defined scope of works (**15 Feb 2016**);

2. Draft Project Report on the progress of work, achievements made, and constraints and suggestions for the way forward for effective project implementation (**11 Apr 2016**);
3. Workshop Report on proceedings and outcomes of the stakeholder workshop (**25 Apr 2016**);
4. Final Report that incorporates the outcomes of the stakeholder workshop and other comments, as well as agreed recommendations for Phase II of the project (**9 May 2016**).

3. REVIEW OF AVAILABLE INFORMATION

3.1 Summary of Publications

Table 3-1 provides an initial list of documents that will be reviewed as part of Task 2. This list will be updated continuously and will include additional documents such as:

- Sub-Saharan African guidelines/manuals on the design and construction of low-volume roads;
- Appropriate standards for the provision of drainage in mountainous/hilly terrain;
- Appropriate standards for erosion control (inclusive of slope stability measures);
- Geometric standards for sealed roads in mountainous/hilly terrain.

Theuns et al. (2006) provided a brief description of the main surface types, and grouped them according to their dominating constituent, and summarized the surfacings and alternative treatments for paved and unpaved roads (see Table 3-2). This also will contribute towards the selection of alternatives surfacings for the project.

Table 3-1: List of Publications for the Study

Source/Author	Title
George K Adison,	Availability of natural gravel for road construction in Ghana. MSc Thesis (2008), Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
Y. A. Tuffour and A. Braimah	Suitability of natural gravels in Ghana for Otta seal construction, IOSR Journal of Engineering (IOSRJEN), Vol. 04, Issue 07, July. 2014, PP 46-53
Ampadu, SIK and FK Addison	A comparison between the life cycle cost of gravel and of bituminous surfacing options for feeder roads in Ghana. International Journal of Pavement Engineering. DOI:10.1080/10298436.2015.1065990
Degraft-johnson, J W, BHATIA, H S, and Gidigasu, D M	The engineering characteristics of the laterite gravels of GHANA
InfraAfrica (Pty) Ltd, Botswana and Dr. Frank Netterberg,	Review of specifications for the use of laterite in road pavements (Contract: AFCAP/GEN/124), May 2014
Madu, RM	The performance of lateritic stones as concrete aggregates and road chippings. Matériaux et Constructions, Vol 13, 78, pp 403-411, 1980.
Amu, O.O., Ogunniyi, S.A. and Oladeji, O.O	Geotechnical properties of lateritic soil stabilized with sugarcane straw ash, American Journal Of Scientific And Industrial Research © 2011, Science Huβ, http://www.scihub.org/AJSIR
Edmund Kwasi Debrah	Low-cost rural road surfacing: The use of burnt clay bricks. 2nd International Convention on Rural Roads, Jinan City, Shandong Province, China, from 26th-29th October, 2010.
SIK Ampadu and CFA Akayuli	Optimizing the pozzolana-lime concentration to maximize geotechnical properties of natural gravel for road construction, International Journal of Pavement Engineering, *In Press,* 2016.
Botswana: Ministry of Works, Transport and Communications..	The design, construction and maintenance of Otta seals. Gaborone, (Guideline No 1), 1999
Van Zyl GD.	*Synthesis on Cape Seal variations in southern Africa*. 2nd International Sprayed Sealing Conference, Melbourne, Australia, 2010
Willem Vonk and Robin van Veldhuysen,	Spray Seals: Quality + Application Rate = Performance Kraton Polymers Research B.V. Amsterdam, The Netherlands

Klasie Jooste and, Gerrie van Zyl, Mycube	THE USE AND PERFORMANCE OF BITUMEN RUBBER IN SPRAY SEALS FOR HOLDING ACTIONS IN SOUTH AFRICA KBK Consulting Engineers, Mycube Asset Management Systems, South Africa
Joanna Towler, John Patrick, and Peter Howe	Trends and changes in chip sealing in New Zealand NZ Transport Agency, New Zealand
Manual 27	Guideline for thin layer hot mix asphalt wearing courses on residential streets, Published by Southern Africa Bitumen Association, 2008
Paige-Green, P.	Practical Aspects of low cost sealing of roads. Invited paper at Africa T2 Conference, Pietermaritzburg, September 2005
Van Zyl GD. 2007.	Measurement and Interpretation of Input Parameters used in the SA Surface Seal Design Method. Conference on Asphalt Pavements for Southern Africa (CAPSA), Gabarone, Botswana
Henry Grace	Investigations in Kenya and Malawi using as-dug laterite as bases for bituminous surfaced roads, Geotechnical & Geological Engineering, September 1991, Vol. 9, Issue 3, pp 183-195
American Journal of Scientific And Industrial Research	Design and Construction of Drainage Structures, American Journal Of Scientific And Industrial Research
A. Bresser, and H. van den Beld	(Concrete) Block paving in developing count: A technical, economical and human alternative for road construction in developing countries.
CSIR Built Environment	Focus on ultra-thin, continuously-reinforced concrete technology, 2010
J R Cook, R C Petts and J Rolt	Low volume rural road surfacing and pavements: A guide to good practice, AFCAP Report, pp 74-83, June 2013
Oliver, JWH	Prediction of the life of sprayed seals and the effect of climate, durability and seal size. International conference on managing pavements, 6th, 2004, Brisbane, Queensland, Department of Main Roads, Brisbane
Oliver, JWH	Adding risk to a model for reseal intervention due to binder ageing. ARRB Conference, 22nd, 2006, Canberra, ACT, ARRB Group Ltd, Vermont South, Vic
Emery SJ, Van Huyssteen S, Van Zyl GD. 1991	Appropriate standards for effective bituminous seals: Final Report RDT Report 17/91 for SABITA, DRTT, CSIR, Pretoria
Western Cape Department of Transport and Public Works	*Materials Manual, Volume 2,* *Volume 6,* Cape Town, South Africa, 2010
Southern African Bitumen Association	Thin Layer Asphalt. Manual 27. Cape Town. South Africa
Southern African Bitumen Association	Labour enhanced construction for bituminous surfacings. Manual 11. Cape Town. South Africa.
Southern African Bitumen Association	Methods for labour intensive construction of bituminous surfacings. Manual 12. Cape Town. South Africa
Wright, B, Emery, S, Wessels, M and Wolff, H. 1990.	Appropriate standards for effective bituminous seals: cost comparisons of paved and unpaved roads. Pretoria: Division of Roads and Transport Technology, CSIR. (Contract Report; 89/1)
Woodbridge, M.E, Greening, P.A.K and Newill	Evaluation of weak aggregates for surface dressing on low volume roads. Trans Res Rec, 1291, Vol 1, pp 263-274, 1991
Woodbridge, M.E, and Slater, C.W.N.	Development of a reduced specification for surfacing aggregate on low volume roads in Botswana. Crowthorne: Transport Research Laboratory. (Project Report 115), 1995
Paige-Green, P.	Thin bituminous surfacings for light pavement structures. In Proceedings 7thConference on Asphalt Pavements for Southern Africa, Victoria Falls, Zimbabwe, Aug 1999, pp 2-116 to 2-123
Paige-Green, P.	The use of marginal aggregates in bituminous seals. 20th ARRB Conference, Melbourne, Australia, March 2001. (CD)
Paige-Green, P.	Aggregate strength for bituminous surfacings for low volume roads: A heavy vehicle simulator experience. 8th CAPSA 04, Sun City, September

	2004
Netterberg, F and Paige-Green, P.	Pavement materials for low volume roads in southern Africa: A review. In: Appropriate materials and methods, (Proceedings of Annual Transportation Convention held at the University of Pretoria, July, 1988), Vol 2D, Paper 2
The World Bank (Theuns Henning)	Surfacing Alternatives for Unsealed Rural Roads, 2005
Ministry of Transportation, Government of Ghana	Standard Specification For Road And Bridge Works, 2007
Sabita Manual 10	Appropriate Bituminous Surfacings for Low Volume Roads And Temporary Deviations, South Africa, 2011
American Journal Of Scientific And Industrial Research	Design and Construction of Drainage Structures, American Journal Of Scientific And Industrial Research

Table 3-2: Description of Surfacing types and Groups (After Theuns et al 2006)

Table 1 Surface Types

SURFACING TYPE	DESCRIPTION
Natural Surfacing	Engineered earth roads or natural surfaces. Generally have poor geometry and drainage.
Gravel	Typically 150-250mm thick natural gravel or other imported layer that is worn down by traffic and the environment.
Dust Suppressants	Additionally to a good construction and a mechanical stabilization, dust can be controlled with chemical additives, such as: Wetting Agents, Salts/Chlorides, Natural Polymers, Wax Agents, etc. Dust suppression has environmental, health, safety and economic implications.
Stone	Crushed stone layers can be placed with machines or manually. The former require heavy equipment for compaction. The latter may be prepared without heavy compaction equipment.
Bricks	Usually prepared from high quality clay bricks. Pavements are very durable and can present a very tight, relatively smooth surface.
Concrete	Very durable, but mostly require minimum thickness for high volume roads. A special application is the concrete block pavement, with similar behavior and performance to brick and clay bricks.
Bituminous Surfaces	Classified in two groups: Seals (bitumen film and stone embedded) and Bituminous mixes (asphalt layers)
Other Surfaces	Recycled rubble, concrete or asphalt mix.

