Africa Community Access Partnership

# Alternative Surfacing for Steep Hill Sections in Ghana – Phase 2

Inception Report

Labour-intensive construction of a low-volume road

**J. Anochie-Boateng, E. Debrah**
Council for Scientific and Industrial Research (CSIR), South Africa
Building and Road Research Institute (BRRI), Ghana

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Cover Photo: *Construction of ultra-thin reinforced concrete pavement*

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ReCAP Project Management Unit
Cardno Emerging Market (UK) Ltd
Oxford House, Oxford Road
Thame
OX9 2AH
United Kingdom

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## Abstract

The Council for Scientific and Industrial Research (CSIR) in South Africa, in partnership with the Building and Road Research Institute (BRRI) of Ghana, was appointed by the Africa Community Access Partnership (AfCAP), being managed by Cardno Emerging Markets (UK) Ltd on behalf of the UK Department for International Development (DFID), to undertake the second phase of a study on alternative surfacing for steep slopes on low-volume (feeder) roads in Ghana. This followed the first phase study to scope for and select suitable surfacing options for the current project. The principal project partner is Ghana Ministry of Roads and Highways represented by the Department of Feeder Roads (DFR).

The contract that was awarded on 24 January 2017, has a start date of 13 February 2017 and is scheduled for completion on 3 February 2020. The objective of the current study is to identify, define and demonstrate appropriate surfacing options as alternatives to the current gravel wearing courses on the steep hill sections of feeder roads in Ghana, and to offer sustainable solutions to address drainage and erosion problems experienced by those steep sections. Demonstration sections will be designed and a nominated contractor will construct the pavements using cost-effective machinery and labour-based methods. The sections will be monitored, and data will be collected for development of guidelines and specifications for steep slopes. It is anticipated that the demonstrated surfacings would be adopted by the DFR as treatment options for steep slopes on feeder roads, and spot improvement to vulnerable steep sections of an otherwise acceptable gravel road on flat and rolling terrains to provide all-season access.

The work will be carried out in the Eastern region of Ghana. This region has mountainous terrain (several low-volume roads are located on gradients in excess of 12%) and annual mean rainfall of 1,800 mm. The study will not only develop and introduce innovative ways of constructing the alternative surfacings, but will also build capacity and knowledge transfer amongst Ghanaian practitioners, researchers at the DFR, BRRI and Ghana Highways Authority (GHA). The work done during the inception phase and the project planning for subsequent tasks are summarised in this report. Suitable project site selected for the study, and viable research matrix of surfacing options to demonstrate in the project are presented. The preliminary recommendations made in this report will be discussed further with the DFR to ensure effective implementation of the works.



**Key words:**
Low-volume roads, Steep gradients, Cobblestones, Cold mix asphalt, Interlocking concrete block, Roller compacted concrete, Thin reinforced concrete


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## 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), and is managed by Cardno Emerging Markets (UK) Ltd.

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## Acronyms

| | |
|---|---|
| AfCAP | African Community Access Programme |
| BRRI | Building and Road Research Institute |
| CBP | Concrete Block Paving |
| CMA | Cold-Mix Asphalt |
| CML | Central Materials Laboratory |
| CSIR | Council for Scientific and Industrial Research |
| DFID | Department for International Development (UK) |
| DFR | Department of Feeder Roads |
| ERA | Ethiopian Road Authority |
| GHA | Ghana Highways Authority |
| GSA | Ghana Standards Authority |
| GSSRB | Ghana Standard Specifications for Road and Bridge Works |
| HMA | Hot-Mix Asphalt |
| HVR | High-Volume Roads |
| KNUST | Kwame Nkrumah University of Science and Technology |
| LVR | Low-Volume Roads |
| LVSRs | Low-Volume Surfaced Roads |
| MoT | Ministry of Transport |
| MRH | Ministry of Roads and Highways |
| PMU | Project Management Unit |
| R&D | Research and Development |
| RCC | Roller Compacted Concrete |
| ReCAP | Research for Community Access Partnership |
| RSIM | Research Statistics and Information Management |
| SATCC | Southern Africa Transport and Communications Commission |
| SEACAP | South East Asia Community Access Programme |
| TMRC | Thin Mesh-Reinforced Concrete |
| TOR | Terms of Reference |
| TRL | Transportation Research Laboratory |
| UTRC | Ultra-Thin Reinforced Concrete |
| vpd | Vehicles per day |

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# 1 Executive Summary

This Inception Report was prepared to highlight the progress of work at the 6-week inception phase of the Phase 2 study on steep hill sections of low-volume (feeder) roads in Ghana and to indicate how subsequent tasks/activities will be undertaken to achieve the goals of the project. The main objective of the inception phase was to sensitise stakeholders to the aims and objectives, and present the work plan with the required inputs and outputs of the project. The selection of a project site with adequate lengths of sections to accommodate the experimental (demonstration and control) sections and gradients more than 12% was challenging, resulting in a change in an initial project site identified for the study. Also, the inclusion of the roller compacted concrete (RCC) surfacing in the study has increased the quantity of materials testing work on the project. Accordingly, the project plan for three tasks — site investigation, draft designs and final designs has been adjusted. As a result of this change, milestone deliverables for Tasks 2, 3, and 4 have been pushed back two to three months depending on the activities involved. However, the overall plan to undertake the assignment over a period of 36 months remains unchanged.

The following key activities were completed at the inception phase:

- Project mobilisation
- Detailed review of related technical documents used in Ghana and other sub-Saharan African countries (i.e. Malawi, Mozambique, Ethiopia, South Sudan, Tanzania)
- Meetings and consultations with key officials of the DFR and other stakeholders so as to obtain technical information to support the study
- Visits to candidate project sites to determine suitability for experimental sections
- Assessment of good practices from the sub-Saharan African countries and evaluation of alternative surfacing options that have been used in these countries
- Visits to four material testing laboratories to assess their respective capabilities
- Development of preliminary research matrix and endorsement from the DFR and AfCAP PMU

The work done during the inception phase and conclusions made are summarised as follows:

- Five surfacing types including roller compacted concrete (RCC) instead of four as per the contract requirement will be demonstrated in this study. These are; cobblestones, innovative interlocking concrete paving blocks, cold mix asphalt, roller compacted concrete and thin mesh reinforced concrete.
    - RCC is being demonstrated under an AfCAP project in Ghana on a road with a relatively gentler gradient. It was strongly recommended for demonstration in this project to compare its performance on steeper gradients. Costs of the inclusion of RCC in the project — relatively insignificant — will be submitted to the AfCAP PMU for a consideration of an addendum to the original contract.

  - In a meeting with the project team on 24 May 2017, the DFR expressed concerns about the inclusion of thin hot-mix asphalt (HMA, 50 mm thick) in the surfacings for demonstration. These concerns are related to production and construction (e.g. scarcity of mobile asphalt plants and limited commercial asphalt plants in Ghana, long haulage distances to the project site, and the need for expensive construction equipment). It was agreed that the thin hot mix should be replaced by cold mix asphalt for demonstration.

- Although whole life cycle cost analysis indicated that a single Otta seal surfacing is economically feasible for use on the steep hill sections of feeder roads, the DFR and Ghana Ministry of Roads and Highways (MRH) were of the view that since Otta seals had already been trialled in the western and central regions of Ghana, they would prefer cobblestone /stone setts to be demonstrated with the other four surfacings.

- Suitable road (project site) with gradients varying between 12 and 22% has been identified for the study. The total length of the road is 3.5 km with 1.9 km of steep hilly sections. The road can conveniently accommodate five demonstration sections and two control sections with a minimum length of 275 m each.

- Majority of pavement structures proposed for the alternative surfacing involve a three-layer system. Based on the work done in Malawi, it is possible to design a two-layer pavement system in which the existing natural subgrade is “proof-rolled” and overlaid with a natural gravel base and surfaced with the proposed surfacing options.

- Based on the lab assessments, materials testing will be conducted at both the GHA Central Materials Laboratory (CML) in Accra and BRRI Lab in Kumasi. The two Labs complement each other in terms of the testing programme proposed for the study. The overall laboratory testing programme will however, -be led and managed by the BRRI.

- Outcomes of the study will be used to initiate the development of guidelines and specifications for steep hill sections of low-volume roads in Ghana. The final guideline/specification will draw on the outputs of the laboratory and field works carried out in the project, and ultimately aligned with the AfCAP West African sub-regional project on the development of low-volume roads manual for Ghana, Sierra Leone and Liberia. It is suggested that a single document instead of individual documents be developed for the five surfacing types. This will further be discussed with the AfCAP PMU as the project progresses.

- Since the DFR will use an existing contract for the demonstration sites, the DFR should clarify deviations from current norms and standard approach of feeder roads construction to the contractor, and highlight research as key component in this project. Selected contractor should have good background /experience in the construction of the proposed surfacings. Preferably, a contractor who has paved similar roads in the country should be nominated for this project.

- The proposed protocol for monitoring is designed to be in line with the AfCAP regional protocol for experimental sections on low-volume roads. Since the DFR is not familiar with this type of monitoring the counterpart staff will be trained in the use of the protocol. Detailed step-by-step procedures of the protocol will be provided during the project training. It is anticipated that this training in the use of the protocol will involve practitioners from Sierra Leone and Liberia.

- For effective knowledge transfer and capacity building, it was emphasised at the inception meeting that the participation of DFR staff should be a continuous process. It is expected that after the contract period of three years the trained staff from the DFR would have acquired the prerequisite skills and knowledge to continue with the monitoring and evaluation of the demonstration sections.
- A detailed work plan for the implementation of site investigation, draft designs and final designs of the demonstration sections is provided in this report with detailed activities and timelines.
- No major concerns were raised at the inception stage and thus, a successful implementation of the project is anticipated.

Based on the findings and issues highlighted in this report, the following recommendations are made:

- Due to concerns raised by the DFR, it is recommended that cold-mix asphalt be accepted to replace the thin hot-mix asphalt (50 mm).
- The project has already experienced a challenge of site selection, and that has impacted some deliverables. To avoid further delays, the DFR should request the nominated contractor to produce a detailed programme of works two weeks after the first stakeholder workshop.
- The DFR team indicated a desire for the study to include instrumentation (such as traffic counters, underlying pavement material monitors, etc.) to allow the DFR to monitor and evaluate the different pavement options. Introduction of appropriate instrumentation in this project is recommended, albeit it is contingent to the ability of the DFR to fund them.
- The BRRI laboratory should coordinate and collaborate with GHA CML to conduct all materials testing. The DFR in consultation with the BRRI should facilitate the process to appoint GHA CML as there could be potential delays.

As monitoring and evaluation of the demonstration sections will be undertaken during two years of the contract period, it is not likely that the economic benefits of the demonstrated surfacings would be fully established. However, several research lessons are to be learned during the contract period. These include the following:

- Potential use of locally sourced construction materials such as screened laterite and marginal materials on steep sections of low-volume roads.
- Viability of new types of road surfacing such as concrete, bituminous and stone paving on steep gradients.
- Challenges associated with the use of labour-based and light machinery-based construction methods on steep hilly sections of feeder roads.
- Construction materials and design concepts for steep gradients of feeder roads that could eventually change the design of low-volume rural roads.

- Evaluation of techniques for design, construction and monitoring of the experimental sections that can be incorporated in national standards.
- Contractor proficiency such as quality of construction, and use of new construction techniques to implement steep gradients interventions on feeder roads.
- Comparison between initial construction costs as well as whole life-cycle costs for innovative surfacing options for the purpose of cost-benefit analyses.

# 2 Introduction

## 2.1 Background

The agenda for Ghana's shared growth and development (2010-13) includes interventions for the rural (feeder) road sector such as re-instating labour-based methods of road construction and maintenance to improve rural roads and maximise employment opportunities, as well as building capacity of local road contractors and consultants. As the main economic activity in Ghana is agriculture, poor rural roads will undermine economic growth of the country. Rehabilitation/maintenance of feeder roads 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. In recent years, research has shown that most earth and gravel roads in Ghana are uneconomical and practically unsustainable. Hence, the identification of appropriate design options for higher risk sections of low-volume (feeder) roads is seen as an important component of Ghana's strategy for improving sustainable all-season rural access. The Department of Feeder Roads (DFR) is responsible for the administration, planning, control, development and maintenance of feeder roads in Ghana.

Steep slopes (gradients in excess of 12%) on of low-volume (feeder) roads are at high risk of slope failure, erosion and drainage-related problems that ultimately affect the rural communities in respect of traffic delays, safety, damage to natural resources, and access to social and economic activities. These problems have been attributed mainly to prolonged rainy seasons, coupled with weak natural gravels that are commonly used as wearing course on the feeder roads. To address these problems, AfCAP through the Research for Community Access Programme (ReCAP) commissioned Phase 1 of a two-phased study on alternative surfacing for steep hill sections of feeder roads in Ghana in 2016. A major outcome was a matrix of three alternative surfacing options (i.e. concrete, bituminous and stone setts/cobbles) for comparison with the gravel wearing courses currently used by the Department of Feeder Roads (DFR), and a scoping report for Phase 2. The three surfacing types and two base/subbase layer materials provided 18 different interventions for feeder roads in Ghana. In addition, various options of erosion control treatments and alternative drainage structures to kerbs were identified. A cost analysis was recently conducted by Anochie-Boateng et al. (2017) to select the six most cost-effective pavement options for demonstration sections to be designed, constructed and monitored under the Phase 2 project. However, due to budget constraints, only four pavement options will be studied in this project as agreed with the DFR.

The Council for Scientific and Industrial Research (CSIR) in South Africa, in partnership with the Building and Road Research Institute (BRRI) of Ghana, was appointed by the Africa Community Access Partnership (AfCAP), being managed by Cardno Emerging Markets (UK) Ltd on behalf of the UK Department for International Development (DFID), to undertake the second phase of a study on alternative surfacing for steep slopes on feeder roads in Ghana. This followed an earlier study to scope for and select suitable surfacing options for steep hill sections in Ghana. The contract has a start date of 13 February 2017 and is scheduled for completion on 3 February 2020.

The following documents will be produced from this project:

- Design guidelines for alternative surfacing for steep slopes on feeder roads in Ghana.
- Construction guidelines for alternative surfacing for steep slopes on feeder roads in Ghana.
- Specifications for alternative surfacing for steep slopes on feeder roads in Ghana.

Whether or not separate design and construction guidelines are required (as opposed to a combined guideline document) would be subject to discussion during the first project workshop. Changing or introducing new design standards for steep hill sections on feeder roads in Ghana may undoubtedly require policy decisions from the Ministry of Roads and Highways in Ghana. Therefore, consultation will be an important element of the development of this part of the guidelines.

This Inception Report provides the overall framework for the study, namely the background, scope and methodology, as well as deliberations during project meetings. Furthermore, a detailed implementation plan is provided with recommendations to guide the project team on how to effectively execute the project to meet the needs of the client. A summary of activities undertaken during the project inception phase is also presented in this report.

## 2.2 Objectives of assignment

The study is aimed at identifying, defining and demonstrating appropriate surfacing options as alternatives to the current gravel wearing courses on the steep hill sections of feeder roads in Ghana. In line with this objective, the CSIR will undertake this assignment to achieve three key objectives: to conduct relevant research, to transfer knowledge and build capacity, and to take up and embed the outcomes of this study into nationally approved guidelines and specifications.

### *2.2.1 Conducting relevant research*

The key focus of the research component is to establish appropriate design and construction techniques for steep hill sections and provide guidelines and work norms to develop standards and manuals for the use of surfacing options for steel hill sections on feeder roads in Ghana. These will be based on the results that emerge from the demonstration and control sections to be constructed and monitored during the project period.

A number of different aims that are listed below constitute the research objective of the project:

- To provide all-season access to low-volume roads by providing better surfacings on steep hill sections than the existing gravel wearing course.
- To demonstrate alternative pavement surfacings suitable for steep hill sections of feeder roads in Ghana so as to reduce the demand for gravel.
- To identify cost-effective and innovative community-based construction methods.
- To create a design concept for steep gradients of feeder roads that will eventually change the design of low-volume rural roads. The present design involves extensive re-gravelling works.