Table 2 Surfacing Treatments

SURFACING GROUP	DESCRIPTION
Bituminous Macadam	Graded crushed stone material or single size aggregate blinded with smaller aggregate mixed with a bituminous binder or bitumen emulsion slurry
Asphalt	Hot or cold bituminous mix
Recycled Asphalt	Hot or cold recycled bituminous mix
Bituminous Seal Surface	Film of bitumen or road tar followed by angular sand, natural gravel or crushed stone, lightly rolled into the bitumen/tar.
Clay Blocks	High quality clay bricks on a thin sand bed.
Concrete Blocks	Concrete blocks laid on a thin sand bed.
Stone Blocks	Dressed stone or stone sett surface, cut and laid by hand
Plain Concrete	Plain mass of concrete
Reinforced Concrete	Steel reinforced mass of concrete
Stabilized Gravel	Road base mixed with stabilizers such as chemical additives or bitumen emulsions
Crushed Stone	A layer of graded crushed stone material derived from fresh sound quarried rock, boulders or granular material.
Stabilized Recycled Material	Use of recycled road pavement materials, brick waste, demolition materials, etc.
Natural Gravel	A layer of compacted natural gravel wearing course
Stabilized Natural Material	Stabilization of the soil or surface with natural materials like quicklime or hydrated lime.
Treated Natural Material	Surface treatment using natural material such as dust proofing
Natural Soil	Smoothing or shaping existing earth or gravel road surface

3.2 Excerpts from Selected Publications

Some findings and recommendations made in selected publications are summarised below:

AVAILABILITY OF NATURAL GRAVEL FOR ROAD CONSTRUCTION IN GHANA

George K Adison, MSc Thesis (2008), Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

This study evaluated some material properties (CBR, grading and Atterberg limits) of natural gravel samples from 454 borrow pits distributed throughout the country for their suitability or otherwise for road construction as a subbase, base and Otta seal. Each material property was compared with G30, G40, G60 and G80 MoT specifications. The ones meeting the criteria were denoted as passed or failed if otherwise. The results showed that it is difficult getting natural gravel meeting the specification for G80 base material. However, there are significant improvements when a relaxed specification of G60 is used. This indicated grading plays a very important part in deciding whether a natural material meets specification or not. Generally Western Region had the greatest difficulty of meeting grading requirements of subbase and base are 26% and 2% respectively. It is almost impossible to find a natural gravel pit meeting the requirements of Otta seal without processing. Most natural gravel in the country will need two cycles of screening for them to meet the grading requirement for Otta seals. It was recommended that there should be research into the use of natural gravels meeting the specification for G60 and G30 as base and subbase respectively by constructing trial pavement sections and monitoring their performance. This is due to the fact that appreciable number of gravel pits met the requirements for G60 and hence the utilization of the gravel materials in the country. Natural gravel should be blended with other materials (stabilized) or crushed stone to improve the engineering properties as layer materials for subbase and base.

SUITABILITY OF NATURAL GRAVELS IN GHANA FOR OTTA SEAL CONSTRUCTION

Y. A. Tuffour and A. Braimah Civil Engineering Department, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and Department of Feeder Roads, Kumasi, Ghana, July. 2014)

The availability of natural gravel deposits throughout Ghana provides the motivation to use the Otta seal technology to upgrade low-volume roads to surfaced standard. However, gravel availability does not necessarily translate to material suitability for the seal. In this study a number of gravel deposits distributed throughout the country were evaluated to establish their suitability for Otta seal construction. Most (about 80%) of the gravels in their natural state met only the strength requirement for Otta seal but deviated from the grading and plasticity requirements due, in most cases, to high contents of clay and oversize fractions. To be able to use them for Otta seal construction, the gravels require screening to reduce certain fractions, particularly the fines content and out-of-range fractions and/or remove oversize fractions, to bring the materials in line with Otta seal grading and plasticity requirements. The evaluation undertaken in this study showed that about 78% of the natural gravels in the country require only one cycle of screening to bring them to Otta seal grading. It was established that in terms of the total requirements, about 75% of the natural gravels in Ghana could be used for Otta seal construction when processed by screening. Even though screening is particularly helpful in reducing the silt and clay contents, it has the disadvantage of *reducing the quantity of gravel material available for use. In general, however, when processed by screening, whether by one cycle or two cycles, most of the natural gravels in the country (about 92%) are not expected to suffer more than 32% wastage in quantity. Material wastage from screening would add some element of cost to the construction which must not be overlooked..*

A COMPARISON BETWEEN THE LIFE CYCLE COST OF GRAVEL AND OF BITUMINOUS SURFACING OPTIONS FOR FEEDER ROADS IN GHANA

Ampadu, SIK, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, and FK Addison, Department of Feeder Roads, Ministry of Roads and Highways, Koforidua, Ghana

Feeder roads, which constitute a key component of rural transport infrastructure, play a vital role in rural development, but only 5% of the total feeder road network in Ghana has bituminous seal surfacing. The remaining 95% have either gravel or earth surfacing. However, gravel surfacing (G-S) is known to deteriorate rather rapidly necessitating expensive frequent maintenance while bituminous surfacing offers a more durable surfacing. Various life cycle cost studies have suggested that even though G-S may have lower initial construction costs, they tend to have higher life cycle costs than bituminous seal surfaced ones. However, since most of these studies are based on ideal maintenance practices, their conclusions do not reflect actual field conditions. This study seeks therefore to compare the life cycle cost of G-S with that of bituminous seal surfacing options for engineered feeder roads in Ghana using actual cost data. Data were collected from eight feeder road projects with G-S and a similar number with bituminous surfacing from six regions of Ghana completed between 2010 and 2013. The life cycle cost for each road was computed using a discount rate of 12% and an inflation rate of 15% over an analysis period of 21 years. The results for G-S are then compared with those for single bituminous seal surfacing and for double bituminous seal surfacing. The results are further compared with those from trial sections of an experimental study of Otta seal surfacing using natural gravel and using crushed rock as aggregates. The results suggest that based on the high initial construction costs of bituminous seal surfacing and actual low maintenance intervention practices, G-S remain the least cost option. The study recommends the need for alternative surfacing technology that does not involve bitumen.

THE ENGINEERING CHARACTERISTICS OF THE LATERITE GRAVELS OF GHANA

Degraft-johnson, J W, BHATIA, H S, and Gidigasu, D M

As a result of the study of about 45 typical laterite profiles in the various geomorphological regions of Ghana, a comprehensive classification of laterites is suggested. The following four types of laterite gravels are considered useful engineering materials i.e. nodular or concretionary laterites iron stone hard pans or cap rock, ground water laterites with detrital quartz, and collavial and terrace laterites. A large number of the laterites of Ghana are mechanically weak and tend to break down as a result of weathering and traffic loading. A mod. Aggregate impact test (b.s.812) is very useful for rating the gravels from the point of weathering and mechanical strength. Gravels considered satisfactory as a result of aggregate impact test are classified into four groups on the basis of their grading and their *engineering characteristics. Within each group there is a strong statistical relation between fraction passing no. 200 B.S. sieve or plasticity index and the saturated C.B.R. value. Strength characteristics of gravels can be assessed by means of simple physical tests. A new parameter, 'suitability index,' which depends on the two fractions of gravels namely: percentage retained on no. 7 B.S. sieve, the liquid limit and the plasticity index of the fines is proposed. The suitability index has a significant relation with soaked C.B.R. values and is therefore a useful parameter for assessing the strength of gravels.*

REVIEW OF SPECIFICATIONS FOR THE USE OF LATERITE IN ROAD PAVEMENTS (CONTRACT: AFCAP/GEN/124)

InfraAfrica (Pty) Ltd, Botswana Dr. Frank Netterberg, South Africa Council for Scientific & Industrial Research, South Africa, May 2014

There is irrefutable evidence that lateritic materials that do not comply with standard specifications can perform particularly well when used in road construction, even as base course. In order to construct cost-effective roads, particularly those classified as low volume roads, it is essential that maximum use is made of these local materials. This will require a standardized method for their testing and the development of appropriate specifications for their selection. Extensive research on lateritic materials has been carried out in a number of countries and the science of their use is fairly well advanced. However, it is necessary to assess the test and specification limits that are currently being applied internationally and optimize these for use in sub-Saharan Africa. Brazil, for instance, has a wide range of innovative and appropriate tests but even these are not used nationally, with only local (regional) use apparently being made. Based on the literature, it is recommended that the Brazilian methods would probably be the first approach but many of these would need to be translated and calibrated for wider use. It is interesting to note that the need for a high degree of compaction is considered essential by most practitioners. In order to achieve this, it is necessary to have a well graded aggregate and the normal Fuller type particle size distributions are proposed in most specifications. This tends to go against the need to simplify the specifications and material testing. . Grading, of course also affects the compactability and surface finish of the layer. The use of in situ strength instead of the wide range of other material requirements certainly simplifies the material selection and specification process.

THE PERFORMANCE OF LATERITIC STONES AS CONCRETE AGGREGATES AND ROAD CHIPPINGS

R. M. Madu, Professor of Civil Engineering, University of Nigeria, Nsukka and Rector, Institute of Management and Technology, Enugu.

Laterites and Lateritic Stones abound in the tropical and semi-tropical areas of the world, more than the igneous and other standard rocks which are used as concrete aggregates and road chippings. The paper studies the properties relevant to the use of lateritic aggregate as road chippings and concrete aggregates, and compares the results to those obtained by the use of an igneous control aggregate. The strength growth pattern of concrete made with lateritic stones, the variation of the tensile strength of the concrete (both flexural and split); the reproducibility of the strength pattern, despite *the known variability in the properties of the lateritic aggregates; the influence of the iron and aluminium oxide contents of the aggregates on concrete made with them etc., are some of the parameters investigated in detail to assess the suitability of lateritic stones and crusts as concrete aggregates and road chippings. The results show that lateritic aggregates are good materials for road chippings and concrete aggregates although they give results slightly inferior to those obtained from igneous aggregates. There does not appear to be any simple relation between the iron and aluminium oxide contents or the sesquioxide contents of lateritic aggregates and the properties of the resulting concrete, although the sesquioxide contents of the lateritic stones are very broad indications of their quality.*

GEOTECHNICAL PROPERTIES OF LATERITIC SOIL STABILIZED WITH SUGARCANE STRAW ASH

Amu, O.O., Ogunniyi, S.A. and Oladeji, O.O., Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

This research determined the geotechnical properties of lateritic soil modified with sugarcane straw ash with a view to obtaining a cheaper and effective replacement for the conventional stabilizers. Preliminary tests were performed on three samples, A, B and C for identification and classification purposes followed by the consistency limit tests. Geotechnical strength (compaction, California Bearing Ratio (CBR), unconfined compression test and triaxial) were also performed on the samples, both at the stabilized and unstabilized states (adding 2, 4, 6 and 8% sugarcane straw ash. Optimum moisture content increased from 19.0 to 20.5%, 13.3 to 15.7% and 11.7 to 17%, CBR increased from 6.31 to 23.3%, 6.24 to 14.88% and 6.24 to 24.88% and the unconfined compression strength increased from 79.64 to 284.66 kN/m2, 204.86 to 350.10 kN/m2 and 240.4 to 564.6 kN/m2 in samples A, B and C respectively. Sugercane straw ash was therefore found as an effective stabilizer for lateritic soils.

LOW-COST RURAL ROAD SURFACING: THE USE OF BURNT CLAY BRICKS

Edmund K Debrah, 2nd International Convention on Rural Roads, Jinan City, Shandong Province, China, from 26th – 29th October, 2010.

The clay brick paved road at the CSIR-BRRI premises in Kumasi, Ghana is a practical demonstration of using burnt clay bricks as a road surfacing material. The burnt clay bricks had engineering properties satisfying the basic requirements of the ASTM specification No. C902-99 for Pedestrian and Light Traffic Pavements. The general performance of the road for the past 10 years shows that it is practically an appropriate alternative for surfacing light to medium trafficked roads. The extensive use of labour and hand tools with light equipment make the construction technique an appropriate method friendly for a wide range of skilled and unskilled labour force which translates into employment opportunities and poverty reduction. The minimal maintenance is also a friendly phenomenon that would ensure sustainability. The direct economic benefits are also a plus, let alone the associated intangible social benefits. Thus, the surfacing of light trafficked roads and pavements with burnt clay bricks is an appropriate, economical, and sustainable alternative to the traditional *gravel roads. This is especially so and applicable for the development of all-weather road accesses to promote socio-economic development.*

OPTIMIZING THE POZZOLANA-LIME CONCENTRATION TO MAXIMIZE GEOTECHNICAL PROPERTIES OF NATURAL GRAVEL FOR ROAD CONSTRUCTION

Samuel Innocent Kofi Ampadu, College of Engineering, Kwame Nkrumah University of Scinece and Technology, Kumasi, Ghana

Charles Freeman Alolibila Akayuli, Building and Road Research Institute, Council for Scientific and Industrial Research, Kumasi, Ghana

This study investigated the optimum contents of the stabilizers, lime and calcined clay-pozzolana, which produces the best engineering properties of the laterite soil studied for use as a road construction material. The effect of lime, calcined-clay pozzolana or a combination of both on the Atterberg limits, compaction and CBR of the laterite soil studied and the optimum contents of the stabilizers were presented. The investigators concluded that: (1) neither pozzolana treatment alone nor lime treatment alone produced optimum engineering properties; (2) A mixture of 4% pozzolana and 6% lime produced the lowest plasticity index of 8.7 and plasticity modulus of 191; (3) Interpolation from the plots of the combined effect of lime and pozzolana treatment on the CBR of A-soil indicated that 4% pozzolana and 6% lime produced the highest strength in terms of CBR of 245%, after which further increments in stabilizer contents generally produced treated samples with lower strength; The percentage swell accompanying the soaked CBR of the treated samples were minimal (less than 0.055%), and the variation of plasticity index and CBR of A-soil and related engineering properties such as the plasticity modulus, maximum dry density and swell suggests that 4% pozzolana and 6% lime is the optimum stabilizer content for A-soil that produces the best engineering properties. It was recommended that the Ministry of Transportation of Ghana specification for lime treatment require that the treated layer is covered with damp uncompacted gravel of minimum thickness of 100 mm to allow for protection and curing of the treated layer.

THE DESIGN, CONSTRUCTION AND MAINTENANCE OF OTTA SEALS

Roads Department, Ministry of Works, Transport and Communication, Botswana.

Dwindling resources for the provision of low volume roads in many developing and industrialised countries have prompted road engineers to search for and develop innovative methods of road design and construction in order to reduce costs and at the same time not impair the quality of the end product. Very often, consideration has to be given to the use of local materials, which may be non-standard or of marginal quality, in situations where the use of conventional materials could be prohibitively expensive. One area where cost savings can be made in road construction is with the judicious choice of bituminous surfacing. Normally, the selection of the most cost-effective alternative would be based on a life cycle analysis of appropriate surfacing types in which the influence of a range of factors is investigated. One type of surfacing which has proven to be eminently cost-effective in appropriate situations is the otta-seal using graded aggregate.

SYNTHESIS ON CAPE SEAL VARIATIONS IN SOUTHERN AFRICA

GD van Zyl, Mycube Asset Management Systems, Cape Town, S Africa

JD van Niekerk, PD Naidoo & Associates, Cape Town, South Africa

The writers note that Cape Seals originated in the Western Cape Province of South Africa and are used world-wide with success. Due to various reasons, several variations to the original compositionoccur and include different aggregate sizes, binder types and slurry gradings. These alternatives are still referred to as Cape Seals and could perform well, provided appropriate adjustments are made to the binder application, slurry binder content and construction method. Stone and slurry combination seals are generally referred to as Cape seals and although the initial Cape Seal consisted of 19 mm aggregate and two layers of fine slurry, numerous combinations of binder types, aggregate sizes and slurry gradings are currently used with success on southern African roads, both as initial construction seals and as reseals. The Cape seal is considered a low risk seal, suitable for construction during cold periods, and can handle heavy vehicle turning actions without loss of aggregate.

SPRAY SEALS: QUALITY + APPLICATION RATE = PERFORMANCE

Willem Vonk and Robin van Veldhuysen, Kraton Polymers Research B.V. Amsterdam, The Netherlands

The intrinsic quality of spray seal binders is sometimes not reflected in the performance of the spray seal. They are expected to provide the following features: to seal the pavement, to provide skid resistance, not to lose aggregate and not to bleed or fat up. The demands on the spray seal binder are such that it is not too difficult to define the required performance properties, but the intriguing question is whether one can transform the quality of the binder into the performance of the seal. Premium products are by no means proof and often require more attention than standard operation with unmodified bitumen. Polymers can bring the cohesive/adhesive strength to keep aggregate in place and retain skid resistance and they also provide the high viscosity to prevent bleeding or fatting up. However, they may also change the boundaries in application conditions that allow these features to be retained on the road. The paper described when and how critical application conditions will be approached and what can be done to shift the boundaries.