- To promote the use of locally sourced construction materials and investigate the use of alternative and marginal materials on steep slopes of low-volume roads.
- To promote the use of labour-based construction methods to provide employment for people in local communities. These people should help maintain the rural road network after construction has been completed.
- To incorporate steep section design concepts as part of the standard used in Ghana for feeder roads.

### 2.2.2 Transfer of knowledge and capacity building

As in the case of all AfCAP projects, an important aspect of Phase 2 is knowledge transfer to the DFR, other road agencies in Ghana, as well as other sub-Saharan African countries faced with steep hill sections on low-volume roads. The transfer of knowledge to the DFR staff is a key component of this assignment, and therefore these staff members were encouraged to participate in all stages of the project during the kick-off meeting.

At the inception of Phase 2, a preliminary assessment of capacity needs was conducted through engagement with the DFR. The project team was informed about the areas that required additional training, what areas should be prioritised, and in what ways capacity building can be incorporated into the DFR strategies to achieve all the project aims. Two senior and four young civil engineers from the DFR will take part in the project. One of them (Mr Joseph Mawusi) accompanied the project team during the site visits. It was agreed that these young engineers would take part in all stages of the project. These engineers will be trained in aspects such as setting up of research projects, laboratory testing, field survey and investigations, data collection, analysis and presentation of results, and development of guidelines/protocols. Their involvement could extend to monitoring the demonstration sections after the contract has been completed. In addition, it was noted that most of the current contractors for feeder roads may not have strong technical backgrounds to successfully deal with the pavement options identified for this study.

Capacity building is therefore critical and it is the responsibility of the project team to assist the DFR and the contractor with any technical aspects involved in the construction of the different pavements. It is envisaged that local personnel will be trained and engaged in carrying out simple tasks during construction and monitoring. This will contribute to capacity building within the community and ensure continuity of the project after the contract has been completed.

### 2.2.3 Uptake and embedment

The uptake strategy as proposed will include efforts to implement the outcomes so as to maximise the impact of the project. The implementation effort will involve information distribution, meetings, presentations, workshops and technical discussions with personnel from the DFR. Presenting the findings at meetings/workshops will for instance ensure that relevant stakeholders at large are engaged. Three workshops will be conducted at different times as main tasks.

At this inception stage, it was emphasised that the full benefits of the project will be realised only if the pavement options are adopted in practice by the DFR. To achieve this objective, the project team initiated discussions with the DFR on a strategy to regularly revisit and check all tasks/activities of the project progress. It was emphasised during the project inception that the project team will assist the DFR to embed the outcomes of this study into nationally approved guidelines and specifications.

### *2.2.4 Comments on scope and terms of reference*

The scope of work for this project is guided by the requirements as stipulated in the Terms of Reference (TOR). The scope comprises 10 main tasks to be carried out to achieve the objectives of the contract. The tasks and activities for the project are more or less the same as set out in the proposal and contract document. The TOR were well understood. It provides a comprehensive description of all the vital information required for a clear understanding of the services and thus the expected outputs of the assignment. The main change proposed is in relation to the timing for Tasks 2, 3 and 4.

The observations made during the Inception Phase of the project are related to some of the services required:

- Five surfacing types including RCC instead of four as required by the TOR of the contract will be demonstrated in this study. Although this is not expected to affect the overall project timeline of 36 months, there is a cost implication on both the research and construction components of the project. Costs of the additional surfacing (i.e. RCC) has been submitted as an addendum for consideration in the original contract.

- A second site selection programme was undertaken since an initial proposed site did not have adequate lengths of steep sections with gradients more than 12% and had to be changed. Consequently, the milestone deliverables dates for Tasks 2, 3, and 4 were affected by the change of site, and have been pushed back two months. This change did not affect the overall timing to complete the project in 36 months. Request for extension of time to deliver on some tasks will be submitted to the AfCAP PMU for consideration of an addendum to the original contract.

- It was necessary to clarify that the research component of the project is to be undertaken by CSIR/BRRI whilst the construction/implementation is the responsibility of DFR under the supervision of the project key experts. Clarity was required on responsibilities of the DFR in terms of managing the monitoring of the demonstration sections after the project is completed. The participation of staff from the DFR is expected be a continuous process.

- A single seal surfacing instead of gravel wearing course as indicated in the TOR will be used for control sections in this study. This change was proposed by the DFR and agreed upon during the kick-off meeting.

- The importance of the quality of field and laboratory data to AfCAP was emphasised, so only two accredited laboratories identified will participate in the study. It is suggested that one of these labs will act as verification lab for the project.

- Following a request by the DFR, training in whole life-cycle cost analysis of the pavements options will be incorporated in the modules of the proposed training programme.

## 2.3 Project organisation

### 2.3.1 Institutional arrangement

The project is hosted by the DFR and divided into two main components:

1. Works component – involves the construction of demonstration and control sections and the implementation of the pavement options. This is a particularly important component of the project because this is where innovation and the development and testing of engineering ingenuity can be applied. Funding for this component is provided by the DFR.

2. Research component – involves design, supervision, quality assurance, and research and production of guidelines and work norms as well as, training capacity development. Funding for this component is provided by AfCAP.

The Eastern Region office of the DFR will play an important role in the execution of the project, assisted by the regional technical team. At project inception, the regional office assisted with the logistics, provided transport to the candidate sites and made available any documentation that was deemed important to the project.

### 2.3.2 Project team

The project staffing presented in Table 1 was originally proposed in response to the TOR. No changes to the project team are anticipated as all team members have confirmed availability. Additional female Civil Engineering Technician (Ms Patricia Duraa) from BRRI has been included in the local project team at no cost to the project. However, her inclusion provides further opportunity to build capacity of local engineers especially a female engineer. Patricia will be involved in the site investigation, and laboratory data collection and analysis. It is believed that the inclusion of Patricia in the BRRI team will assist in making up some of the time lost as a result of the change in project site.

The project team will work closely with the DFR management and staff, as well as a representative from the Research Statistics and Information Management (RSIM) Division of the Ministry of Roads and Highways (MRH), and the PMU of AfCAP. In addition, the project team will engage with staff from the selected laboratories during lab testing and data analysis.

### 2.3.3 Local counterpart staff

The bulk of the key local counterpart staff come from the DFR. The Head of the DFR's Planning Division will oversee the project and act as the liaising officer at management level. The day-to-day running of the project from the DFR team lies with the Project Coordinator, who will be assisted by the Eastern Region Deputy Manager. At project inception, it was agreed that young civil engineers from the DFR needed to be fully involved to ensure knowledge transfer and capacity building. Subsequently, four staff members (young civil engineers) were identified and assigned to the project. The positions and responsibilities of the key experts as proposed and discussed during the project inception are provided in Table 1.The local counterpart staffing positions and responsibilities, are also presented in Table 2.

**Table 1: Key project team members and responsibilities**

| Name | Position | Responsibility |
|---|---|---|
| Joseph Anochie-Boateng, CSIR | Team Leader | Overall responsibility for managing the successful completion of the project, providing technical direction and liaising with the DFR project team and the AfCAP Regional Technical Manager. Other responsibilities include the development of the research plan, design of the research demonstration and control sections, oversight of constructions and the development of guidelines and work norms as well as capacity building and embedment of outcomes within the DFR. The management and quality control of all project deliverables and representation of the service provider at progress meetings form part of the team leader's responsibilities. |
| Edmund Debrah, BRRI | Local Civil Engineer | Assisting the Team Leader in the assigned activities leading to the successful completion of the project. Coordinating all field and laboratory testing of the project. Responsible for the project site investigation and management of the field research programme. |
| Bernice Adjarolo, BRRI | Local Civil Engineering Technician | Managing the site investigation and field surveys; monitoring laboratory testing, quality control, as well as data capture against agreed protocols/guidelines. Liaising with Eastern Region DFR staff and providing quality assurance in accordance with DFR procedures. Ms Adjarolo will also support the research and field coordinator. |
| Vincent Aquah-Bondzie, BRRI | Local Civil Engineering Technician | Sharing the same responsibilities as Ms Adjarolo. In addition, Mr Aquah-Bondzie will oversee the quality assurance system put in place by the project team. |

**Table 2: Local staff (DFR) and responsibilities**

| Name | Position | Responsibility |
|---|---|---|
| John Asiedu | Representative from RSIM, MRH | Representing the RSIM Division of the MRH, Ghana and local representative of AfCAP. |
| Kwasi Osafo Ampadu | Head of Planning, DFR | Directing the research, liaising at higher levels at the DFR and between the DFR and the CSIR. Providing guidance and advice to the project team in line with the expectations of the DFR. |
| Patrick Bekoe | DFR local project coordinator | Coordinating project activities at the DFR head office and supervising the DFR staff on the project. Collaborating with the project team about the management of the project. Arranging logistics for the project team. Liaising with the contractors and consultants on site, contributing to the project with local experience. |
| Alfonso Quaye | DFR Deputy Manager, Eastern Region | Coordinating project activities at the regional level and supervising field studies conducted by the DFR staff. Collaborating with the project team about the management of the project. Arranging logistics for the project team in the Eastern Region. Liaising with the contractors and consultants on site, contributing to the project with local experience. |
| Young civil engineers from the DFR (J Mawusi, F Agyemang, F Addison, A Minta) | Civil Engineering Trainees | Involve in laboratory and field studies, as well as the recording and collation of data. Taking part in data analysis in collaboration with project team. |

### *2.3.4 Contractual responsibilities of the DFR*

The Ministry of Roads and Highways through the DFR is be responsible for the provision of the following facilities and services:

- Procurement of contractors for the construction
- All cost involved in construction
- Costs of three stakeholder workshops to review the inception report, construction progress and the draft report in terms of venue, refreshments and lunches
- Land transport for the project team to site and laboratories
- Provision of office space for project team
- Counterpart staff to understudy the service provider
- Instrumentation of demonstration sections if needed (not part of original contract)

# 3 Main Activities Undertaken at the Inception Phase

Activities under Task 1 of the contract constitute the main work to be carried out at the inception of Phase 2.

## 3.1 Review of phase 1 reports

*Activity: Review of project reports and data derived from the scoping study (Phase I)*

The review concentrated on the Final Report as it embodies all relevant and detailed information of the other three reports leading up to Phase 2 of the project. Notable findings relevant to Phase 2 (with review comments) are presented below:

- A considerable amount of work was done to review the documents prepared during Phase 1 of the study. However, it was found that limited information is available on steep sections of low-volume roads for the sub-Saharan Africa region. Concrete and bituminous surfacing techniques have been predominantly used to mitigate erosion and drainage problems of steep slope sections (gradient > 12%) of low-volume roads in Mozambique and the Eastern Region of Ghana. Accessibility to historic information on steep slopes was limited by the fact that, it seems information was not being centralised or no systematic information management procedures were being followed during the execution of the project. The quality and extent of available data is critical for effective performance evaluation of the demonstration sections. In particular, only few reports on the Mozambique project could be found to address the erosion and drainage problems with steep hill sections of low-volume roads in the region.

- An important comment made in the Final Report was that the present standards and specification documents of the DFR do not pay much attention to the steep sections of feeder roads, although they are the reference documents for the DFR road designs and material selection. Likewise, little information is available in the sub-Saharan Africa region on steep hill sections of feeder roads, which is the main reason why AfCAP is funding this important project. This study therefore, offers an opportunity to develop guidelines and specifications on steep hill sections that can be incorporated into the existing documents. The on-going AfCAP regional project on climate adaption that involves a study of risk management and resilience optimisation for vulnerable road access in Ethiopia, Ghana, and Mozambique aims at providing methodologies and guidance on the assessment of climate threats and for the identification and prioritisation of adaptation options. Climate adaptation measures proposed will be adopted and incorporated in the guidelines to be developed for the steep sections on feeder roads.

- A number of recommendations were highlighted in the outcome of Phase 1 of the study (i.e. the four reports) that will serve as guide to the project team. One of the key recommendations was that further investigation is needed into the use of lateritic gravels on steep sections of feeder roads in Ghana. It appears that limited investigations have been undertaken to develop specifications for their use in such terrains. The DFR was to seriously consider using the current study (Phase 2) for further investigation of these natural materials. The project team is of the opinion that some of these recommendations can be addressed immediately, while others may require further consideration and monitoring before they can be implemented.

- Although the use of local materials is emphasised and will be pursued in the current project, it was noted at project inception (meetings and discussions with staff from the DFR) that shortages often occur in certain parts of the country. This assertion could not be proven, especially in the absence of a well-documented road materials mapping for feeder roads in Ghana, and contradicts an earlier assertion that in many parts of the country local materials are within a reasonable haul distance from project roads. Reports on low-volume roads from a number of sub-Saharan African countries, as captured in the Phase 1 reports, all provide compelling evidence of the potential for successful and cost-effective use of many non-standard materials (i.e. lateritic, calcareous and quartzitic gravels, river gravels, residual gravels, and granular materials resulting from weathering and weathered granite) in the construction of low-volume roads. The challenge in Ghana is the lack of a database on materials sources, as well as their availability and sustainability for future construction and maintenance. This challenge may well be addressed by the AfCAP on-going regional project on development of a materials database for use at national level. In addition, it was reported in the Phase 1 study that there is no accepted method of prospecting for materials in Ghana for low-volume roads. Mapping of naturally occurring construction materials for feeder roads (lateritic gravel, quarry deposits, etc.) was reported as potential research areas identified for future study by the DFR. Previous research in Mozambique and surrounding countries, for instance, has shown that the local materials, despite not conforming to traditional material requirements can perform satisfactorily and result in significant cost savings and environmental benefits. Further experience in construction materials needs to be gained by the DFR through a scoping study for road materials prospecting and mapping. A pilot study focusing on one region for instance, can be carried out to evaluate information on all materials along selected feeder roads. A good knowledge of the requirements of different materials for road construction purposes will be necessary, as well as assessing and carrying out a detailed investigation of the local soils and geology, and to confirm techniques that can be used for various road materials.

- The current DFR criteria for material selection may be too stringent and lack the methods or procedures for optimisation of new or unconventional pavement materials. Although many naturally occurring local materials do not meet specification criteria, the DFR indicated that satisfactory performance has been observed in Ghana. Depending on the availability of construction records, the current project can be used to validate the performance of the materials. Where applicable, a number of current DFR projects will be monitored to collect data to support this study.

- Bituminous and reinforced concrete surfacings have been used by the DFR. The bituminous surfacings were single seals with a nominal aggregate size ranging between 10 mm and 14 mm, and the concrete surfacings were continuously reinforced concrete slabs with a thickness of 200 mm. Single seal would normally not be recommended for any low cost surfacing in African road conditions. It is believed that even double seal might not be appropriate for steep slopes above about 8% grade. The DFR can use the outcomes of the current study to compare performances of their existing seal and concrete surfacings with a thin cold-mix asphalt layer (50 mm thick) and a thin concrete layer (70 mm thick) that will be demonstrated.

- Predominant defects observed on bituminous-surfaced roads include spalling, disintegration of sealing material, cracks, potholes, depressions and "premature failure". It was noted that these bituminous surfacings are single seals. Thus, defects could be expected. Although Otta seals was found to be a viable option to demonstrate, information obtained from the DFR and the MRH at the inception phase indicate that it had already been experimented in the western and central regions of Ghana. Otta seal technology was found to be potentially 34% more labour intensive than the corresponding chip seal in Ghana, thus, there is the potential to create more jobs than using the conventional chip seal technology. However, preliminary findings indicated that as softer grade of bitumen was used, Otta seal suffered from bleeding in the first few weeks after construction. It can therefore be inferred that potentially, Otta seals may not perform on steep slope sections on feeder roads in Ghana.

- Predominantly, sealed and un-sealed (gravel or earth) surfacings were observed on steep slope sections (gradient > 12%) of the feeder roads that were visited. Gravel loss and erosion-related problems (sheets, rills and gullies) were common on these unpaved roads. The use of gradient more than 12% as a criterion for this study is clear in all four reports. However, it was noted that the gradients of the 10 sites studied in Phase 1 ranged between 12% and 22%. This is critical to the selection of potential sites for the project.