THE USE AND PERFORMANCE OF BITUMEN RUBBER IN SPRAY SEALS FOR HOLDING ACTIONS IN SOUTH AFRICA

Klasie Jooste, KBK Consulting Engineers, South Africa, Gerrie van Zyl, Mycube Asset Management Systems, South Africa

The paper notes that Non-homogenous Bitumen Rubber was introduced to South Africa in 1983. Due to a rapidly deteriorating road network and visible outstanding performance to extend the life of road pavements, the use of this binder type increased dramatically within a few years. The purpose of this presentation was to provide some background to the composition of bitumen rubber as used in South Africa, to highlight successes using this non-homogenous modified binder in double seals *and to share the lessons learnt. Bitumen rubber has been used with success on roads exhibiting serious cracking and also on roads carrying very high traffic volumes and loads. However the availability and lower costs of synthetic polymer modified binders since 1986, has resulted in more and more roads being resealed with these binders instead of with bitumen rubber.*

TRENDS AND CHANGES IN CHIPSEALING IN NEW ZEALAND

Joanna Towler, NZ Transport Agency, New Zealand, John Patrick, Opus International Consultants Ltd, New Zealand, Peter Howe, NZ Transport Agency, New Zealand

The writers note that an analysis of the age of chip seals when they are resealed on New Zealand state highways shows that, despite increasing traffic stress, there has been no significant reduction in chip seal life. The paper presents data on chip seal lives, compared with changes in traffic volumes, over a 15 year period. Different initiatives covered include the change from single coat to predominantly two coat chip seals, changes in contract types from traditional to predominantly performance based maintenance contracts, and the introduction of a skid resistance policy. An analysis is made of reasons for resealing and other concepts that may have contributed to chip sealing life remaining substantially the same despite long term continued growth in traffic stress on the state highway network.

GUIDELINE FOR THIN LAYER HOT MIX ASPHALT WEARING COURSES ON RESIDENTIAL STREETS

Manual 27, Published by Southern Africa Bitumen Association, 2008

The purpose of this manual is to present a set of general guide lines to assist clients, consultants, paving contractors and asphalt manufacturers to design, construct and manage the quality of thin hot mix asphalt wearing course layers on roads carrying light (pre dominantly passenger car) traffic, mostly in residential areas. In these locations the layers would normally be expected to meet functional requirements, rather than to contribute significantly to the structural capacity of the road pavement. The current application in the de sign and construction of thin layer asphalt which are more germane to layers that contribute to structural capacity, are critically appraised and, where appropriate, alternative methods and procedures proposed. In doing so, it is anticipated that a more uniform, rational approach to the design and construction of such layers would be furthered. In South Africa, widespread use has been made of 20-30mm thin asphalt on low speed roads in residential areas. Most of the mixes have consisted of continuously graded asphalt using aggregates with a nominal maximum aggregate size of either 13.2 mm or 9.5 mm. As performance of these layers was generally considered to be variable, and the consistent achievement of good compaction has often proved to be difficult, a review of the technology associated with the design and construction of these layers appears to be justified.

PRACTICAL ASPECTS OF LOW-COST SEALING OF ROADS

Dr P Paige-Green, CSIR-Built Environment

Many kilometres of earth and unsealed road in South Africa become impassable during the wet season cutting communities off from access to schools, clinics and job opportunities. In addition, the cost of operating vehicles on these roads during the remainder of the year is disproportionately high for the communities affected in relation to the service offered. Of equal or greater impact is the unsustainability of replacing the gravel lost from these roads under environmental and traffic influences. Using conventional economic analysis and pavement design techniques, paving of these roads cannot be justified. However, when environmental and social benefits are considered, upgrading of many of these roads carrying traffic as low as 20 vehicles per day can be justified, particularly when large communities are affected. Economic justification is, however, subject to the use of innovative pavement designs and the use of appropriate surfacing types that reduce the overall construction, maintenance and rehabilitation costs of the project. This paper describes some of the practical fundamentals of the design and construction of such roads.

MEASUREMENT AND INTERPRETATION OF INPUT PARAMETERS USED IN THE SOUTH AFRICA SURFACE SEAL DESIGN METHOD

Gerrie van Zyl, PD Naidoo & Associates (Pty) Ltd, Cape Town, South Africa

Seal design in South Africa using (Technical Recommendations for Highways (TRH 3)) requires information related to conditions on the road at time of sealing and properties of materials to be used for this purpose. Although the design process and input parameters are described in TRH 3, the significance and sensitivity of the various input parameters are perhaps not covered sufficiently to guide designers. In addition, injudicious utilisation of standard test results could result in incorrect application rates for the conditions at hand. The seal design process incorporates investigating the situation under which the seal must perform, dividing the project into uniform areas, sampling of materials, measurement of input parameters, selecting appropriate seal and binder types, calculation of application rates, adjustment on site (if required), verification of aggregate spread rates, managing the opening to traffic and monitoring the initial performance of the seal. The construction process is as important as the design process as the type of equipment and utilization thereof could result in the binder application rate being either too high, appropriate or too low. Therefore, the designer cannot distance himself from the project after specification of application rates.

INVESTIGATIONS IN KENYA AND MALAWI USING AS-DUG LATERITE AS BASES FOR BITUMINOUS SURFACED ROADS

Henry Grace. Geotechnical & Geological Engineering, September 1991, Vol. 9, Issue 3, pp 183-195

In Kenya 1974/5 and in Malawi 1984/5 trial sections of bituminous-surfaced low volume roads were constructed using as-dug laterite in place of stone or stabilized material as a base course. The laterite *did not conform with any accepted specifications but performed equally well when compared with adjoining sections of road using stone or stabilized material as a base. The construction procedures employed are described. A period of 4–6 weeks between the compaction of the base and its surfacing is considered essential if the road is to perform satisfactorily. During this period it is exposed to the weather and traffic or to periodic watering and rolling. This treatment fills any cracks with dust or mud and closes them by the kneading action of rubber-tyred traffic. The bituminous surfacing is applied where the base has dried out to about half the optimum moisture content and is extended about 1.5 m beyond each edge of the carriageway. In 1984, $40000 US per km was saved in Malawi in this way, approximately 70% being in convertible.*

DESIGN AND CONSTRUCTION OF DRAINAGE STRUCTURES

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One of the key elements of rural gravel and earth road construction and maintenance is the provision of sufficient drainage – surface and side drainage (by camber or cross-slopes, and side ditches), and stream and river crossings (i.e. culverts, causeways or also known as drifts or fords, and bridges). Many rural roads and tracks whose surfaces consist of local material, either naturally or occurring on the road or imported from nearby sources, are quite adequate structurally when traffic is light weight and low volume and the wearing course surface is well drained and has sun exposure. However, poor drainage is responsible for most of the structural deficiencies of these roads because unrestrained or uncontrolled water flows cause erosion scouring. Unpaved road surfaces must be sloped (with a camber of up to 5%) to remove standing water and to prevent softening and surface slipperiness after rains. Unfortunately this is often compromised with during construction, or neglected in maintenance. Side drains over 2-3% gradient usually need frequent scour checks and turn outs (mitre drains), and must sometimes be provided with cross-drainage pipes to ensure good lateral drainage. Both machine and hand labour methods have been successfully used to construct good drains for rural roads. Their continued good performance depends on the consistency in maintaining the original camber specifications, and to keep the drains clear of debris. Drainage structures have usually been an integral part of rural roads design and construction and much has already been written on this topic. Therefore, detailed design and construction aspects are not covered in the present paper. Given the importance of good drainage for adequate performance of rural gravel and earth roads it is essential that drainage specification are clearly defined and disseminated.

LOW VOLUME RURAL ROAD SURFACING AND PAVEMENTS: A GUIDE TO GOOD PRACTICE

J R Cook, R C Petts and J Rolt, AFCAP Report, pp 74-83, June 2013

Irregular Cobble Stone Paving consists of a layer of irregularly approximately cubic shaped stones of thickness about 100 - 120mm, laid on a bed of sand or fine aggregate of thickness 50 – 100mm. The individual stones should have at least one face that is fairly smooth and even, to be the upper or surface face when placed. The sand around each stone (or cobble) is adjusted with a small (mason's) hammer and the stone is then tapped into position and to the level of the surrounding stones. Coarse sand is brushed into the spaces between the stones. When a sufficient area of stones is placed, the *layer is compacted with a vibrating or non-vibrating roller. Additional sand is brushed into the surface if necessary. An edge restraint or kerb constructed (for example) of mortared stone or concrete improves durability.*

Cobble Stone Paving is an historically well-established option consisting of a layer of roughly cubic shaped or selected stones of thickness about 100 - 150mm, laid on a bed of sand or fine aggregate within mortared stone or concrete edge restraints. The individual stones should have at least one face that is fairly smooth, to be the upper or surface face when placed. Each stone (or cobble) is adjusted with a small (mason's) hammer and then tapped into position to the level of the surrounding stones. Sand or fine aggregates is brushed into the spaces between the stones and the layer then compacted with a roller.

Stone Setts or Pavé consists of a layer of cubic shaped stones of approximate size 80 - 100mm laid on a thin bedding sand layer (20 – 50mm). The setts can be cut by hand from suitable hard rock such as granite or basalt, which easily breaks into smooth faced pieces. Sand is brushed into the joints between the laid stones and they are compacted using a vibrating plate or light roller. An edge restraint or kerb constructed (for example) of large or mortared stones is required for durability. Sand-cement mortar joints can be used to improve durability and prevent water penetrating to the foundation layers and weakening them. Stone Setts is normally laid on a sub base layer over the in situ soil foundation.

CONCRETE BLOCK PAVING IN DEVELOPING COUNT: A TECHNICAL, ECONOMICAL AND HUMAN ALTERNATIVE FOR ROAD CONSTRUCTION IN DEVELOPING COUNTRIES

A. Bresser, ROADS and H. van den Beld TRANSPORT DEPT.DHV Consulting Engineers, Amersfoort, The Netherlands

In developing countries, notably landlocked countries, the cost of energy has a relatively large influence on road construction costs as well as maintenance costs. It is thus desirable to consider the usual construction methods for pavement of rural and urban roads and to investigate whether or not more economical variants, adapted to local conditions, do exist. Technically satisfying construction methods, which in Europe have been abandoned because of prohibitive prices and/or for other reasons, may be suitable for developing countries. Pavement types to consider in this paper are block pavements and - surface treatments. A comparison of the respective construction costs will be made, including any capital investments required as well as a comparison of the maintenance costs. Maintenance aspects of the various pavement types will be reviewed. Last but not least the human and social aspects of the construction methods will be considered. As international donor, agencies tend to emphasize the involvement to a large extent of local labour and to reduce the foreign currency requirements of infrastructural projects, it will be demonstrated that block pavement meets both requirements.

FOCUS ON ULTRA-THIN, CONTINUOUSLY-REINFORCED CONCRETE TECHNOLOGY

CSIR Built Environment, 2010

Labour-intensive construction of a low-volume road

Ultra-thin (50 mm thick), continuously-reinforced concrete technology was successfully developed and tested by the CSIR and its partners. This technology, aimed at low-volume roads, has also been applied as a single foundation slab for the CSIR low-income demonstration house, in place of conventional foundations, to prevent walls cracking.

The ultra-thin concrete technology passed stringent testing with flying colours. The CSIR, in collaboration with the University of Pretoria and the Gauteng Department of Roads and Transport (DRT) evaluated an experimental road using the CSIR-developed heavy vehicle simulator (HVS) and other equipment and tests.

The HVS is used to determine the effects of traffic on roads, simulating the results of 20 years of traffic within three months.

Low-volume roads

Following the successful research results, the Gauteng DRT decided to use the ultra-thin concrete technology for its roads upgrading programme. A few roads have already been constructed in Soshanguve, Mamelodi and Atteridgeville. The construction of these concrete roads is labour-intensive and requires light equipment, creating job opportunities for small contractors and local communities.

Such roads provide an all-weather surface and improve the lives of communities along the roads by curbing dust and reducing damage to vehicles. Research established that these roads will require minimal maintenance—indications are that they have a life span of more than 20 years, resulting in reduced life cycle costs and disruption to road users.

3.3 Roller Compacted Concrete Solution

One of the previous main disadvantages of traditional concrete surfacings for low volume roads was the increased complexity associated with pavement design and high initial costs which can be excessive for low volume pavements. In large, these have been overcome by the development of design catalogues and easy to use design guides for low-volume roads.

Roller Compacted Concrete (RCC) is reported to be an appropriate pavement construction solution (more durable than bituminous surfacing) for local streets and roads. RCC construction and maintenance costs have been speculated to be 30 per cent lower than those of asphalt. RCC could therefore be a viable alternative for low-volume roads, and specifically for use on steep gradients. A key advantage of RCC is that it allows for roads to be reopened to traffic soon after construction.

3.4 Brief Overview of Drainage and Drainage Structures

Drainage from the road relates more directly to the capacity of the road to shed water without causing erosion. Roads with good profile tend to shed water rapidly, avoiding the development of potholes and potentially impassable conditions. Where the profile is flat, water tends to pond in localised depressions resulting in softening of the wearing course and the development of potholes and other defects. Failure to timeously repair a flat road will usually result in the development of ruts under traffic. These may become preferential water paths resulting in erosion, accelerated gravel loss and significant deterioration in riding quality. On grades, the impact of the transverse profile becomes less dominant than the actual grade. Table 3-3 summarizes ratings/degree of drainage on and from the road (THM 9 2013). Where grades are steep, roads assessed as degrees 4 and 5 will act as drainage courses during periods of intensive rainfall leading to severe erosion. A key component of this study is the identification of appropriate drainage structures for the steep sections of low volume roads.

Table 3-3: Summary of Drainage and Drainage Structures

	Rating of the Degree Drainage
Drainage on the Road	*Degree 1:* Very good shape, well-formed camber (about 3 to 5%) *Degree 2:* Good shape, good camber (about 3%) *Degree 3:* Flat, some unevenness with camber mostly less than 2% *Degree 4:* Uneven, obvious development irregularities that will impeded drainage and form depressions *Degree 5:* Very uneven, development of severe irregularities impeding drainage and likely to cause extensive localised ponding. Water tends to flow to the centre of the road or individual lanes
Drainage from the road	*Degree 1:* Well above ground level. Edges of the road are at least 300mm above natural ground level with effective side drains. *Degree 2:* Slightly above ground level. Road is between 50 mm and 300mm above natural ground level. Side drains are present. Stormwater could cross in isolated places. *Degree 3:* Level with ground. Road is generally at ground level with ineffective side drains. Stormwater could cross in most places. *Degree 4:* Slightly beneath ground level. Isolated areas of the road are below natural ground level. No side drains are present and localised ponding of water will occur. *Degree 5:* Canal. Road is the lowest point and serves to drain the entire area.

4. INCEPTION PHASE MEETINGS AND SITE VISIT

4.1 Project Kick off Meeting

A kick-off meeting was held on 5 February 2016 at the offices of DFR in Accra. The project team met with the management team of DFR, led by the Managing Director. The AFCAP Regional Manager provided an overview of the ReCAP programme and the inclusion of Ghana in the AfCAP Partner Countries. The project team leader tabled the proposed approach that will be pursued for the Inception phase of the project. The DFR representative on the project was introduced to the project team by the Deputy Director for Planning.

Discussions were held on the state of feeder roads in Ghana, and potential problems that required immediate intervention.

The meeting was attended by:

1. Mr FOM Digber — Director, DFR
2. Mr JO Asiedu — Deputy Director of Planning, DFR
3. Dr Paulina Agyekum — Technical Manager AFCAP, West Africa
4. Dr Joseph Anochie- Boateng — Project Team Leader, CSIR
5. Dr K Osafo Ampadu — Chief Engineer, Development, DFR
6. Eng. Edmund Kwasi Debrah — Local Partnering Engineer, BRRI

Following the kick-off meeting, a technical meeting was held in the afternoon attended by the project team and the DFR representative on the project (Dr KO Ampadu). The purpose was to develop a methodology that will facilitate the identification and selection of road sections. The minutes and action points of the meeting are summarized below:

Technical Meeting			
Attendees	JK Anochie-Boateng KO Ampadu EK Debrah		
Time	*From:* 14:45pm	*To:* 16:30pm	
Venue	Meeting Room 1, Luxe Suite Hotel, Accra, Ghana		
Item	**Actions / Discussions**	**Responsibility**	**Time Frame**
Task 1 Objective	The team discussed the key components for the set objectives for Task 1, and mapped out strategies for accomplishments	Team Members	Programme Period
Site Selecting Criteria	>12% vertical slopes of roads Significant Rainfall (*almost all-year round*) 150~200vpd – with loaded trucks		
Candidate/Selected Sites for Visit	Desk evaluation of candidate sites from; Volta, Eastern, Western, Ashanti and Brong-Ahafo Regions were considered. **Eastern** Region sites settled for site visits.	Team Members	08 – 09 February 2016
Tried Surfacing Options in Ghana	Implemented surfacing options with problems; bituminous derivatives, concrete, composite-		

	serial combinations. Such sections to be visited, if practical		
Cost-effective options for Phase II consideration	Bituminous derivatives including steel slag asphalts Concrete base options		
Supplementary Activities	Source for technical data/info for review Visit steel slag sites in Tema for assessments Schedule meeting with Private Contractors	Team Team Members	By 10 February 2016 08 February 2016 10 February 2016

4.2 Meeting with DFR Directors and Engineers

The meeting was held at the conference room of DFR on 11 February 2016. The meeting was chaired by the Deputy Director of Planning. The purpose of the meeting was to introduce the key players in the project, and register the official date for commencement of work. The meeting was chaired by the Deputy Director of DFR. The AFCAP Regional Manager gave an overview of the ReCAP programme and the inclusion of Ghana as an AfCAP Partner Country. The project team leader discussed the approach developed to pursue the inception phase of the project.