- It was reiterated in Phase 1 that the better way of addressing road surface drainage and erosion control is to shape the cross section of the road surface properly to the required camber or to use proper drainage structures to channel water away from the road surface in a manner that minimises effects on adjacent areas. This was the rationale for kerbs to be used by the DFR for controlling drainage on all sections of the feeder roads visited, including the steep sections – yet with little or no success. For the large volumes of runoff water normally expected on roads sections in the Eastern Region of Ghana, the researchers observed a significant number of deep gullies (erosion problem) on the majority of the roads visited. At the stakeholder workshop, participants agreed that concrete u-drains could be a better option than kerbs to address drainage problems. During the selection of the demonstration sites, it was observed that concrete u-drains had been used successfully at cut sections, and appear to be predominantly used by the DFR.

- The availability of local construction materials is critical to this project. The outcomes of Phase 1 indicate that a wide range of local materials, including lateritic, calcareous and quartzitic gravels, river gravels, residual gravels and granular materials resulting from the weathering of rocks, are available for use as road base and/or sub-base materials in Ghana. The availability of natural gravel deposits throughout was also emphasised, although it is noted that most of these gravels would need screening or re-processing for bituminous and concrete surfacings. The DFR clarified that natural gravel deposits are within haulage distances less than 10 km, but not at 10-20 km as indicated in the Phase 1 reports. It was also noted that other materials such as pozzolana, quarry dust, natural sand, sugarcane ash, cement and paving blocks are readily available in the Ghanaian market. In essence, it seems unlikely that the current project will face problems with construction materials.

- In Phase 1 it was reported that the Eastern Region of Ghana receives considerable amounts of rainfall during the year. The rainfall pattern of the Eastern Region resembles that of the Brong-

Ahafo, Ashanti, Western and Central Regions of Ghana. Thus, the challenges experienced in these regions are very similar. In Ghana, the Eastern and Volta regions are the most hilly and mountainous regions. At the inception of Phase 2, it was agreed that detailed rainfall data of the selected road would be collected from the Ghana Meteorological Office.

In addition to the four reports, a paper prepared by the CSIR, DFR and AfCAP PMU after the Phase 1 study, and presented at the 8th Africa Transportation Technology Transfer (T2) Conference held in Livingstone, Zambia from the 8–10 May 2017 was reviewed, purposely to check the total life-cycle cost of six pavement options identified for the study. All six pavement options (listed below) were found to be economically feasible for use on the steep hill sections of feeder roads.

1. Thin [70 mm mesh reinforced concrete] on 200 mm mechanically stabilised laterite base [crushed stone and quarry dust.
2. Screened natural gravel single Otta seal [14 mm-25 mm aggregates] on 100mm mechanically stabilised base and 150 mm mechanically stabilised subbase.
3. Graded cobblestone/stone setts [100 mm-250 mm] arranged on spread sand/quarry dust blinding of average depth 25 mm on100 mm mechanically stabilised laterite.
4. Interlocking concrete paving blocks on 150 mm mechanically stabilised laterite [crushed stone and quarry dust].
5. Double seal [10 mm and 14 mm] on 100 mm mechanically stabilised base and 150 mm mechanically stabilised sub-base.
6. 50 mm hot-mix asphalt with processed lateritic gravel with AC-10 bitumen on 200 mm mechanically stabilised base [laterite with crushed stone and quarry dust].

The 70 mm thin mesh reinforced concrete has the lowest life cycle cost (GBP 69.7/m²), whereas a 50 mm hot-mix asphalt pavement emerged as the option with the highest cost (GBP 91.7/m²). The cost of this asphalt pavement takes into consideration a long materials haulage distance that might not be the case during implementation, i.e. the actual cost could be 10-15% lower than the cost presented. The life cycle cost of the screened natural gravel single Otta seal was however comparable to the ultra-thin concrete pavement (i.e. cost difference is 2%). However, because Otta seal was already demonstrated in two regions in Ghana, the DFR do not want this study to demonstrate it again. Generally, the cost difference between the initial construction, and total life-cycle was insignificant for all six pavement options selected for this study. The selected options for demonstration are discussed in Section 3 of this report.

Final pavement structures for demonstration would be determined during the design phase of the current project. It is likely that both the proposed sections and their respective costs may vary.

## 3.2 Climate resilience

In recent years, large-scale and heavy flash flooding hit many parts of Ghana. These flash floods were fatal in some instances and made several roads impassable, especially rural roads (venerable road infrastructure). It is believed that these roads were heavily flooded, partly due to the fact that poor drainage systems are in place. Inclement weather causes heavy flooding that destroys or causes huge damage to the road infrastructure, leading to a lack of access roads for the communities concerned. The lack of maintenance on gravel roads is also associated with conditions of poor or inefficient drainage systems on the road.

As mentioned previously, the on-going AfCAP regional project on climate adaption will provide methodologies and guidance on the assessment of climate threats and for the identification and prioritisation of adaptation options. As part of the project, three roads were identified as candidate for demonstration in the three countries. In Ghana, the Tampion-Tibognaayili-Tidjo road in the northern region is the demonstration road. It was reported by the researchers that this road has several un-engineered earth sections with little attention paid to water control, resulting in numerous areas always under water during the wet season for significant periods. Five dominant problems identified by the researches along this road were as follows:

1. Erosion of side drains and road surface
2. Impassability due to poor materials and local ponding of water
3. Poor road condition due to unsuitable wearing course gravel
4. Flooding of the road where no drainage or insufficient structures exist
5. Erosion around existing drainage structures

The proposed adaptation measures that would benefit the steep slope project include the following:

- Provision of sufficient drainage structures such as drifts, culverts, lined side drains in potential flooding susceptible areas.
- Conduct detailed hydrological surveys to identify /design appropriate structures to handle the expected water.
- Construct better road cross-sections.
- Raise road where necessary to allow adequate and effective side-and mitre-drains to be installed.
- Construct to the highest quality, particularly the compaction.
- Construct with the proposed shape and drainage.
- Ensure that the wearing course complies with the standards.
- Widen some areas to accommodate drains and to fill existing depressions in other areas that are below natural ground level to ensure that the side-drains are effective.
- When necessary, provide improved re-alignment for the geometry of the road.
- At points along the road where natural water courses occur, the catchment area must be defined and the expected maximum (or some percentile of these) flows generated within these catchments under predicted future precipitation regimes calculated.

In the case of steep hill sections of feeder roads, floods and high water levels can significantly affect both the performance and lifetime of these roads, as these events can cause problems such as the following: erosion; slope instability of cut sections; landslides; landslips; roads being washed away or submerged; inundated culvert supports; roads closures. Therefore, ensuring the reliability and safety of feeder roads, this study will incorporate innovative design, as well as construction and maintenance techniques that will address climatic issues and provide a more durable surfacing for the steep sections of feeder roads in Ghana.

Figure 1 and Figure 2 show the effect of climate (rainfall) on two feeder roads in the Eastern Region of Ghana. These figures were taken during site reconnaissance of the Phase 1 study. The average gradient of the steep sections on these roads shown in Figure 1 is more than 12%. Figure 2 shows that troughs of steep sections are susceptible to flooding and water stagnation and would require proper drainage systems and structures. At the trough sections, detailed designs would be required to select appropriate and adequate drainage systems. Some interventions to be considered include, but not limited to, culverts, French drains, and normal / vent drifts.

**Figure 1: Road section requires proper drainage /surfacing intervention**

**Figure 2: Flooding on a feeder road—requires intervention**

## 3.3 Current materials and pavement design methods

*Activity: Familiarisation with current methods for materials and pavement designs for steep slopes within local practices, as well as that of other sub-Saharan African countries and broader international practices if non-existent in Ghana*

### *3.3.1 Pavement design for low volume roads*

The conventional practices for designing roads over the past years have been largely based on empirical methods such as AASHTO design principles. The empirical methods are generally directed at relatively high levels of service requiring numerous layers of selected materials. Thus, the design of low volume roads (LVRs) requires a different approach which differs in a number of respects from that of high volume roads.

DCP application has been recently developed for pavement structural design by utilising the DN value (cone penetration rate) obtained directly from DCP measurements to quantify the in-situ strength of pavement layers. This procedure was successfully trialled under AfCAP projects in Kenya, Malawi, and Mozambique. Currently for LVRs, extensive research work carried out in sub-Saharan African countries (e.g. Tanzania, Malawi, Mozambique, and Ethiopia.) and Asia show that the design of upgrading rural road is best based on the DCP. The Ghana Ministry of Roads and Highways (MRH) expressed interest in the use of DCP-DN method for the design of low-volume roads in Ghana. There is an on-going AfCAP project to build capacity in the DCP-DN design method in Ghana. The project involves training of engineers from the DFR in application of the DCP-DN method.

The DCP approach of design primarily aims at achieving a balanced pavement design by optimising the engineering properties of in situ materials rather than the introduction of competent materials as mostly in the case of conventional empirical design methods. Benefits for adopting DCP method have been documented, ranging from savings in economic terms, environmental impacts, employment opportunities, road safety, capacity building through use of local contractors, community participation for general socio-economic development. Detailed step-by-step procedures for the DCP DN method can be found in the low-volume roads manuals that are based on DCP-DN method (Malawi Ministry of Transport and Public Works, 2013; Tanzania Ministry of Works, Transport and Communication, 2016).

### 3.3.2 The DFR design practices

The DFR do not have substantive well documented and standardised approaches to the design of steep hilly sections on feeder roads in Ghana. Presently, the DFR use empirical and 'catalogue' conventional methods based on sub-grade CBR for the design and maintenance of all sections of their roads. Catalogue method is the most convenient and common method of design for the DFR. For each type of pavement structure, designs have been produced based on experimental and empirical evidence for a range of subgrade strengths and a range of traffic loading levels. However, this does not adequately utilise the insitu material strength and thus does not optimise the use of local 'marginal' materials. Such design charts have been published by the TRL in 1996.

There will be a new low-volume roads manual for Ghana as an output from the current AfCAP West African sub-regional project in Ghana, Sierra Leone and Liberia (*Development of Low Volume Roads Design Manuals and Update of Standard Specifications and Detailed Drawings for Three AfCAP Member Countries in West Africa*) that is expected to complete in 12 months' time. The manual will be based on the general principles of existing design manuals developed from AfCAP projects for other AfCAP member countries. The design process for this study will be in line with the manual.

At the project kick-off meeting, it was indicated that the AfCAP DCP-DN design approach for low-volume roads will be used to design the pavement structures of the study. This would allow further verification and adoption of the design approach for steep hill sections of feeder roads in Ghana.

### 3.3.3 Geometric design for low volume road

The current Manuals developed from AfCAP projects on low-volume roads propose four different basic geometric standards (DC4-DC1) for low volume roads based on the daily number of 4-wheeled (and more) vehicles. The traffic level is the sum of traffic in both directions and is estimated at the middle of the design life period. The guidelines provided in Table 3 would be an important resource to this project.

**Table 3: Road geometric parameters (ERA)**

| Road Class[1] | AADT | Surface Type | Total Right of Way (m) | Carriageway (m) | Shoulder |
|---|---|---|---|---|---|
| DC4 | 150-300 | Paved, Unpaved | 50 | 6.5-7.5 | Varying(1) |
| DC3 | 75-150 | Paved, Unpaved | 30 | 6.0-7.0 | Varying(1) |
| DC2 | 25-75 | Paved(3), Unpaved | 30 | 3.3-6.5 | Varying(1) |
| DC1 | < 25 | Paved(3), Unpaved | 20 | 3.5-4.5 | n/a |

[1] DC1 is defined as the lowest class of engineered road; (1) Normal width 1.0 m where required and feasible, but width varying with terrain (2) DC5 roads with < 400vpd and not likely to change to a higher functional classification within the design period; (3) On steep sections.

Critical sections such as troughs which are susceptible to flooding and water stagnation would require proper drainage systems and structures. At such sections, survey inputs would be detailed relative to other sections to ensure the design and implementation of appropriate and adequate drainage systems. Some drainage structures to be considered include, but not limited to, culverts, French drains, and normal drifts.

Though, from the site reconnaissance, no extremely critical sections were observed that would require special drainage structures such as vented drifts, gabion abutment, and a bridge, a guide in the provision of drainage structure as provided in the AfCAP project manuals would be used. This guide was developed from a review of international practices. Table 4 shows storm design periods for different types of drainage structures for the various classes of engineered roads (ERA, 2016).

**Table 4: Storm design return period (Years)**

| Types of Drainage Structure | Geometric Design Standard | | | |
|---|---|---|---|---|
| | DC4 | DC3 | DC2 | DC1 |
| Side drains | 10 | 5 | 5 | 2 |
| Fords and drifts | 10 | 5 | 5 | 2 |
| Culvert diameter <2m | 15 | 10 | 10 | 5 |
| Large culvert diameter >2 m | 25 | 15 | 10 | 5 |
| Gabion abutment bridge | 25 | 20 | 15 | - |
| Short span bridge <10 m | 25 | 25 | 15 | - |
| Masonry arch bridge | 50 | 25 | 25 | - |
| Medium span bridge (15-50 m) | 50 | 50 | 25 | - |
| Long span bridge >50 m | 100 | 100 | 50 | - |

### 3.3.4 Materials design methods

The goal was to familiarise with materials design guidelines and manuals that can be adopted or customised for the surfacing options selected for the project. Recommendations are to be made as to the appropriate usage, design principles and considerations of the various materials during the design phase of the project. Some of the identified design methods and guidelines that present a wealth of information for this study are presented in the table below.

| Material Type | Method (s) |
|---|---|
| Concrete | • Guidelines for UTRCP |
| Bituminous | • AfCAP Manuals/Reports<br>• Ghana design manuals<br>• Marshall mix design<br>• Sabita manuals (appropriate guidelines for low volume roads) |
| Stones | • AfCAP Manuals/Guidelines |

### 3.3.5 Framework for design and construction guidelines

The proposed frameworks for the development of design and construction guidelines are presented in Figure 3 and Figure 4. These frameworks are intended to form the basis for discussion with the DFR and will be finally adopted for further development of the guidelines for steep hill sections on feeder roads.

The final guidelines will supplement the new AfCAP low-volume roads manual for Ghana (expected in 12 months' time) that will be developed based on the general principles of existing design manuals for other AfCAP member countries.

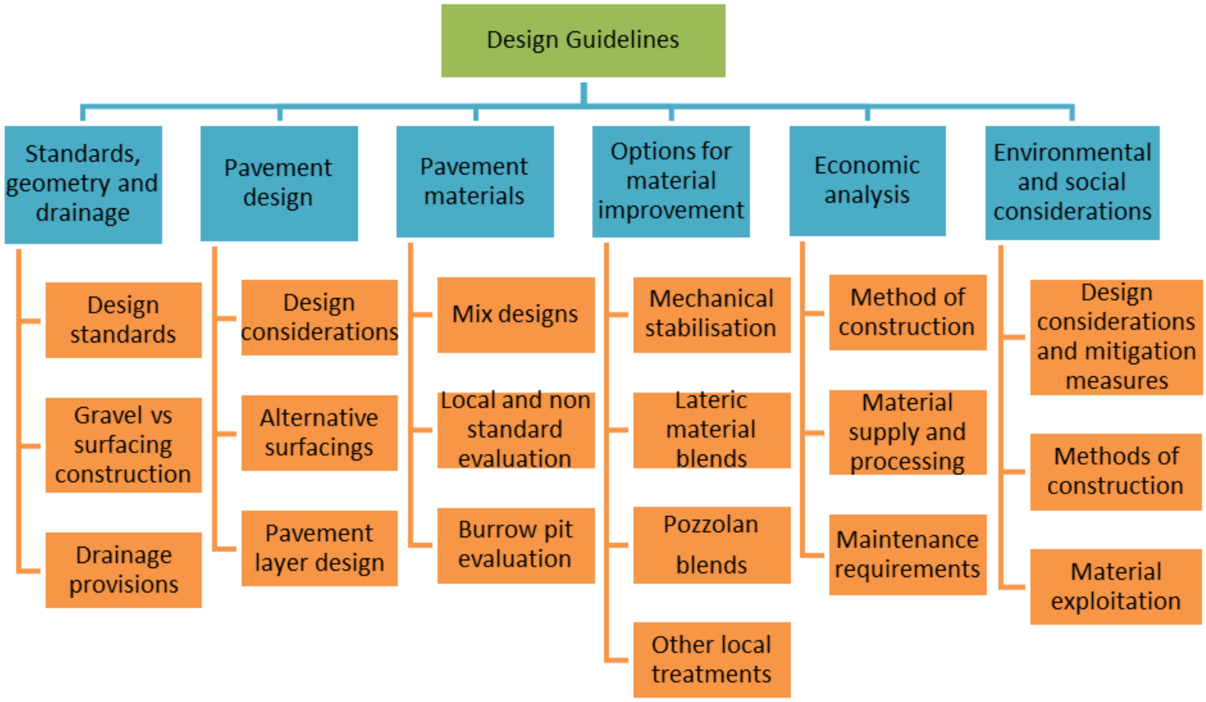



**Figure 3: Framework for the development of design guidelines**

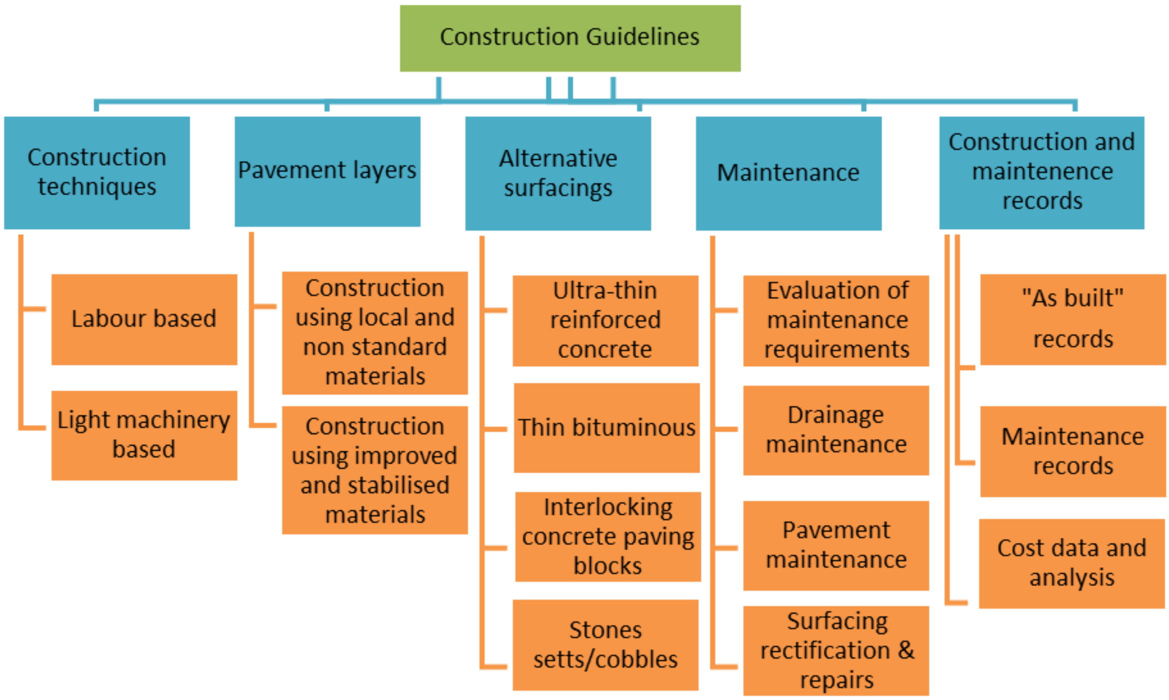



**Figure 4: Framework for the development of construction guidelines**

## 3.4 Assessment of general properties of optimised materials

*Activity: Review of the properties of suitable locally available materials for steep slopes*

### *3.4.1 Engineering properties of construction materials*

The Phase 1 reports show that a significant review of the properties of locally available materials for feeder roads was carried out in the Phase 1 study. It was however reported that the properties of materials on steep sections of feeder roads have not been exclusively investigated in Ghana. At the inception stage, further review of all identified construction materials was carried out for demonstration in the current study.

At steep hill sections, braking and traction forces can be significant, leading to increased stresses and the potential for distortion or tearing of the pavement layers. Considerations of materials selection are to focus on the strength as some materials may not be appropriate at these sections. For the underlying pavement layers that is naturally occurring lateritic soils, there would be a need for mechanical stabilisation to achieve better strength properties. This is important especially for the 'marginal' lateritic soils that would require improvement in strength and plasticity. Mechanical stabilisation techniques would be employed as a way to strengthen the in-situ materials for subgrade, subbase and base layers of the pavement options.

During the review, it was identified that materials properties and the relevant test methods of natural gravels, crushed stones, bituminous materials, cement, and concrete are available for evaluation for this study. From the initial assessment of the potential laboratories for this study the BS, AASHTO, and modified GHA standards are the standard test methods that have been followed to establish the physical and engineering properties of the construction materials in Ghana. Such properties include plastic and liquid limit, particle size distribution, flakiness, crushing and impact value, moisture content, etc. Currently, anecdotal evidence shows that mechanical production of cobblestones and stone setts is virtually absent, hence no data is available for their properties. It is yet to be established whether, existing and operational quarries close to the demonstration road can be the main source of supply for these stones. The tables below show properties of potential materials that will be evaluated for this study.

**Table 10.1: Grading of gravel wearing course materials**

| Sieve size (mm) | % by mass passing | |
|---|---|---|
| | Class 1 | Class 2 |
| 37.5 | | 100 |
| 20 | 95- 100 | 85- 100 |
| 10 | 65- 100 | 55- 100 |
| 5 | 45 -85 | 35 -92 |
| 2 | 30 -68 | 23 -77 |
| 0.425 | 18 -44 | 14 -50 |
| 0.75 | 12 -32 | 10 - 40 |
| Grading Coefficient (Gc) | 16 – 34 | 16 – 34 |
| Maximum oversize (% > 37.5 mm) | 5 | 5 |
| Shrinkage Product (Sp) | 100 - 365 | 100 - 365 |

Gc - (Grading coefficient) = (P26.5 – P2) x P4.75/100 (percentage passing 26.5 mm sieve minus percentage passing 2.00 mm sieve multiplied by percentage passing 4.75 mm sieve)/100

Sp - Shrinkage Product = Product of linear shrinkage (GHA S6) and percentage passing 0.425 mm sieve

All particle size analyses used to determine these parameters must be normalised for 100% passing the 37.5 mm sieve.

### Properties of bitumen viscosity gradedat60°C (ASTMD 3381)

| Test | AC-10 | AC-20 |
|---|---|---|
| Viscosity60°C(Poise)<br>Viscosity, 135°C(min, cSt)<br>Penetration, 25°C,100g, 5 s, min<br>Flashpoint Cleveland open cup, (min °C) Solubility<br>in Trichloroethylene (min %)<br>Tests on residue from thin film oven test<br>Viscosity, 60°C, max, P Ductility, 25°C,<br>5cm/min, cm | 1 000±200<br>150<br>70<br>219<br>99.0<br><br>5 000<br>50 | 2 000±400<br>210<br>40<br>232<br>99.0<br><br>10 000<br>20 |

### Grades of cutback bitumen

| Application | Classification grade | ASTM/AASHTO grade | Viscosity(cSt) | % cutter (kerosene) by volume |
|---|---|---|---|---|
| Priming | AMC00<br>AMC0<br>AMC1 | -<br>MC30<br>MC70 | 8-20<br>30-60<br>70-140 | 56<br>44<br>34 |
| Primer seal | AMC2<br>AMC3<br>AMC4 | MC250<br>MC800 | 250-500<br>500-1 500<br>1 500-5 000 | 27<br>21<br>16 |
| Seal | AMC5<br>AMC6<br>AMC7 | MC3000 | 5 000-12 000<br>12 000-32 000 | 11<br>7<br>3 |

### Characteristics of coarse aggregate for cold-mix and hot-mix asphalt

| Coarse Aggregate (retained on a 4.75 mm sieve) | | | | |
|---|---|---|---|---|
| **Aggregate Class** | | **A** | **B** | **C** |
| LAA<br>FI<br>10% Fines Dry (kN) Wet: Dry ratio % Water absorption (%) (coarse aggregate) | Max<br>Max<br>Min Min Max | 30<br>20<br>160<br>75<br>1.0 | 35<br>20<br>160<br>75<br>1.0 | 40<br>25<br>160<br>75<br>1.0 |

**Table 18.1: BS EN 197 Cement strength requirements**

| Strength Class | Compressive strength requirement (MPa) | | | | Initial setting time | Lower level limit values for single results | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Early strength | | Standard strength | | | Early strength | | Standard strength | Initial setting time |
| | 2 days | 7 days | 28 days | | (min) | 7 days | 28 days | (min) | |
| 32.5 N | | ≥ 16.0 | ≥ 32.5 | ≤ 52.5 | ≥ 75 | | 14.0 | 30.0 | 60 |
| 32.5 R | ≥ 10.0 | | | | | 8.0 | | 30.0 | |
| 42.5 N | ≥ 10.0 | | ≥ 42.5 | ≤ 62.5 | ≥ 60 | 8.0 | | 40.0 | 50 |
| 42.5 R | ≥ 20.0 | | | | | 18.0 | | 40.0 | |
| 52.5 N | ≥ 20.0 | | ≥ 52.5 | - | ≥ 45 | 18.0 | | 50.0 | 40 |
| 52.5 R | ≥ 30.0 | | | | | 28.0 | | 50.0 | |

**Table 18.3: Classes of concrete**

| Class of concrete | Characteristic cylinder strength ($N/mm^2$) | Characteristic cube strength ($N/mm^2$) | Maximum water/cement ratio | | Minimum cement content ($kg/m^3$) |
|---|---|---|---|---|---|
| | | | A | B | |
| C20/25 | 20 | 25 | 0.7 | 0.65 | 260 |
| C25/30 | 25 | 30 | 0.6 | 0.55 | 280 |
| C30/37 | 30 | 37 | 0.55 | 0.5 | 300 |
| C35/45 | 35 | 45 | 0.5 | 0.45 | 320 |
| C40/50 | 40 | 50 | 0.45 | 0.4 | 340 |
| C45/55 | 45 | 55 | 0.45 | 0.4 | 360 |
| C50/60 | 50 | 60 | 0.45 | 0.4 | 360 |

**NOTE:** Under water/cement ratio, column A applies to moderate and intermediate exposure, and column B to severe exposure.

### 3.4.2 Material selection

The Phase 1 study established that the DFR relies on the Ghana standard specifications for road and bridge works (GSSRB), which is a working document primarily prepared to serve the needs of high volume roads. Thus, the traditional specifications for low-volume roads embrace material specifications for HVRs, a situation that usually leads to high rejection of naturally occurring construction materials.

Further review of the GSSRB, and additional documents identified at the inception stage established that;

- Specifications for pavement layer materials are based on empirically derived structural design charts in which the quality of the specified materials is determined from standard laboratory tests, including parameters such as grading, plasticity and CBR, which serve as the criteria for selecting materials to be used in the pavement structure.
- Criteria for material selection may be too stringent and lack the methods or procedures for optimisation of new or unconventional pavement materials.
- There is a lack of specifications for alternative surfacing options to gravel and bituminous surfacings that have been traditionally used on feeder roads.

In order to optimise the use of naturally occurring materials, a holistic approach is required in which attention is paid to the compatibility between the pavement structure, the materials used, the type of surfacing, construction processes and, above all, control of moisture through effective drainage.

The concept of Environmentally Optimised Design (EOD) (Pinard et al. 2009) will be adopted in the selection and utilisation of materials for this study. The flow diagram below (Figure 5) will be followed and developed for the select materials for the experimental sections of this study.

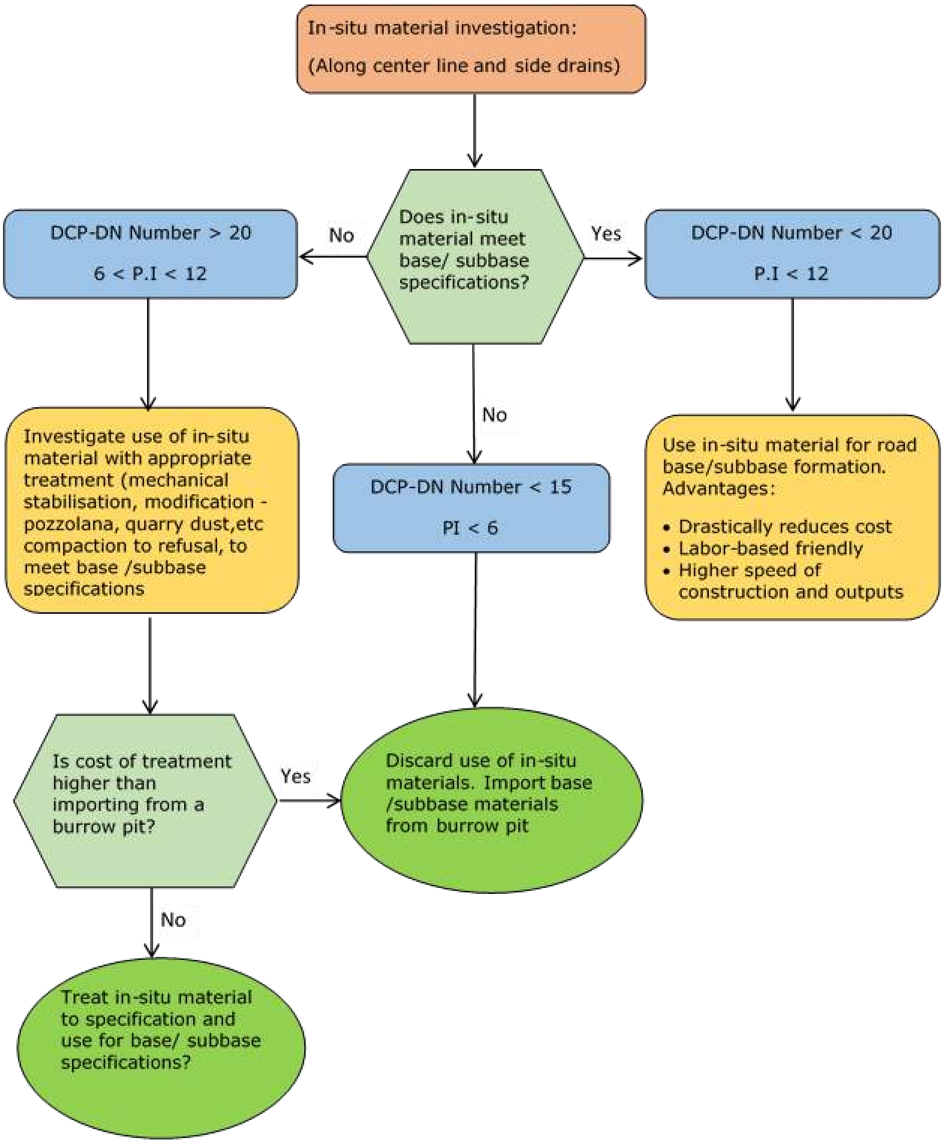



**Figure 5: Flow diagram for pavement materials selection and design**

## 3.5 Review and assessment of on-going similar project

*Activity: Review and assessment of the results of any demonstration sections carried out or ongoing in Ghana or other sub-Saharan African countries for other alternate road surfacing types on steep slopes*

The reports listed below were reviewed in detail as they provide a wealth of relevant and well-documented information on low-volume roads from Tanzania, Malawi, Botswana and South Africa. These reports present approaches towards the use of locally available materials for low-volume road construction, as well as appropriate design standards based on extensive research carried out in the respective countries over a number of years.

- *Investigation into the suitability of roller compacted concrete as pavement material in Ghana. Report by Aurecon (December 2016)* - This project investigates the suitability of Roller Compacted Concrete (RCC) for low volume road construction in Ghana and especially for the construction of pavements on rugged sections and steep slopes. The assignment will be carried out over a period of 48 weeks and include a literature review, selection of materials, testing and finalization of concrete mix proportions. A RCC demonstration road section will then be designed and a nominated contractor will construct the pavement using machine and labour based methods. The construction process will be monitored to allow for the development of construction specifications and a guideline document. This project has similarities with the current study on steep hill sections in Ghana.