The importance of the project to Ghana was reiterated in the meeting, and the need to expedite the entire study to come up with appropriate surfacings for steep sections on the feeder road network in Ghana was emphasized. It was apparent from the discussions and interactions that DFR is in a dire need for all-weather surfacing technologies for feeder roads in Ghana.

The meeting was attended by the following personnel:

1. JO Asiedu — Deputy Director of Planning, DFR
2. P Agyekum — Technical Manager AFCAP, West Africa
3. JK Anochie-Boateng — Project Team Leader, CSIR
4. K Osafo Ampadu — Chief Engineer, Development, DFR
5. EK Debrah — Local Partnering Engineer, BRRI
6. E Duncan Williams — Deputy Director Maintenance, DFR
7. JA Ashley — Deputy Director Development, DFR
8. D Boakye Yiadom — Chief Engineer Maintenance, DFR
9. KO Ampadu — Chief Engineer Development, DFR
10. RO Otoo — Chief Engineer, DFR
11. K Lanquaye — Chief Engineer, DFR
12. Akosah Kodua — Chief Engineer, DFR
13. H Koranteng — Chief Engineer, DFR

4.3 Discussion Points of the Meeting

The following issues were discussed in the meeting

- It was noted that DFR has successfully used marginal materials for feeder roads in Ghana. It was discussed that in order to minimise construction costs, the use of locally available materials must be encouraged. Although many naturally occurring local materials do not meet specification criteria, DFR indicated that satisfactory performance has been observed in Ghana. In many parts of the country, these marginal materials are often within a reasonable haul distance from project roads. However, it was suggested that if it should be included in this study, then there will be a need to verify current specifications and standards.

- DFR to assist in providing information on existing borrow pits and related information to the project team. Discussions were held on the identification of trial sections on ongoing construction/maintenance projects from DFR. This approach will be more economical when compared with the establishment of new demonstration sections. If sections of ongoing projects fail to meet the selection criteria for the study (i.e. gradients < 12 per cent), then DFR is ready to fund the construction of the underlying layers prior to the construction of alternative surfacings.

- The use of construction waste materials and the merits and demerits of the potential use of steel slag for low-volume roads were discussed. It was noted that Ghana's steel smelting plants are all centralized in one city. Although close to 180 tons of slags are produced per month, it was agreed that the cost-effectiveness of using steel slag in feeder roads should be carefully considered. The major concern is long haulage distances from the production plant to the construction sites.

- DFR team suggested that it would be a good idea to consider entirely new surfacing options other than the traditional surfacings they have been using on low-volume roads in Ghana (i.e. single seal with emulsion bitumen).

- Concerns were raised on the use of AC 10 and AC 14 bitumens. A DFR engineer mentioned that performance of these unmodified binders has not been encouraging. It was mentioned that the use of modified binders in bituminous surfacings can possibly be considered in this study.

- A question was raised on the monitoring of the demonstration sections. The project team clarified that monitoring forms part of Phase II of the project. It was however mentioned that monitoring of experimental sections could be done at six-monthly intervals over at least one year to cater for both the dry and wet seasons.

- Drainage – inappropriate structures for cut sections was raised as a concern. In most cases the use of kerbs to collect water from the surface of the roads are inadequate, and has caused erosion problems. Proper drainage structures must be investigated for use on low-volume roads.

- DFR team was made to understand that this project does not involve the construction and studying of whole stretches of feeder roads, but rather focuses on the construction and monitoring of short (~250m) experimental sections.
- DFR suggested the use of Roller Compacted Concrete (RCC) in the study. In response, the project team indicated to DFR that all options will be considered in this phase of the project.
- Importance of the involvement of DFR engineers in the project for knowledge transfer and capacity building. DFR indicated that their technical team will be ready to provide inputs in the final scoping report of the study.

4.4 Project Site Visit

Ghana consists of ten Regions. Out of these, the Eastern and Volta Regions are considered mountainous with more roads located on hilly and rolling terrains (Source: DFR, Ghana). Similarly, the project team was informed that the Western, Eastern and Ashanti Regions of Ghana experience the highest annual rainfall. After deliberations, and taken cognisance of costs and logistical implications on the overall project, it was agreed that the project sites will be identified in the Eastern Region (high rainfall, mountainous area). In consultation with DFR's technical team, the Eastern Region presented a model area for the field investigations.

The project team travelled to the Eastern Region on 8 February 2016 to start the process of site selection. DFR made the arrangements for the trip to the Eastern Region.

The selection criteria for potential/candidate road sections for experimental trials to be carried out in Phase II were spelt out. This was guided by several factors such as traffic, rainfall pattern, slope in excess of 12 per cent, and socio-economic factors of the area.

4.4.1 Feeder Road Network in Eastern Region

The Eastern Region has a land area of 19,323 km² representing 8.1 per cent of the total land area of Ghana, and the sixth largest region of the country. Approximately 30 per cent of the roads in this Region are located on hilly and rolling terrains, thus characterised by significant gradients in excess of 10 per cent. Three main classes of the road network were identified from the network as:

- Non-engineered earth roads
- Gravel roads
- Bituminous surfacings or concrete roads

4.4.2 Field Reconnaissance Survey

The survey was carried out to:

1. Identify steep road sections (more than 12 per cent gradient);
2. Assess existing road conditions on the identified sections;
3. Characterise traffic on the road sections;

4. Assess surfacing interventions at the identified sections, if present;
5. Characterise the materials used for surfacing interventions;
6. Identify sources of available/potential future materials;
7. Recommend sites for experimental trials for Phase II of this project using optimum alternative surfacing technologies that are cost-effective and efficient.

4.4.3 Climatic and Topographical Conditions of Eastern Region

The Eastern Region receives considerable amounts of rainfall during the year. The rainfall pattern of the Eastern Region typifies that of the Brong-Ahafo, Ashanti, Western and Central Regions of Ghana. Thus, the challenges experienced in these regions are very similar. In Ghana, Eastern and Volta are the most hilly and mountainous regions.

4.4.4 Identification of Road Sections

Eng. Eng. Alfonso Quaye, the Deputy Regional Manager, led the project team for the field trip. A total of ten road sections were identified for the project. The route locations and their associated characteristics are presented in Table 4-1.

Table 4-1: Identified Road Sections

Section No.	Route Name	Length of Section (m)	Gradient (%)	Surfacing Type
1	Teiwanya - Sekesua	400	18	Gravel
2	Teiwanya - Sekesua	350	17	Gravel
3	Klo Agogo - Oluahai	1400	22	Gravel/Earth
4	Awukugua bypass	400	12	Gravel
5	Aprade - Troum	500	17	Bituminous Seal
6	Odumase - Oterpolu	400	16	Bituminous Seal
7	Odumase - Oterpolu	300	15	Bituminous Seal
8	Tafo - Nobi	150	18	Concrete
9	Agogo - Opesika	240	17	Concrete
10	Opesika - Samlesi	180	18	Concrete

4.4.5 General Observations of Problems

Erosion

The natural earth and gravel roads, and especially those located on steep terrains were the hardest hit by erosion. Season rainfall [between May and July] could wash away a 100-200 mm thick gravel wearing course in its entirety.

Gullies were formed on the road surface, thereby undermining the functionality, riding quality and safety of the road. On certain sections, the erosion had exposed rock masses of sizes 100 mm and larger that could pose challenges to all forms of motorized and non-motorized transport. At steep sections where the road sides are in cuts, erosion of the cut surfaces deposited eroded material on to road surface undermining the road's functionality. Severe erosion rendered kerbs dysfunctional (cf. Figure 4-1).

Drainage

In many cases, cuts were found to be very close to the shoulder of roads. It was observed from the site visit that where the road is traversing cut sections, there is significant runoff. In these areas, Kerbs were rather found to be the drainage structures mostly used by DFR to capture such runoffs. It was observed that these kerbs were inappropriate to capture large volumes of run-off water on the surfaces of the roads. Proper drainage structures must be used to intercept water and prevent it from entering the surface of road at these sections. Concrete u-drains for instance, have been used successfully at cut sections.