- *Design and construction of demonstration sites for district road improvement in Tanzania, Final Report, 2013* - This report summarises all project activities including the selection of demonstration sites and the design, construction and monitoring of the demonstration sections. Following completion of construction works at Bagamoyo and Siha sites, baseline monitoring data were collected and compared with data collected in subsequent monitoring periods in order to assess the performance and suitability of the surfacing options. Construction costs and whole life costs have been described and quantified in this report. The report presents an assessment of the local counterpart staff, who participated in the monitoring work to indicate their ability to continue the monitoring work following completion of the Consultant's services. It was concluded that the staff were fully capable of the monitoring work following their continued participation. The report also indicated that further monitoring and analysis is expected to be undertaken over a period of eight years.

- *Malawi Low Volume Roads Study: An investigation into the use of Laterite instead of crushed stone or stabilised material as a base course for bituminous surfaced roads. Report by Scott Wilson Kirkpatrick & Partners/Henry Grace & partners and Imperial College of Science and Technology, UK. December 1988* - The objective of the investigation was to ascertain if plastic laterite could be used successfully in place of crushed stone or stabilised material as base course for low volume roads beneath a thin bituminous surface. The report discusses the results of a one kilometre trial section that was part of a 51 km road in the Vipya highlands of Northern Province during 1984 and 1985. The report concluded that after five years of trafficking the trial length of pavement had performed as effectively as the adjacent lengths with crushed stone. The study confirms similar experience in Kenya, and concluded that with appropriate construction techniques lateritic gravels can be used as a cost-effective base/subbase for low volume road with bituminous surfaced pavements.

- *Collaborative Research Programme on Highway Engineering materials in the SADC Region: Volume 1 – Performance of Low Volume Sealed Roads: Results and Recommendations from Studies in Southern Africa. Report by Transport Research Laboratory, UK. November 1999* - The overall aim of the study was to investigate the use of natural gravels for road bases and to recommend innovative approaches for their use in a way that is cost-effective and environmentally sensitive. Sections of a road were selected in four Southern Africa Development Community (SADC) countries, including nine sections in Malawi. The study focused on measuring how road pavements performed with time and traffic, and in different climatic conditions. It also identified features which need to be included in the road design to minimise risk. One of the conclusions was that road base materials which are considered marginal but commonly found in the SADC region, can give satisfactory performance on low volume rural roads.

- *Recommendations on the use of marginal base course materials in low volume roads in South Africa. South Africa Dept. of Transport. Research Report RR 91/201. November 1996* –This report highlights an investigation into the performance of 57 sections of roads that were constructed using marginal quality base course materials. The study showed that current material standards are generally too high for affordable low volume roads and emphasised that good drainage and construction quality are the primary requisites for good performance of low volume roads.

- *Analysis of Pavement Monitoring Sections in Botswana. InfraAfrica (Pty) Ltd./CSIR. January 2010* -One of the main objectives of the project was to provide data required for the revision of Botswana Roads Design Manual with regard to the design and specification of low volume roads. Marginal materials were successfully used for construction. Good drainage and high standards of construction were considered to be contributory factors to good performance. It was reported that majority of the low volume surface roads with traffic level of 3 million E80soutperformed their expected performances

- *Low Volume Rural Road Surfacing and Pavements A Guide to Good Practice (Cook et al, 2013)-* This Guideline is aimed at engineers, road managers and others involved with the planning, design, construction or maintenance of low volume roads in developing and in temperate and tropical climates that is similar to Ghana's climate. It is intended to provide key knowledge and guidance on a range of proven road surfacing and paving techniques that offer relatively low cost and sustainable solutions for road works, focusing on the optimal use of local resources, in often challenging physical and operational environments. This guideline would strongly be beneficial to the Phase 2 of the project. The Guideline compiles vital information on lessons learnt from the design, construction, supervision and monitoring of surface and paving types trialled and investigated in the Cambodia, Laos and Vietnam SEACAP projects. There is therefore, a wealth of information that will benefit this project.

- *Guidelines for the construction of a 50mm thick ultra-thin reinforced concrete pavement (UTRCP) (2011)-* This document is based on the observations made, experience gained and data gathered on a number of projects, the performance of the UTRCP under accelerated pavement testing as well as research work on the performance of UTRCP. The document constitute the overall guideline on design and construction of UTRCP.

- *Back analysis of previous constructed low volume roads in Mozambique, AFCAP/MOZ/001/G, Final Report, CPR1612, June 2013.* The report provides information on the activities carried out and the data collected during the execution of the project. The report provides results of the analysis and the recommendations and conclusions from the results of the analysis. The project was aimed at evaluating the performance of low volume roads constructed 10 years ago and earlier. The criteria used for the selection of the study sections included the road classification, traffic levels, age of road, construction type, current pavement condition and the local knowledge and expertise of the staff from the National Roads Administration of Mozambique (ANE). Twenty-one sections on eight roads in six provinces were selected for the study. Activities and the reconnaissance surveys that were carried out in the project are presented. The report gives a detailed account of the field surveys particularly data collected from the measurements carried out in the field and the materials tests results.

☞ *Labour enhanced construction for bituminous surfacings, Southern African Bitumen Association (Sabita Manual 11, 1993)* - The purpose was to provide a manual, which will give recommendations on bituminous surfacings suitable for labour enhanced construction, and to guide and advise the practitioner who may be getting involved with this for the first time. The manual covers the choice of bituminous surfacings for labour enhanced construction, with information on the limitations of the construction technique to be used. It also includes criteria for, choosing the surfacing to suit objectives of job creation, maximisation of labour, and skills transfer.

## 3.6 Evaluation of materials testing laboratories

*Activity: Evaluate capacity of possible road materials testing laboratories.*

The project team visited four laboratories recommended by the DFR to conduct a preliminary assessment of the equipment and personnel in these laboratories, as well as to determine their capacities to carry out field survey and testing. The four laboratories are housed by the BRRI Lab in Kumasi, the Ghana Highway Authority (GHA) Central Materials Laboratory (CML) in Accra, and Soils/Aggregates Lab in Koforidua, and the DFR Soils/Aggregates Lab in Koforidua.

As part of the assessment, the project team engaged with researchers and technicians from these laboratories to understand their background and determine their actual interest in taking part in the project.

In the case of the CML laboratories, the project team had the opportunity to meet the Director, who confirmed that they have the capacity in terms of equipment and the needed skills to conduct both laboratory and field testing. Although the Director indicated that their lab has a busy schedule throughout the year, he expressed interest in this project as the research component could enhance the skills of his technicians. He suggested that the project team should consider including the CML to take part in the project. Accordingly, the Director nominated five researchers and technicians who would be available for background assessment for the project.

A detailed assessment of the four laboratories will be made as the project progresses (will form part of Task 2). Based on the preliminary assessment, we might not get one lab to provide all services required by the project.

Following this assessment, the project team – in consultation with the DFR – the CML and the BRRI laboratories will be used for materials testing and design. Apart from the basic tests that all candidate laboratories are able to conduct, the CML and BRRI Labs have the capacity to carry out the following additional tests:

- Triaxial tests on soils and aggregates
- Bitumen tests
- In situ density tests using nuclear density devices

Furthermore, the following observations were made:

- Some of the laboratory technicians at the CML are involved in on-going road projects across the country. This leaves them with limited availability to participate in this project.
- Resources at the DFR laboratory in Koforidua is a concern (inadequate) as it falls short of the counterpart staff complement required to carry out both field investigations and laboratory testing.
- Although the BRRI laboratory has the advantage of conducting the chemical analyses of test samples (especially as 'marginal' materials), the current set-up has inadequate capacity to carry out tests on all bituminous surfacing materials. The project team was informed that there are plans to procure new equipment in the next six months or so.
- The equipment in some of the laboratories needs calibration. This requires consultation with the Ghana Standards Authority, which has the capacity to carry out such calibrations.

Appendix A shows the assessment of the four Labs in terms of capability in relevant tests and the standard protocols used, and provides the background information of key personnel from the four Labs.

## 3.7 Development of a research matrix

*Activity: Development of a research matrix with variables and control sections.*

As previously indicated, Phase 1 of the project proposed a matrix of 18 pavement options, and eventually scaled them down to six cost-effective options. This contract however, requires that the CSIR demonstrate four alternative surfacings. RCC is included as the fifth surfacing type.

The following are considered for the development of the research matrix for the Phase 2 study.

- Construction methods will vary.
- Pavement design method for the structural layers will be fixed.
- The thicknesses of the base/subbase material layers will vary.
- Asphalt and concrete mix designs will consider screened lateritic gravels and marginal (substandard) materials if available.
- The drainage structure is to be fixed, i.e. trapezoidal drains for all demonstration sections.

Table 5 presents the proposed research matrix for the study.

**Table 5: Research matrix and selected pavement options**

| Section | Chainage[1](km) | | Length (m) | Prepared Subgrade[a][3] (mm) | Subbase Course[b3] (mm) | Base Course (mm)[b2] | Surfacing Type[2] (mm) | | | | | | Innovative pavement design | Innovative construction technique |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start | End | | | | | S1 | CS/SS | ICB | CMA | RCC | TMRC | | |
| Main Works | 0+00 | 3+500 | 3,500 | 150 | | | | | | | | | | |
| Control Section 1 | 1+575 | 1+850 | 275 | 150 | 150 | 150 | 14 | | | | | | | |
| Demo Section 1 | 1+850 | 2+125 | 275 | 150 | 150 | 150 | | 100-150 | | | | | ✓ | ✓ |
| Demo Section 2 | 2+125 | 2+400 | 275 | 150 | 150 | 150 | | | 75 | | | | ✓ | ✓ |
| Control Section 2 | 2+400 | 2+675 | 275 | 150 | 150 | 150 | 14 | | | | | | | |
| Demo Section 3 | 2+675 | 2+950 | 275 | 150 | 150 | 150 | | | | 50 | | | ✓ | ✓ |
| Demo Section 4 | 2+950 | 3+225 | 275 | 150 | 150 | 150 | | 70 | | | 100 | | ✓ | ✓ |
| Demo Section 5 | 3+225 | 3+500 | 275 | 150 | 150 | 150 | | | | | | 70 | ✓ | ✓ |

**Definitions:**

S1 = Single Seal (DFR prefer a single seal to serve as control since it's the current practice of paved feeder roads); CS/SS = Cobblestone/Stone Sets; ICB = Interlocking Concrete Block; CMA = Cold-Mix Asphalt; RCC = Roller Compacted Concrete; TMRC= Thin Mesh Reinforced Concrete

**Notes on research aspect:**

[1]: Interim, detailed change positions will be determined after full site reconnaissance work is completed in Task 2 of the project.

[2]: Maintain proposed thickness

[3]: Reduce or increase thicknesses by increasing the strength (mechanical stabilisation) of base/subbase course;

[a]: Prepared subgrade (natural gravel/lateritic gravel)

[b]: Mechanical stabilisation (lateritic gravel + crushed stone/quarry dust or sand/pozzolana)

(1) Investigate pavement options with or without subbase (Two-layer system)

(2) Investigate subbase course with or without stabilisation—mechanical stabilisation, pozzolana stabilisation

(3) AfCAP DCP-DN pavement design method

(4) Different construction techniques – LIC, Light equipment

(5) Different materials design approach (asphalt design, concrete design, etc.).

## 3.8 Assisting the DFR in the selection of the site

*Activity: Assist DFR in the selection of up to four suitable demonstration sites based on project criteria for different surfacing methods. Criteria for site selection should consider the similarity or homogeneity in the characteristics of all selected sites for effective comparison.*

### *3.8.1 First meeting (kick-off meeting) at the DFR*

During the kick-off meeting, it was agreed that the DFR's already engaged contractors on potential sites could be included in the study. Accordingly, the selection of candidate roads was carried out and focused on roads that have already been awarded on contract by the DFR.

The following criteria were proposed in the methodology of the contract:

- pavement options and availability of materials testing information
- availability of construction and maintenance activity records
- suitability of alignment, (gradient >12%)
- minimum length of 500 m to allow for the control section
- consistency of subgrade conditions
- access and availability of construction materials
- availability of traffic information
- practicality and safety issues
- availability of historic pavement performance

It was noted that gradient of more than 12%, and minimum length of 500 m are two critical conditions for the study. In addition, the demonstration road was to be selected based on the following:

- The demonstration section must carry reasonable levels of traffic for a typical low volume road.
- The road should be typical of the Eastern Region of Ghana.
- The road should be accessible to proper utilities.
- Traffic count on the roads should be feasible.
- The road should have access to local materials.

### *3.8.2 Site visit*

The project team and staff from the DFR head office and Eastern Region initially visited four potential sites on 1 and 2 March 2017.The purpose of each visit was to conduct a survey (purely visual inspection) to assess the following:

- Physical terrain, especially the limiting criterion of slopes (i.e. minimum 12%)
- Nature and physical characteristics of the natural material of the road sections
- Availability and proximity of borrow material deposits, e.g. gravel pits
- Volume of traffic per day

Ideally, all demonstration sections and the control sections should be selected from one stretch of road. This means the demonstration road should have a minimum of 2 km sections with slopes of more than 12%. Such a selection approach would make it much easier to identify the reasons for differential performance of the alternative surfacings, because variables such as traffic, climate, pavement structure and materials used could be assumed to be the same. This criterion was adhered to during the site selection, except that it was difficult to obtain the minimum length of 500 m while maintaining the slope of more than 12% over the entire length. Where not feasible, it was agreed that a reverse curve of 250 m on each side of vertical curves (sag and crest) will be used for demonstration and control sections.

Highlights from the preliminary findings from the site visits were summarised as follows:

- Four main road sections were visually surveyed, namely Anum Apam – Obuho road, Akatawiah – Terwanya road and Akosombo – Jakiti road. Additionally, the Klo Agogo – Oluahai road was visited as a road section of special interest to the DFR staff of the Eastern Region.
- Sections of the four roads visited met the criteria of having sections steeper than 12%, though many of the sections that met the minimum slope criterion lacked continuous stretch of 500 m to provide for a test (250 m) and corresponding control (250 m) sections. For example, on the Anum Apapam – Obuoho road, getting a slope section that could accommodate both the demonstration and control sections constituted a real challenge
- Since the road surfacing option was the main variable for the project, disparities with regard to other variables such as terrain, rainfall, traffic, etc., had to be minimised. Thus, the demonstration sites to be selected would be best located on a road that could accommodate all four surfacing trials with the controls.
- When the four road sites were ranked in terms of all the criteria, including traffic volume, the Akosombo – Jakiti road was first, followed by the Anum Apamu – Obuoho road, and the Akatawiah – Terwanya and Klo Agogo – Oluahai roads were ranked third, and fourth, respectively.

### *3.8.3 Second meeting at the DFR*

Following the site reconnaissance, a meeting was held at the DFR offices on 3 March 2017 for the project team to discuss the assessment of the four potential sites visited. This meeting was held to allow the project team members to air their views, thoughts and concerns about the four sites proposed by the DFR. The team gave an overview of the field visit to the proposed demonstration sites in the Eastern Region.

The meeting was attended by selected staff members from the DFR and the project team (see Table 6 for details of attendees).

**Table 6: Atendees of second meeting with the DFR**

| Name | Organisation/Position | Contact details |
|---|---|---|
| Kwasi Osafo Ampadu | DFR, Director of Planning | 0265443521 koampadu@gmail.com |
| Joseph Anochie-Boateng | CSIR, Project Team Leader | +27128412947 janochieboateng@csir.co.za |
| Edmund Debrah | BRRI, Project Civil Engineer | 0244665149 ekdebrah@csir.brri.org |
| Vincent Acquah-Bondzie | BRRI, Project Civil Engineering Technician | 0277740956 paabondzie@yahoo.com |
| Bernice Adjorlolo | BRRI, Project Civil Engineering Technician | 0277771977 erdemadjo@yahoo.com |
| Patrick Amoah Bekoe | DFR, Senior Engineer, Planning | 268430889 pabekoe@gmail.com |
| KN Akosah Koduah | DFR, Chief Engineer | |
| RO Otoo | DFR, Chief Engineer | 244297408 roosedat@gmail.com |
| Eric Anyidoho | DFR, Assistant Engineer | 266433407 Kindombuilder17@gmail.com |
| Frank Amofa Agyeman | DFR, Assistant Engineer | |

The agenda of the meeting was as follows:

- debate the pros and cons of the four candidate roads surveyed and select one of them for the study;
- discuss and agree on four pavement options for the demonstration sections on the selected road, and
- confirm the designated counterpart staff members from the DFR assigned to the project.