Erosion Caused Gullies On Teiwanya-Sekasua Road Section

Severe Erosion Renders Kerbs Non-Functional: Teiwanya-Sekasua Road Section

Exposed stones (100mm) due to erosion on the Klo Agogo – Oluahai section

Run-offs from cut sides caused serious road surface erosions - Teiwanya – Sekasua

Figure 4-1: Gravel Roads Showing Severe Erosion.

Terrain

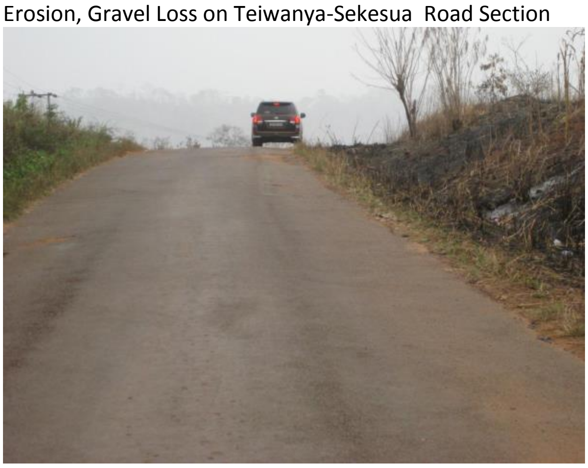
Many sections of the feeder roads are on hilly and winding terrains. Gradients could be as high as 22% as noted on the Klo Agogo-Oluahai road (Figure 4-1). This worsens the effects of erosion and significantly affects movement of vehicles. Transport is greatly affected by such steep sections as the surfacing conditions are poor.

Sharp Curves

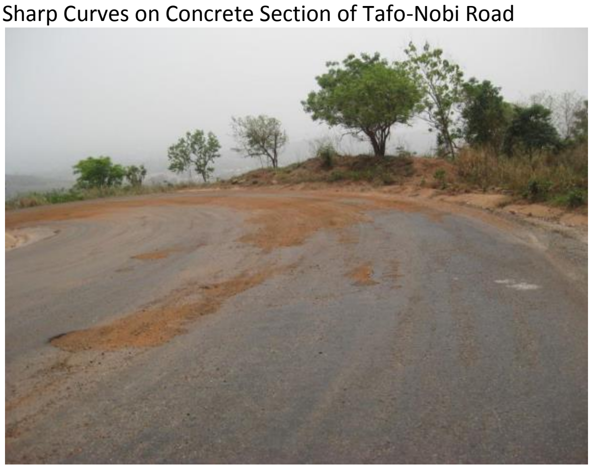
Turning effects of vehicles, particularly heavy trucks, often causes significant damage to the pavement surfacing and structure. Figure 4-2 provides an example of a failed bituminous surfacing seal on a sharp curve on the Somanya-Oterpolu road, even as the road is under construction.

Erosion, Gravel Loss on Teiwanya-Sekesua Road Section

Sharp Curves on Concrete Section of Tafo-Nobi Road



Steep Slope with Single seal surfacing on Opesika-Samlesi Road



Eroded Single Seal on Sharp Curve, on Steep Slopes: Somanya-Oterpolu Road Section

Figure 4-2: Bituminous Surfacing on Steep Slopes and Sharp Curves.

Slippery Surface

The steepness of roads could render road surfaces slippery during the raining seasons, particularly on the gravel roads. It was gathered that during raining seasons, several gravel roads become non-trafficable at steep sections and/or sharp bends due to slippery road surfaces.

Traffic

Traffic volumes on most of the roads are best assessed during market days. On market days, the traffic volumes are relatively high in the range of 100 to 200 vpd, whereas the volumes could decrease to less than 50 vpd on non-market days. The terrain and road surface conditions are the driving factors affecting the levels of motorized traffic on roads. Generally, these roads carry a wide variety of different road users, from heavy vehicles to motorcycles and bicycles.

4.4.6 Existing Surfacing Types

Sealed surfaced sections are of two types: bituminous seals or reinforced concrete. The bituminous surfaces typically consist of a bitumen-emulsion binder and aggregate with a nominal size range of 10mm to 14mm. When placed on steep slopes, they tend to be susceptible to various forms of pavement distress. The concrete treated sections are usually reinforced slabs with a thickness of approximately 200 mm.

Patching of Bituminous Single Seal Surfaced on Aprade-Somanya Road

Rehabilitated Section with both Concrete and Bituminous Surfacing

Reinforced Concrete Surfaced on 18% Gradient Section on Tafo-Nobi Road

A 200 mm Thick Reinforced Concrete on a Steep Section of Agogo-Opesika Road

Figure 4-3: Different Surfacing Types on Steep Slopes.

4.4.7 Conditions of Bituminous Sections

The following photographs show predominant defects on the bituminous sealed roads investigated. These sections have experienced various forms of failures, some of which occurred during the construction period. On the Aprade-Somanya road section, the single seal surfacing had failed prematurely on steep slopes and curves due to the movements of heavy good vehicles (low volume).

Spalling of Single Seal Surfacing on: Aprade-Somanya Road Section

Disintegration of Single Seal Surfacing on Somanya - Oterpolu Road

Potholes on Bituminous Surface Due to Traffic Action - Aprade-Somanya Road Section

Surface Failure of Single Seal Section on the Somanya-Oterpolu Road

Figure 4-4: Surface Failures of Bituminous Surfacing on Steep Slopes.

4.4.8 Specific Observations on Concrete Surfacings

Some of the observations on roads surfaced with concrete include:

- Poor workmanship and finishing, worn-out concrete surfacings;
- Over-designed pavement structures – 200 mm concrete with reinforced steel size of 12 mm;
- Longitudinal and transverse cracking of the concrete layers was observed on most of the concrete sections.

Partially failed concrete structure showing longitudinal and transverse cracks

Washed material from cut surface on the road: Tafo – Nobi road section

Drainge Structure on Conrete Surfacing Road Section

Sever Block and Corner Cracks Road Section

Figure 4-5: Drainage Structure and Failed Concrete Surfacing on Steep Slopes.

4.4.9 Material Sources and Availability

Previous research in Ghana has shown that the local materials, despite not meeting standard material requirements for road construction can perform satisfactorily on low volume roads, resulting in significant cost savings and environmental benefits.

One of the fundamental principles behind this study is the requirement for locally orientated solutions based on available local resources and the local road environment. This approach is seen as crucial in the development of affordable and sustainable rural road infrastructure. If large quantities of local material with marginal properties are available, the road sections will be designed to make optimal use of these materials.

Sufficient borrow pits should, however, be available along or close to the feeder roads to provide the necessary quantity of materials within economical haul distances. It is assumed that in some cases, suitable materials can be obtained from cuttings of reasonably large quantities of materials from the road during construction or maintenance. In addition, it is possible to achieve blending of naturally occurring materials with different properties to constitute a material with improved characteristics (plasticity, grading, strength etc.) for base/subbase layers. If blended materials are unlikely to provide sufficient strength owing to their quality and variability, then bituminous or cement stabilisations will be considered for these layers.

The available materials and sources identified during the site visit are presented in Table 4-2. At this stage it is noted that the proximity of borrow pits and stone quarries, for instance, is an important criterion to select a site for the construction of the demonstration sections.

Table 4-2: Materials Sources and Description

Material Type	Description	Source / Comments
Sand	Fine	Winning sites within catchment
Crushed aggregates	All sizes for road construction	Quarry sites maximum haulage- 50km
Gravel	Lateritic soils	Gravel Pits
Bitumen	Unmodified and modified	Supplier dealers
Cement	Regular classes, e.g. N32, R42, etc.	Dealer companies
Concrete products	Paving blocks of various strengths; 30 – 50 $N/mm^{2,}$ Kerbs, etc.	Supplier companies
Clay brick units	Compressive strengths up to 50 N/mm^2	Supplier companies
Steel products	Mild tensile rods of varying sizes	Six steel plants and dealer companies
"Waste" materials and industrial by-products	Demolition concrete, Steel slag	Waste from three steel smelting companies in the heavy industrial area at Tema, Ghana

4.4.10 Criteria and Selection Process of Alternative Surfacings

There is a wide range of surfacing options for low volume rural roads. For this project, selection will be based on consideration of the factors and the criteria shown in Figure 4-6 (interim). Extensive consultations will however, be made to obtain guidelines that need to be used to determine life-cycle costing of the various feasible paving options.