The selection of the project site from the four roads was debated within the wider context of the DFR's aspirations for potential use of the outcomes from the demonstration sections as interventions for steep hilly sections on feeder roads in Ghana. The project team observed that on the Anum Apamu – Obuoho road, the pavement structures were adequate and might not even need mechanical stabilisation – thus, defeating the purpose of the research. After deliberation on the four sites, an interim decision was made to conduct the study on the Akosombo – Jakiti road. The main advantages of this road over the other three roads were as follows:

- Visual observations shows that it has more steep sections than the other three roads.
- The road is already awarded to a contractor by the DFR, hence it is anticipated that delays in construction of the demonstration sections could be minimised.
- A constant stream of different vehicle types (heavy, medium, light and pedestrians) appears to use this road. These vehicles were observed during the survey.

- The natural soils observed on this road looked weak when compared with the other three roads. The project team was of the opinion that it is in such a weak condition that the study can vividly evaluate the effectiveness of the proposed pavement options.
- This road appears to pose serious problems during the rainy season. As the gravel layer wears off, the road becomes weak and slippery, which leads to passability problems.
- Another AfCAP project in Ghana will demonstrate Roller Compacted Concrete (RCC) on this road, the results of which could be incorporated into the current project.

A detailed survey was conducted by the project team on the Akosombo – Gyakiti road from 28 April-5 May 2017 to determine actual slopes and lengths of demonstration sections, and to assess the materials availability at the project site. In addition, traffic counts and socio-economic survey were conducted on the road. The survey results showed that Akosombo – Gyakiti road does not meet the key criteria to demonstrate the surfacing options.

#### *3.8.4 Third meeting at the DFR*

Based on the results of the detailed survey of the Akosombo – Gyakiti site, there was a need to change the project site. A meeting was held between the project team and the DFR on 25 May 2017 to revise the programme for the project inception phase. This meeting was also used by the project team to communicate the comments on the Inception Report to the DFR especially on the research matrix and the need for change of project site.

### 3.9 Development of protocols / guidelines

*Activity: Develop protocols/guidelines for establishing and monitoring demonstration sections.*

The objective of this activity is to establish and agree the processes and procedures to be followed for monitoring the demonstration sections, and also the field and laboratory investigations to carry out during the monitoring period. A draft guidelines and protocols for monitoring of experimental and long-term pavement performance (LTPP) sections in Mozambique developed by Verhaeghe et al (2015) and Paige Green (2016) have been identified and is adapted as a starting point for this project.

In addition, protocols/guidelines for the establishment and operation of LTPP sections in South Africa (Paige Green and Jones 2004, Anochie-Boateng and O'Connell 2013) were consulted for this study. These protocols are used to monitor roads under AfCAP projects. For a more consistent and reliable data, the same protocol will be used in this project. Prior to the start of construction, the project team will explain the layout of the experimental sections, and procedures to use in monitoring to the DFR and contractor.

As the project progresses and experienced gained, revisions will be made in these guidelines for steep hill sections of feeder roads in Ghana. The final guideline will draw on the outputs of the laboratory and field investigations carried out in this project. Draft protocols/guideline will be discussed at the first workshop once the proposed layout and data parameters are approved.

The training component of the project will present details of the protocols to the DFR and other stakeholders. It is anticipated that practitioners from Sierra Leone and Liberia will be included in training programme in the use of the protocols for monitoring demonstration sections of low-volume roads.

### 3.9.1 Layout of sections

For this study, the experimental section from Verhaeghe (2015) and Paige-Green (2016) is presented as demonstration section whereas the LTPP section is presented as experimental section (i.e. the demonstration plus control sections).

***Demonstration Section***

Figure 6 displays a diagrammatic representation of the proposed demonstration section for the study. The section is 275 m long and divided into 13 panels, with panels A, B and C being 25m long, and panels 1 to 10 each being 20m long.

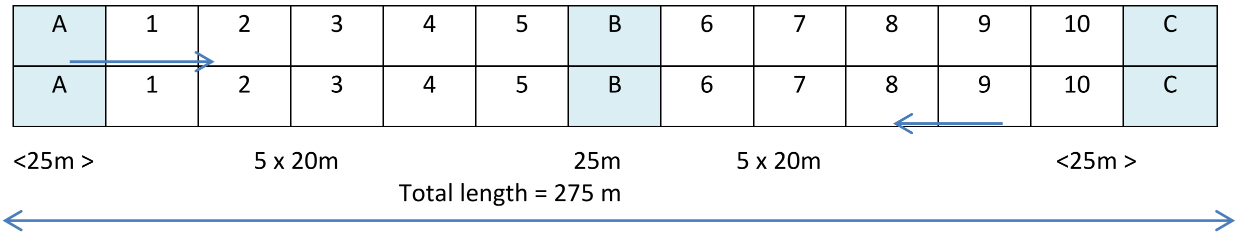



**Figure 6: Proposed layout of demonstration section (two lanes)**

***Experimental Section***

Figure 7 displays the diagrammatic representation of the proposed experimental section for the study. The section is 550 m long and divided into 25 panels, with panels A to E generally be used for destructive purposes (each 22m long), and panels 1 to 20 generally used for non-destructive testing (also 22m long).

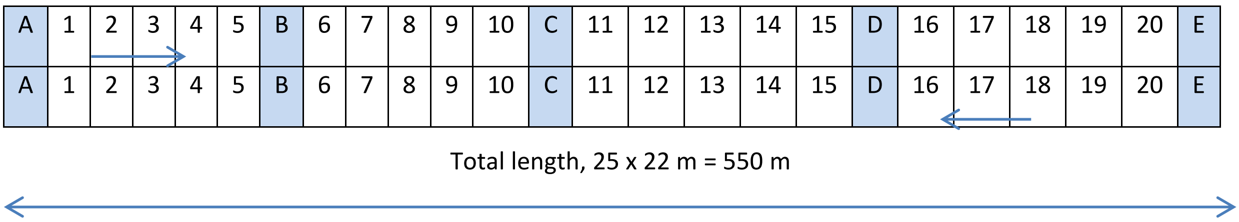



**Figure 7: Proposed layout of experimental section (two lanes)**

### 3.9.2 Construction (Verhaeghe 2015, Paige-green 2016)

The Project Engineer is responsible for construction quality in line with design and project specifications. The Project Engineer is also responsible for overviewing and ensuring that all aspects relating to the safety of road users, road construction teams and inspectors monitoring and recording the quality of the sections as constructed are maintained throughout the road construction operations.

It is a recommended practice that only experienced contractors should be used for construction of experimental sections, and imperative on all experimental sections that the specified layer thicknesses and compaction densities are achieved on both the demonstration and control sections and that all materials used comply with the prescribed specifications for those materials.

Conventional quality control measures based on the DFR requirements should be implemented during construction. Complete and accurate records of the construction process (including photographs and videos where appropriate), material sources and properties, application rates, quality control procedures and results, etc. must be collected and archived for ready access in later years.

Site marking during and after construction is an important aspect of establishing and monitoring the experimental sections. Before marking the test sections, reference must be made to the site plan. Chainages where tests are to be carried out must be identified precisely. The chainages must be classified into three groups: routine measurements, destructive tests and once off tests. A reference marker post or chainage must be known and must be verified as correct. The team must make sure that markings are properly done using tools such as nails, string lines, hammers, measuring tape, templates, paint, paint brushes, and a GPS device. Billboards containing information about the trial sections should also be installed at either end of the experimental sections. GPS coordinates of the section chainages should be recorded for future reference in case something the section markers were to be become unreliable or unavailable in future.

During and after construction, safety on site must be ensured for the team members and the road users. There should be strict enforcement of the use of high visibility vests, barriers and cones. The design of warning signs is also specified, together with the distances and the locations of where these are to be placed to warn drivers of any road works or investigations taking place on the road. The involvement of local traffic police is recommended during the establishment and monitoring of the sections, since the construction/monitoring of those will cause disruptions to the normal flow of traffic and the teams involved in such activities need to be safeguarded. The DFR is responsible for all arrangements with the Police Department in Ghana.

Detailed responsibilities of monitoring staff presented by (Verhaeghe 2015, Paige-Green 2016) will be adapted for this study.

### *3.9.3 Sampling and testing*

The materials used in the roads should be sampled and tested before, during and immediately after construction. Prior to the experimental section being constructed, samples of potential borrow materials to be used in the road construction will be tested. A summary of the properties and test methods to evaluate bituminous, concrete and granular soils/aggregates are presented in Appendix B (Test methods not finalised). Detailed protocols of sampling procedures will be developed and presented for discussion in the first workshop.

### *3.9.4 Field and laboratory measurements*

#### *Field Measurements*

The following standards will be consulted for the field measurements.

| Data Parameter | Equipment | Standard/Reference |
|---|---|---|
| **Visual Assessments** | Draft TMH 9 (COTO, 2013) | Draft TMH 9 (COTO, 2013) |
| Traffic Monitoring | Manual traffic counts | Traffic tallying chart |
| Temperature | Temperature button loggers | Jones and Paige-Green (2004) |
| | Weather station | Jones and Paige-Green (2004) |
| Rainfall | Weather station | Jones and Paige-Green (2004) |
| Density and Moisture | Single probe hydro-density meter | HDM testing: SANS 3001-NG5, |
| Wind intensity | Weather station | |
| **Structural strength** | | |
| Deflection | Falling weight deflectometer | ASTM D4695-03, TMH 13(COTO, 2014), FHWA LTPP Manual, 2016) |
| In situ strength/ balance | Dynamic Cone Penetrometer | ASTM D6951 |
| **Material investigations** | | |
| Asphalt materials | Indicator & performance-related tests | Anochie-Boateng and O'Connell (2013) |
| Concrete materials | Indicator & performance-related tests | Anochie-Boateng and O'Connell (2013) |
| Granular Materials | Indicator & performance-related tests | Mgangira et al (2011) |

#### *Frequency of analysis and Sampling Data*

Data parameters will be determined at a 6 month monitoring period, and the analysis will be conducted during a surer and wing period. The tables below depict the suggested frequencies of experimental section data capturing.

| Data Parameter | Frequency of analysis |
|---|---|
| Visual assessment | 6 Months |
| Temperature | Daily |
| Rainfall | Daily |
| Deflection | 6 Months |
| Rutting | 6 Months |
| Density and moisture content | 6 Months |
| In situ strength | 6 Months |
| Pavement surfacing layer evaluation (bituminous, concrete, cobblestone/stone setts) | Before construction and at the middle and end of performance evaluation programme |
| Base/Subbase course | Before construction and at end of performance evaluation programme |
| Test pits | |
| Traffic Data | 12 hours a day for 7 days / Manual: 6 Months |

| Assessment | Data Parameter | Frequency of analysis |
|---|---|---|
| Environment | Traffic monitoring | Automated: Daily, Manual 6: Months |
| | Temperature | Daily |
| | Rainfall | Daily |
| | Density and Moisture | 6 Months |
| | Wind intensity | Daily |
| Structural Strength | Deflection | 6 Months |
| | In situ strength/balance | 6 Months |
| Materials investigation | Bituminous materials | Before construction and at the middle and end of performance evaluation programme |
| | Concrete materials | Before construction and at end of performance evaluation programme |
| | Base/Subbase materials | |
| | Stones | |

### *Sampling Data*

Recommendations on sampling data are provided below, but these depend on the method to be used to capture data.

| Data Parameter | Equipment/Standard | Panels | No. of Samples | Notes |
|---|---|---|---|---|
| **Visual Assessments** | Draft TMH 9 (COTO, 2013) | - | | All 500m length |
| Traffic Monitoring | Manual traffic counts | - | - | |
| Temperature | Thermometers/Temperature button loggers | A - E | 5 | Lane Centre |
| | Weather station | - | - | - |
| Rainfall | Weather station | - | - | - |
| Density and Moisture | Dual-probe hydro density | A - E | 15 | Inner, outer and centre lanes |
| Wind intensity | Weather station | - | - | - |
| **Structural Strength** | | | | |
| Deflection | Falling weight deflectometer | 2, 4, 7, 9, 12, 14, 17, 19 | 8 | Lane Centre |
| In situ strength/ balance | Dynamic Cone Penetrometer | A - E | 15 | Inner, outer and centre lanes |
| **Material Investigations** | | | | |
| Asphalt materials | Indicator & performance-related tests | | | |
| Concrete materials | Indicator & performance-related tests | | | |
| Mechanically stabilised materials | Indicator & performance-related tests | | | |
| Granular soils/aggregates | Indicator & performance-related tests | | | |

The applicability of equipment/methods to pavement types are presented below.

| Data Parameter | Equipment / Standard | Pavement Option | | | | | |
|---|---|---|---|---|---|---|---|
| | | S1 | CS/SS | ICB | CMA | RCC | TMRC |
| Visual Assessments | Draft TMH 9 (2013) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Traffic Monitoring | Manual traffic counts | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Temperature | Thermometers/Temperature button loggers | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Rainfall | Weather station | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Density and Moisture | Dual-probe hydro density | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Sand replacement method | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Wind intensity | Weather station | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Structural strength | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Deflection | Falling weight deflectometer | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| In situ strength/ balance | Dynamic Cone Penetrometer | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

S1 = Single Seal; CS/SS = Cobblestone/Stone Sets; ICB = Interlocking Concrete Block; CMA = Cold-Mix Asphalt; RCC = Roller Compacted Concrete; TMRC= Thin Mesh Reinforced Concrete

### 3.9.5 Weather data

Temperature, rainfall and wind data of the experimental sections are to be recorded from a weather station. Experimental sections are to be strategic positioned near an existing weather station, if possible. A weather station comprising of at least a thermometer (maximum and minimum) and a rain gauge should be available for this study. Other data that may be collected from the weather station are displayed in the table below.

| Daily Data from Weather Station | |
|---|---|
| Weather station location, GPS coordinates | Average monthly temperature |
| Average maximum daily temperature by month | Average minimum daily temperature by month |
| Average monthly precipitation | Average monthly percent sunshine |
| Average annual number of days of precipitation | Average monthly wind speed |

### 3.9.6 Traffic data

Manual traffic counts are recommended for the demonstration sections. Manual traffic counts are typically 24 hours a day for 7 days. For this study, it is proposed that the traffic count should be done in 12 hours a day for 7 days. The traffic tallying form to be further developed for this study is provided in Appendix C.  Traffic is counted in both directions for the duration of the survey.

The following technologies will be explored to improve the quality of manual traffic counts:

- Mechanical manual counters (clickers) used with clipboards.
- Electronic manual counters in which the passage of each vehicle is recorded.

- Video recorders that are used to record the traffic stream (with time and date stamps).

## 3.10 Development of feasible and cost-effective construction techniques

*Activity: Develop construction techniques that are feasible and cost-effective under the local conditions*

### *3.10.1 Review of reports and guidelines*

This activity was carried out with information from the DFR especially on the labour-based construction of feeder roads. The information was particularly important because it gave the project team some insight into what had transpired during construction of feeder roads. Since the DFR intends to use an already existing contractor for the construction of the demonstration sites, the capability of the contractor to execute labour-based contracts will be assessed (e.g. equipment, personnel, background in terms experience in similar jobs). In particular if there is lack of capacity to carry out some of the works in terms of knowledge and experience, and training and mentorship would be needed throughout the duration of the project.

In particular the feasibility of using labour-based construction methods in all surfacing types will be evaluated. Prior to construction of the pavement sections, the project team in collaboration with the DFR will organise a short programme/seminar for the contractor and supervisors to familiarise themselves with the labour based techniques that will be used in the project. It is anticipated that the contractor and key staff on the project will build on this seminar during the formal training that will be organised as part of the project.

During a meeting with the provincial delegation, the AfCAP team, and the provincial consultant, it was concluded that while the provincial team was well organised, there was lack of capacity to carry out some of the works in terms of knowledge and experience, and training and mentorship was needed throughout the duration course of the project.

One of the expected outcomes of this study is to develop and introduce ways of constructing the proposed pavement options in a more cost-effective way by taking account of local conditions and utilising low-cost, locally available natural road construction materials and techniques. Construction techniques and guidelines provided in AfCAP-related projects (including low-volume roads manuals for Tanzania, Malawi, Mozambique and Ethiopia) were reviewed for information that can be useful for this project. The low-volume roads manuals Ethiopia (2016) for Tanzania (2016) have more updated information when compared to the manuals from the other countries. The Manual provides detailed information on construction strategies, appropriate type of equipment, construction issues, compaction, quality assurance and control. It is believed that there are many sections of feeder roads in Ghana where low-cost construction techniques were applied and non-conventional materials used. However, no systematic monitoring of these sections nor scientific evaluation of their performance in relation to the designs and materials was undertaken. The technique of compaction to refusal (the maximum achievable density for a particular type of material, moisture content and compaction equipment) will be investigated in this study.

The construction cost information from similar projects in relation to the various types of pavement will be further reviewed, along with the construction costs for similar types of road construction recently completed in Ghana. The aim will be to establish a basis for comparing the relative construction and maintenance costs associated with the various road construction techniques, including those involving innovative pavement construction technologies. One of the key methods that will be investigated is construction techniques for ultra-thin concrete and thin cold-mix asphalt surfacings.

A two-layer system technique that has been used successfully in Malawi will be considered for this study. The Malawi study found that using a proof-rolled subgrade with a two-layer pavement system was just as good as the traditionally constructed three-layer system having a subbase as the additional layer. Thus, the use of a single imported layer of appropriate quality base material on a proof-rolled subbase/subgrade offers significant cost savings in the construction of typical low-volume roads.

In addition to the main construction materials for the surfacing, other ancillary materials have been earmarked for this study including, the use of worn tyres that are abundant in Ghana. These tyres could be used for scour checking, which has been identified as a major roadside drainage problem. The concept is to partially cut out the worn tyre, anchor them into place and fill them with loose stones—to break the high velocities of runoffs from the road surface and also the intercepted runoffs from the adjoining sides. It is anticipated that this innovation would be more cost-effective than the conventional rock piling that is presently used by the various road agencies as scour checks.

The International Labour Organization, ILO (2013) guideline on "*Construction of Low Volume Sealed Roads- Good Practice Guide to Labour-Based Methods,*" was reviewed for this project. Table 7 highlights different work applicable to labour intensive methods for the construction of low-volume sealed roads. This guideline demonstrates that high quality low-volume sealed roads can be successfully constructed using employment-intensive approaches. It indicates that with the adoption of more appropriate design specifications and locally derived techniques in the use of locally available resources, construction of low-volume sealed roads can be more cost-effective.

**Table 7: LIC techniques for low volume sealed roads**

| Section | Description | Highlighted Tasks |
|---|---|---|
| Setting Out | Basic setting out of equipment | Setting equipment such as ranging rods and pegs |
| | Setting out a straight line | Use of interpolation and extrapolation. Setting of angles |
| | Design gradient | Using rods and basic mathematics |
| | Uniformity of gradient | Fixing and checking rods from the ends |
| | Horizontal curves | Use of protractors, charts and calculating tangents and curves |
| | Vertical curves | Setting of vertical curves |
| Site Clearing and Earthworks | Earthworks | Labour based method – by transverse balancing |
| | Hauling by labour | Use of wheel barrow for haulage |
| | Ditching and sloping | Construction of open drains by labour based methods |
| | Excavation requirements | Excavating trenches, measuring quantities, |
| | Quarry operations | Borrow pit identification and layout |
| Pavement Layers | Centre line survey | DCP testing |
| | Construction of base layer using in-situ materials | Excavate, place shutters, pegs and material. Spread and compact base layer. |
| | Compaction of layers | Understanding of moisture content and dry density |

| | | |
|---|---|---|
| | | curves |
| | Improving in-situ materials for base courses | Understanding of stabilisation |
| Drainage | Mitre drains | Setting out, excavating and constructing |
| | Catch water drains, | Construction process |
| | Scour checks | Scour spacing to be checked |
| | Culverts | Setting out of culverts |
| | Drifts | Construction process |
| | Subsurface drainage | Stone collection, loading, hand placing, construction. |
| Concrete works | Hand mixing | Use of shovels, spades and water. |
| | Machine mixing | Transporting material, follow procedures |
| | Placing and compacting | Set formwork and shuttering, hand or vibrator compacting |
| | Reinforcement | Placement (manual) |
| Sealing options using Labour Based Methods | Sealing operators | Base preparation and dampening |
| | Binder application | Procedure and operation |
| | Construction of penetration seal | Construction procedure |
| | Stone paving | Construction procedure |

Table 8 (ILO, 2013) illustrates the impact of employment generation based on choice of construction technique and the selection of road surfacing material type in low-volume road construction/rehabilitation. The table that follows provides recommended productivities for drainage works by hand. Other tables presented in Appendix D depict the productivity and inputs for different labour intensive methods (ILO, 2013).

**Table 8: Comparison of labour/employment generated to surfacing type**

| Road type | Width | Construction technology | Labour input per km. (worker-days) | % increase in labour content |
|---|---|---|---|---|
| Class D Gravel Road | 5 m | Plant-based | 309 | 742% |
| | | Labour-based | 2 294 | |
| Class D Asphalt Road | 3 m | Plant-based | 864 | 302% |
| | | Labour-based | 2 610 | |
| | 5 m | Plant-based | 1 246 | 317% |
| | | Labour-based | 3 956 | |
| | 6 m | Plant-based | 1 586 | 359% |
| | | Labour-based | 5 693 | |
| Class D Concrete Block Road | 3 m | Plant-based | 819 | 312% |
| | | Labour-based | 2 558 | |
| | 5 m | Plant-based | 1 103 | 341% |
| | | Labour-based | 3 763 | |
| | 6 m | Plant-based | 1 509 | 407% |
| | | Labour-based | 6 143 | |
| *Source: South Africa's Construction Industry Development Board (CIDB) Best Practice Guideline Part 1* | | | | |

| TASK RATES / PRODUCTIVITY NORMS | | | |
|---|---|---|---|
| ACTIVITY | | TASK RATE | REMARKS |
| **Stone Collection and Loading** | | 2.5 $m^3$/wd | |
| **Sand Collection and Loading** | | 3.0 $m^3$/wd | |
| **Hand Placing of Stones for Retaining Walls** | | 2.5 $m^3$/wd | |
| **Scour Check Construction** | | 5 Nos./wd | Where stone is available close by. |
| **Culvert Construction** | Standard slab culvert | 48 wd/culvert | |
| | 600 mm Ø culvert | 17 wd/culvert | |
| | 900 mm Ø. culvert | 18 wd/culvert | |
| **Drift Construction** | set out + supervision | 4 wd/drift | Standard 10 x 6 drift. |
| | excavate foundation | 5 wd/drift | |
| | prepare base and place welded mesh | 2 wd/drift | |
| | cut-off wall | 12 wd/drift | |
| | casting slab | 20 wd/drift | |
| | outlet protection, etc. | 7 wd/drift | |

### 3.10.2 Use of light machinery

As per the South African Pavement Engineering Manual (2014) of the African National Roads Agency Ltd (SANRAL), construction equipment was discussed together with method guidelines. Table 9 highlights some of the construction equipment used for road structure focussing of light machinery.

**Table 9: Light machinery for road construction (SANRAL, 2014)**

| Parameter/Construction | Equipment |
|---|---|
| Crushing and screening | Jaw, impact, cone crushers, screening |
| Asphalt production | Drum mixer |
| Concrete plant | Tilting drum mixers |
| Milling machines | Small machines: maximum cut width of 1000 mm |
| Concrete paving | Vibrating beams, bowel bar inserters, Burlap drag, spreader, finishers |
| Compaction | Flat wheel roller, single drum roller, Rammer |

Other forms of light machine equipment that can be used for pavement construction.

- Light earthmoving (compact track loaders, mini excavators, skid steers)
- Compactors (manually operated compactors)
    - Manually operated compactors have a number of different applications. They are used in areas where it is not possible to use a full size compactor. This includes such applications as compacting the fill over a trench, compacting soil around a footing, or working in areas where large equipment might cause damage to adjacent structures or property. There are small steel-wheel rollers, vibratory plate compactors, and rammers. While these smaller compactors allow the Contractor to work in small areas, they require more time and effort

to compact the material to the required density. The use of full-size equipment is generally preferred where possible

The uses of agricultural tractors in key operations as presented in the Tanzania low volume roads Manual (2016) include the following:

- Loading/transport: A few tractors can operate many small trailers intermittently, thereby giving labourers sufficient time to load the trailers and maximising the utilisation of the mechanical units. Such trailers usually have a practical height for manual loading. Otherwise, it may be necessary to use the bench method for loading by hand.
- Spreading/shaping: Towed graders are available in several sizes to carry out these operations, although spreading and shaping can also be done by hand.
- Mixing on the road: Towed agricultural disc harrows drawn by a large tractor are very effective.
- Compaction: Towed vibrating, grid or tamping rollers. Rollers on labour-based works are often hand controlled.
- Surface reparation: Towed mechanical brooms.
- Bitumen operations: Towed bitumen sprayers can be used for priming and binder application in conjunction with suitable heating and pumping plant. Emulsions are generally preferred to hot binders on labour-based sites to avoid the need for heating to high temperatures, and to ensure the safety if the workforce.
- Surfacing aggregate: Spreading aggregate by hand from towed trailers; tractors may be used for towing chip spreader units.

### *3.10.3 Guidelines for labour-based construction*

A number of guidelines for labour based construction of single seal, and ultra-thin reinforced concrete pavements are presented in Appendix E.

These guidelines/procedures have been identified for review and modification for steep hill sections of feeder roads in Ghana.

# 4 Project Site and Pavement Options

## 4.1 Selection of preferred site

A matrix of proposed sites and key evaluated criteria for the selection of the project site is summarised in Table 10. The matrix incorporated length and slopes of various road sections and their suitability in terms of the two key criteria set for site selection (i.e. gradient > 12%, and total min length of 1,500 m). The selection of a suitable road was very challenging as most of the roads did not meet these two key criteria for selection for an experimental section.

For instance, the DFR wanted demonstration sections to be located on the Akosombo-Gyakiti road or KloAgogo – Oluohai road, however, the number of hilly sections with gradients of more than 12% and the lengths of those sections were not enough to accommodate five demonstration sections. The preferred site in accordance with Table 10 is therefore, the Akwasiho-Twenedurase road.

**Table 10: Summary of criteria used to select project site**

| Road Name and Length(km) | Observed Traffic | Road Section | Section length (m) | Av. Slope (%) | Length suitability | Slope suitability | Comments |
|---|---|---|---|---|---|---|---|
| Anum Apapam – Bouhu (7.5 km) | Very low <20vpd | 0.48-0.94km | 460 | 7.8 | Yes | No | • Fewer sections to cater for required demonstration and control sections |
| | | 4.74-5.26km | 520 | 12.1 | Yes | Yes | |
| | | 5.46-5.86km | 400 | 20.7 | No | Yes | |
| Akwatawiah-Terwenya (21.0 km) | Very low <20vpd | 2.44-3.62km | 600 | 9.2 | Yes | No | • Fewer sections to cater for required demonstration and control sections<br>• There were unresolved contractual issues on this road |
| | | 5.28-5.84km | 560 | 11.6 | Yes | Yes | |
| | | 9.10-9.41km | 310 | 10.7 | No | No | |
| | | 12.8-13.23km | 430 | 10.8 | No | No | |
| | | 16.22-16.54km | 320 | 11.6 | No | Yes | |
| Akosombo – Jakiti (24.3 km) | Moderate >80vpd | 5.80–6.49km | 690 | 11.5 | Yes | Yes | • Fewer sections to cater for required demonstration and control sections |
| | | 8.74-9.00km | 260 | 9.6 | No | No | |
| | | 10.35–10.60km | 250 | 10.2 | No | No | |
| | | 15.80–16.30km | 500 | 9.4 | Yes | No | |
| KloAgogo – Oluahai (4.5 km) | Very low <10vpd | 0.22-1.52km | 1300 | 8.2 | Yes | No | • No adequate road length for demonstration and control sections |
| | | 1.60-2.40km | 800 | 17.3 | Yes | Yes | |
| **Akwasiho–Twenedurase (3.5 km)** | **New road (No Traffic)** | **1.60-2.30km** | **900** | **13.0** | **Yes** | **Yes** | • **Meets critical criteria, can accommodate demonstration and control sections** |
| | | **2.30-2.90km** | **600** | **15.5** | **Yes** | **Yes** | |
| | | **2.90-3.50km** | **600** | **20.0** | **Yes** | **Yes** | |

The summary of findings from the five roads are presented in the following tables and figures below.

### *Anum Apapam– Obuoho road*

Table 11, Figure 8 and Figure 9 provides overview of features of the Anum Apapam– Obuoho Road.

**Table 11: Summarised findings for Anum Apapam – Obuoho road**

| | | | |
|---|---|---|---|
| **Road Name** | Anum Apapam – Obuoho Road | | |
| **Road Length** | 7.5 km | Geo-location | |
| **Physical Description** | • Road stretches over a rolling terrain with several sections having slopes >12%.<br>• Most slope sections were relatively short (<500m).<br>• Road had several sections (including slope sections) with bituminous surfacing (some were recently constructed and some were old).<br>• Available local material was mainly quartzitic lateritic gravel. Lots of crushed quartzite were seen along road sides.<br>• Erosion defects were common, even on sections with bituminous surfacing. | | |
| **Observed Traffic** | • Very few vehicles were seen on this road (<5vph).<br>• Traffic consisted mostly of motorcycles and a few cars. | | |


**Figure 8: Aerial and longitudinal section of Anum Apapamu– Obuoho road (Google Earth)**

Alternate sections of single seal surfacingand unsealed lateritic gravel surface

Some failures seen on slope sections

Quartzitic stones available locally

Crushed quartzitic stones

Road section showing unlined side drain

Newly covered single seal surfacing

**Figure 9: Some terrain features of Anum Apapam– Obuoho Road**

### *Akatawiah – Terwanya road*

Table 12, Figure 10 and Figure 11 provides overview of features of the Akatawiah – Terwanya Road.

**Table 12: Summarised findings for Akatawiah – Terwanya road**

| | | | |
|---|---|---|---|
| **Road Name** | Akatawiah – Terwanya Road | | |
| **Road Length** | 21 km | Geo-location | |
| **Physical Description** | • Road stretches over a rolling terrain with several sections having slopes >12%.<br>• The existing surface material was found to be lateritic soil with lots of fragmented sandstones that overlay slightly to moderately weathered sandstones and shales.<br>• At hill tops, the surface materials were found to be mainly lateritic soil with ferruginous pebbles. In other sections, the road surface was covered by large gravels and cobbles of sandstones and shales.<br>• Erosion defects were visible on sections of this road. | | |
| **Observed Traffic** | • Traffic volume was less than 3vpd.<br>• Traffic consisted mostly of motorcycles and a few cars. | | |

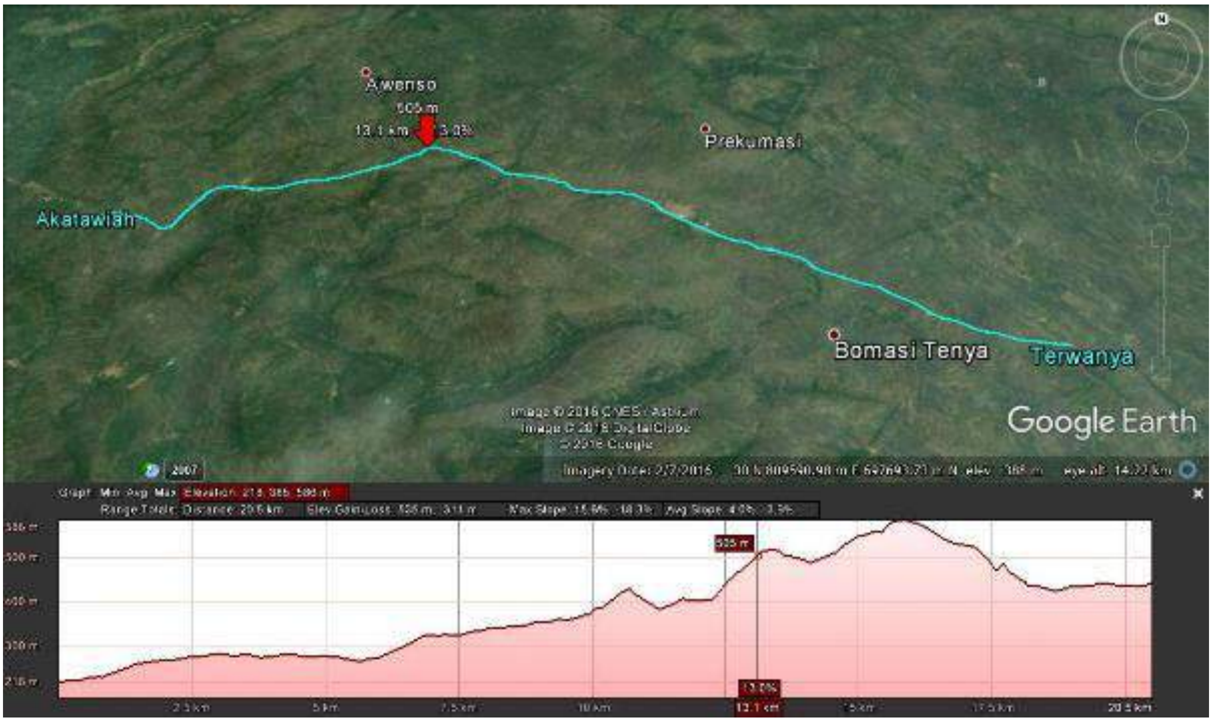



**Figure 10: Aerial and longitudinal section of Akatawiah– Terwanya Road (Google Earth)**

| | |
|---|---|
|  Road surface at hill top |  Erosion defects on road |
|  Eroded subgrade material showing fragments of sandstones and shales |  Section of hill showing rock cobbles and boulders on road surface |
|  |  |
| Road section showing rock outcrops and fragments | |

**Figure 11: Some terrain features of Akatawiah – Terwanya road**

### *Akosombo - Jakiti road*

Table 13, Figure 12 and Figure 13 provides overview of features of the Akosombo - Jakiti Road.