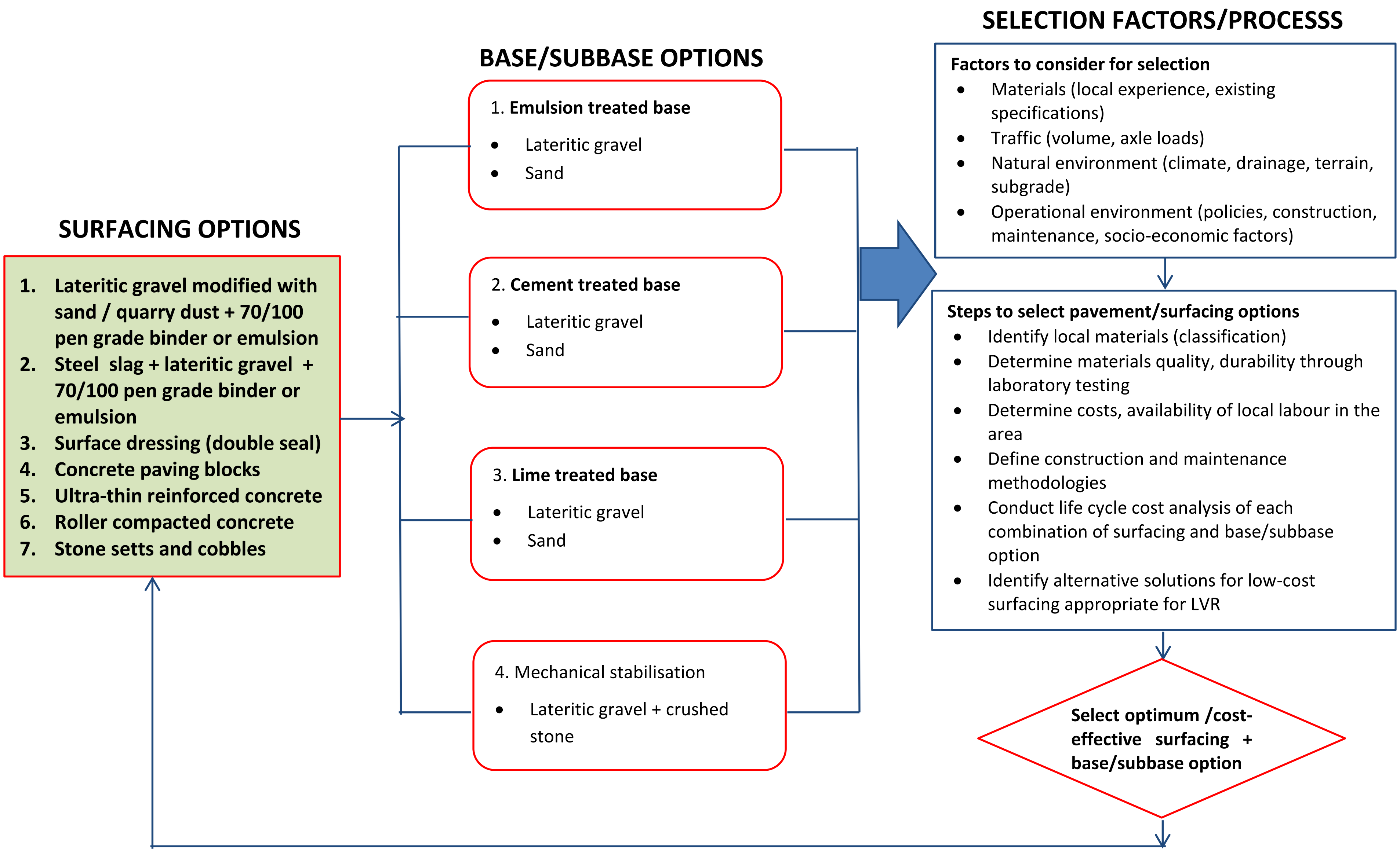


Figure 4-6: Selection Factors and Process for Surfacing

5. IMPLEMENTATION PLAN FOR PHASE I

5.1 Gantt Chart

The Gant chart below shows the summary of the activities planned for the first phase of the project. Detailed activities are presented in section 5.2.

Activity	Time (Month/Weeks)															
	February 2016				March 2016				April 2016				May 2016			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Activity Group I	■	■														
1.1 Project start up meeting	■															
1.2 Literature study	■	■														
1.3 First trip to Ghana by project team leader (**4 - 14 February 2016**)	■	■														
1.3 Stakeholder consultations and site visit	■	■														
1.4 Prepare and submit Inception Report (**Milestone 1: 15 February 2016**)		■														
Activity Group III			■	■	■	■										
2.1 Detailed Review of available literature, data and reports			■	■	■											
2.2 Examine existing guidelines and standards			■	■	■											
2.3 Inventory of local materials for low-volume roads			■													
2.4 Assessment of all available information sources			■	■												
2.5 Progress Report (**Internal, 14 March 2016**)					■	■										
Activity Group III			■	■	■	■	■	■	■	■						
3.1 Conduct detailed site reconnaissance			■	■	■											
3.2 Stakeholder consultation				■	■											
3.3 Drafting of scoping document						■	■									
3.4 Second trip to Ghana by project team leader (**29 Mar - 21 Apr**)								■	■	■						
3.5 Prepare and submit Draft Project Report (**Milestone 2: 11 April 2016**)										■						
Activity Group IV										■	■	■				
4.1 Analysis and discussion of Draft Report (**Project Team**)										■						
4.2 Stakeholders workshop on Draft Project Report (**18 April 2016**)											■					
4.3 Prepare and submit Workshop Report (**Milestone 3: 25 April 2016**)												■				
Activity Group V													■	■	■	■
5.1 Prepare Interim Final Report (**2 May 2016**)													■			
5.2 Technical review of deliverables (**3 -5 May 2016**)													■			
5.3 Prepare and submit Final Report (**Milestone 4: 9 May 2016**)													■	■		
5.4 Comments from AfCAP and Project Closure															■	■
6.1 Project planning and management	■	■	■	■	■	■	■	■	■	■	■	■	■	■		

5.2 Overview of Planned Activities

5.2.1 Activity Group I

- Inception phase -project appraisal, identification of priorities and drafting of Inception Report
- Project start-up meeting and introduction of project team to DFR
- Stakeholder meeting, site visit and selection of experimental sections
- Inception Report

5.2.2 Activity Group II

- Review the planning and coordination of the remainder project activities (i.e. Task 2 to Task 5)
- Conduct detailed review of all available literature, data and reports – analysis and documentation on alternative surfacing materials and techniques for low-volume roads
- Examine existing guidelines and standards including soil classification systems to provide:
    - a means of grouping and identifying the expected behaviour of soil, water management, drainage measures, erosion control techniques used in low-volume roads, design, construction, and maintenance interventions
    - recommendations on appropriate temporary and permanent control methods
    - identification of suitable new technologies and knowledge gaps
- Inventory of naturally occurring local materials for low-volume roads and database (i.e. mapping of material resources for road construction)
- Assessment of all available information sources, including previous road materials investigations, quarry and borrow pit data, and conduct a gap analysis
- Progress Report

5.2.3 Activity Group III

- Conduct detailed site reconnaissance for the development of project scoping
- Stakeholder consultation
- Drafting of scoping document that defines erosion problems, outlines general causes, and provides various options of erosion control treatments and alternative surfacing techniques with recommendations for research during Phase II of the project
- Finalise action plans, incorporating the comments and suggestions received from DFR and experts from overseas, and produce a final scoping document for the project
- Second trip to Ghana by project team leader
    - Schedule and interact with DFR on general issues relating to the study
    - Prepare Scoping Report
    - Visit to the selected road sections in the eastern Region
    - Receive feedback from the DFR team on Scoping Report
- Draft Project Report

5.2.4 Activity Group IV

- Analysis and discussion of Draft Report
- Conduct a workshop with stakeholders to discuss the findings, recommendations and suggested solutions, including proposals and agreement of follow-up research for Phase II
- Workshop Report

5.2.5 Activity Group V

- Prepare Interim Final Report for comments
- Final report proposing cost-effective and sustainable surfacing options for hilly slopes on low- volume roads, and a matrix for further research (i.e. Phase II)
- Conduct technical review of deliverables
- Final Report

5.3 Deliverables

The following are the deliverables and timelines:

- Inception Report (**due 15 February 2016**)
- Progress report (due 14 March 2016) containing the following:
    - Detailed review of all available literature, data and reports
    - Existing guidelines and standards including soil classification systems
    - Inventory of naturally occurring local road materials
    - Minutes of the meeting with DFR
- Draft Project Report (**due 11 April 2016**) containing the following :
    - Detailed site reconnaissance
    - Proposed surfacing options for low-volume roads
    - Status report on project scoping
    - Report on meetings held with DFR on the project scoping
- Workshop Report (**due 25 April 2016**) containing the following:
    - Analysis and discussion of the Scoping and Draft Project Reports
    - Status on knowledge transfer and capacity building/skills development
    - Report back on workshops held
- Final Report (**due 9 May 2016**) containing the following:
    - Minutes of meetings held between project team and DFR
    - Revised scoping plan for the project
    - Consolidation of all reports produced from the study

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