**Table 13: Summarised findings for Akosombo - Jakiti road**

| | | | |
|---|---|---|---|
| **Road Name** | Akosombo - Jakiti Road | | |
| **Road Length** | 24 km | Geo-location | |
| **Physical Description** | • Road stretches over a rolling terrain with several sections having slopes >12%.<br>• Sections (including slope sections) of the road had bituminous surfacing.<br>• Local materials were found to be mainly weathered shales and sandstones.<br>• Lateritic soils with ferruginous pebbles were also found.<br>• Abundant sandstone rocks also lay along the road sides.<br>• Erosion defects were common, even on sections with bituminous surfacing. | | |
| **Observed Traffic** | • Traffic volume was relatively high<br>• Traffic composition varied and heavy trucks, medium buses, cars and two-wheeled vehicles were seen. | | |

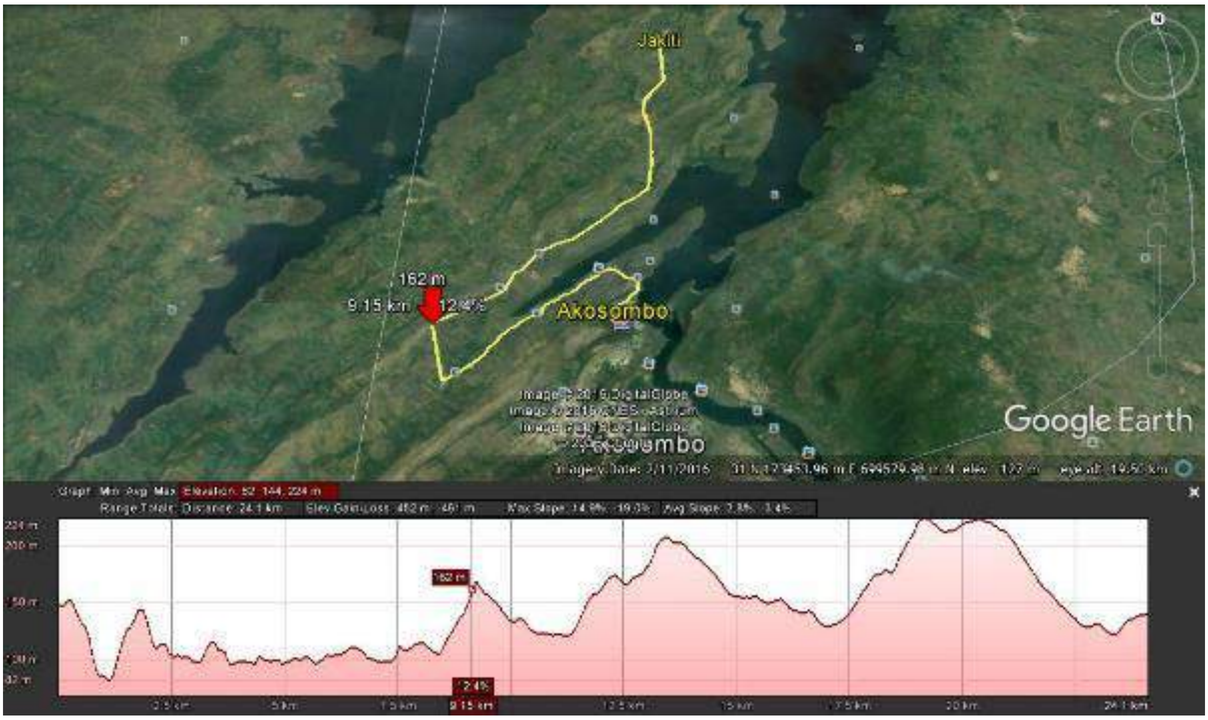



**Figure 12: Aerial and longitudinal section of Akosombo- Jakiti road (Google Earth)**

| | |
|---|---|
|  Bituminous-surfaced slope section completely ripped off |  Slope section with lateritic gravel surface |
|  Slope section with side u-drains |  Slope section surfaced with primer seal that had been completely ripped off |

**Figure 13: Some terrain features of Akosombo– Jakiti road**

### *KloAgogo–Oluahai road*

Table 14, Figure 14 and Figure 15 provides overview of features of the KloAgogo–Oluahai Road.

**Table 14: Summarised findings for KloAgogo–Oluahai road**

| **Road Name** | KloAgogo–Oluahai | | |
|---|---|---|---|
| **Road Length** | 4.5 km | Geo-location | |
| **Physical Description** | • Road stretches over a rolling terrain with few sections having slopes >12%.<br>• Sections (including slope sections) of the road had bituminous surfacing.<br>• Local material was found to be mainly weathered sandstones.<br>• Lateritic soils with ferruginous pebbles were also found.<br>• Erosion defects were common. | | |
| **Observed Traffic** | • Traffic volume was relatively low. | | |


**Figure 14: Aerial and longitudinal section of KloAgogo– Oluahai road (Google Earth)**

Road with lateritic surfacing

Erosion defects on road

**Figure 15: Some terrain features of KloAgogo– Oluahai road**

### *Akwasiho - Twenedurase road*

Table 15, Figure 16 and Figure 17 provides overview of features of the Akwasiho - Twenedurase road.

**Table 15: Summarised findings for Akwasiho – Twenedurase road**

| | |
|---|---|
| **Road Length** | 3.5 km |
| **Terrain type** | Gentle rolling, and mountainous |
| **Surfacing** | Unpaved and Gravel |
| **Available local material** | Sandstones and shales, lateritic gravel with ferruginous pebbles. |
| **Defects** | No critical road defects seen as road being a new construction. However, expected defects include;<br>• Roadside drainage problems<br>• Road surface defects due high slopes<br>• Side slope stability of cut surfaces<br>• Ground (sub-surface) water ingress effects on road underlying pavement materials |


**Figure 16: Aerial and longitudinal section of Akwasiho– Twenedurase road (Google Earth)**

| | |
|---|---|
|  |  |
| A sharp curve on a high slope at chainage 2+750 | Determining the location of experimental sections along the road |

| Cut and exposed rocky surface with sub-surface water driping out at Ch 3+250 | Exposed cut side slope that requires stabilization at Ch 2+850 |
|---|---|

**Figure 17: Some terrain features of Akwasiho - Twenedurase road**

## 4.2 Description of demonstration site (Akwasiho – Twenedurase road)

Subsequent to the review of Inception Report (version 1.0, dated 20 March 2017) by the AfCAP PMU, a meeting was held between the PMU and project team at the 8th Africa Transportation Technology Transfer (T2) Conference that was held in Livingstone, Zambia from the 8–10 May 2017 to further discuss the proposed research matrix, and the selected project site. It was agreed that five surfacing options including RCC will be demonstrated in this study. Regarding the initial proposed project site, it was noted that only few sections have gradients between 10 and 12%. The major concern was inadequate length of sections (i.e. many section < 500 m) to demonstrate the alternative surfacings. It was therefore agreed during the meeting to select a new project site for the study.

Following the meeting at Livingstone, the project team initiated discussions with the DFR to identify a new site for the study. A meeting was held at the DFR offices on 24 May 2017 to finalise the selection of Akwasiho-Twenedurase in the Eastern Region as the project site. The project team visited the site on 25 May 2017 and acknowledged that it is suitable for the project. A second round site visit was conducted on 6 June 2017 by the AfCAP Technical Manager, the project team, DFR and contractor to conduct a detailed site inspection (visual) and to select the exact locations of the demonstration and control sections for the various pavement options. Details of these sections were presented in Section 3.

The proposed project site is a virgin road that would link Akwasiho (6.617906; -0.820665; elevation 249m) and Twenedurase (6.613102N; -0.787185W; elevation 570m) in the Nkawkaw district of the Eastern region. The road has a relatively gentle undulating terrain from Akwasiho (beginning of the road) with average slope rising from almost flat to about 6% for an overall distance of 1.8 km. There is a sharper continuous rise from a slope of 10% (at 1.8km) to the summit of the rock with an average slope of about 22% at 3.5km. The road is characterised by three critical curves at chainages 2+400; 2+700; and 3+150.

A reconnaissance survey was conducted on 6 June 2017 to assess the state of the proposed site and to identify the experimental sections. The following were observed;

- About 2km stretch of the road from Akwasiho has been covered with lateritic material
- At the time of visit, the road alignment work was underway with blasting of rock masses
- Subgrade preparation with some minimal earthworks was underway
- The road has no surface sealing with no lined side drains
- Existing earth drains seen at some sections of the road were affected by erosion
- The road surface is characterised by a conglomeration of fine grain soil with sedimentary rock fragments
- Towards the summit around 2.9km, sub-surface water were seen to drain from the cut (exposed) surface of the side slopes of the rock

## 4.3 Proposed experimental sections

Tests and control sections to be demonstrated were identified and their respective locations (chainages) and sectional slopes determined. Figure 18 displays a schematic representation of demonstration and control sections and the proposed surfacing options.

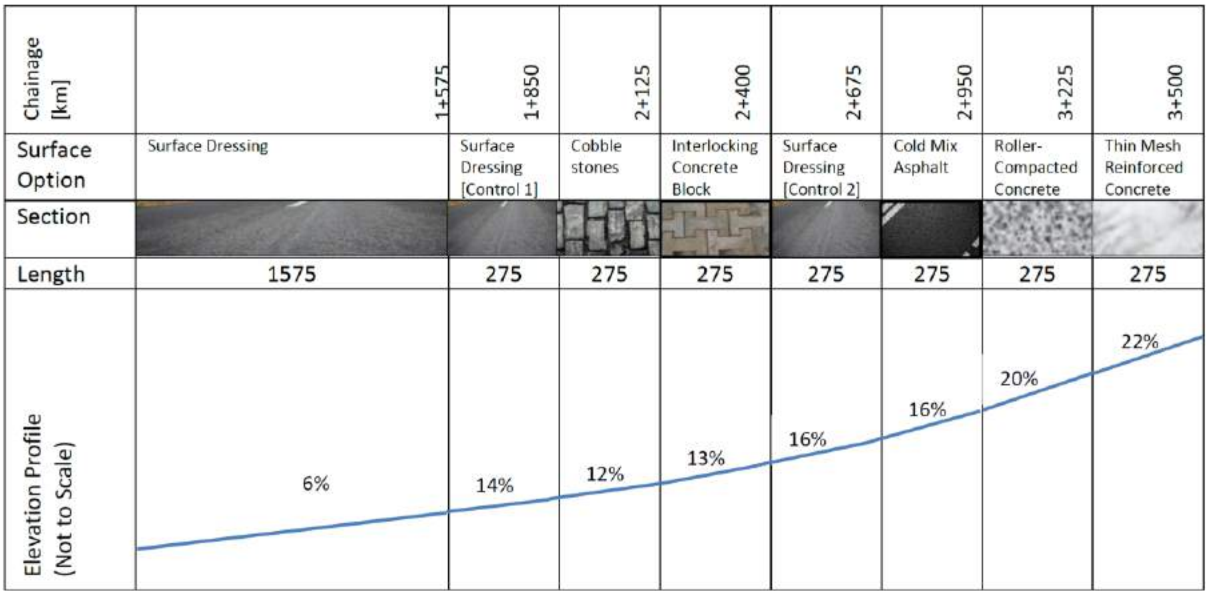



**Figure 18: Schematic representation of the experimental sections**

Figures 19 to 24 present some of the key challenges that should be considered during the constructions and monitoring of the project site.

**Figure 19: Road section on a slope ~ 20% with rock fragments**

**Figure 20: Road section on a slope ~ 20%, requires effective drainage systems**

**Figure 21: Road section on a slope ~16%, and a curve, requires safety considerations**

**Figure 22: Road section on a slope ~18%, and a curve, requires safety considerations**

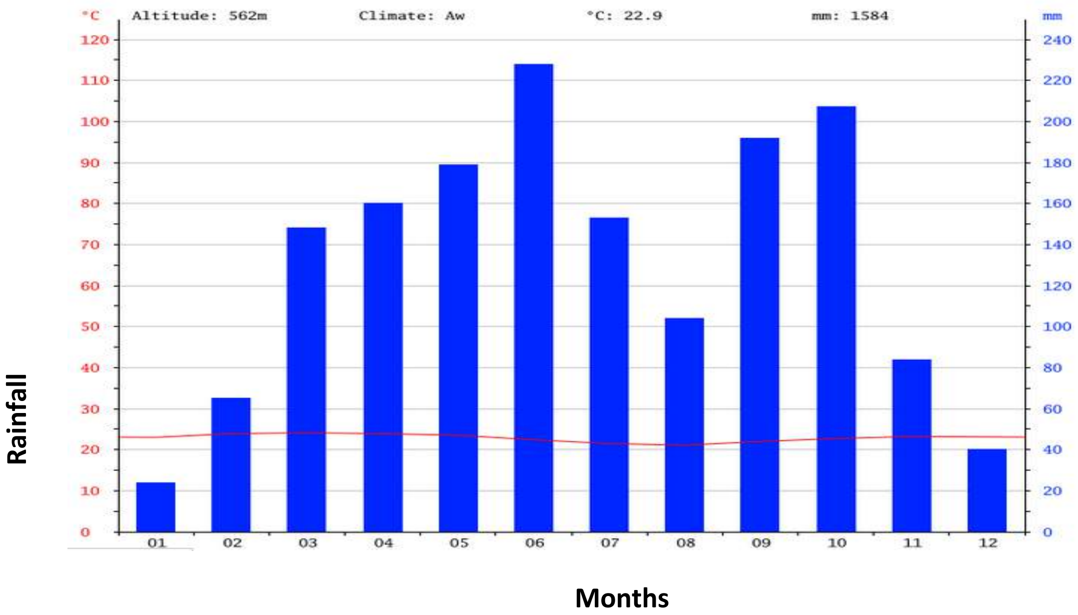
**Figure 23: Early erosion signs of road surface due to steep slopes on gravel surface**

**Figure 24: Prepared road foundation damped due to ground water action**

## 4.4 Climatic characteristics

The Akwasiho – Twenedurase area fall within the equatorial climate, classified as Aw according to Köppen and Geiger. The area experiences large amounts of rainfall with an average annual rainfall of 1584 mm and average annual temperature of 22.9°C. The graph below shows the average climatic indicators for Twenedurase area (Figure 25). The corresponding climatic graph of Akwasiho is very similar to that of Twenedurase.

**Monthly rainfall - Twenedurase**




**Monthly temperature - Twenedurase**

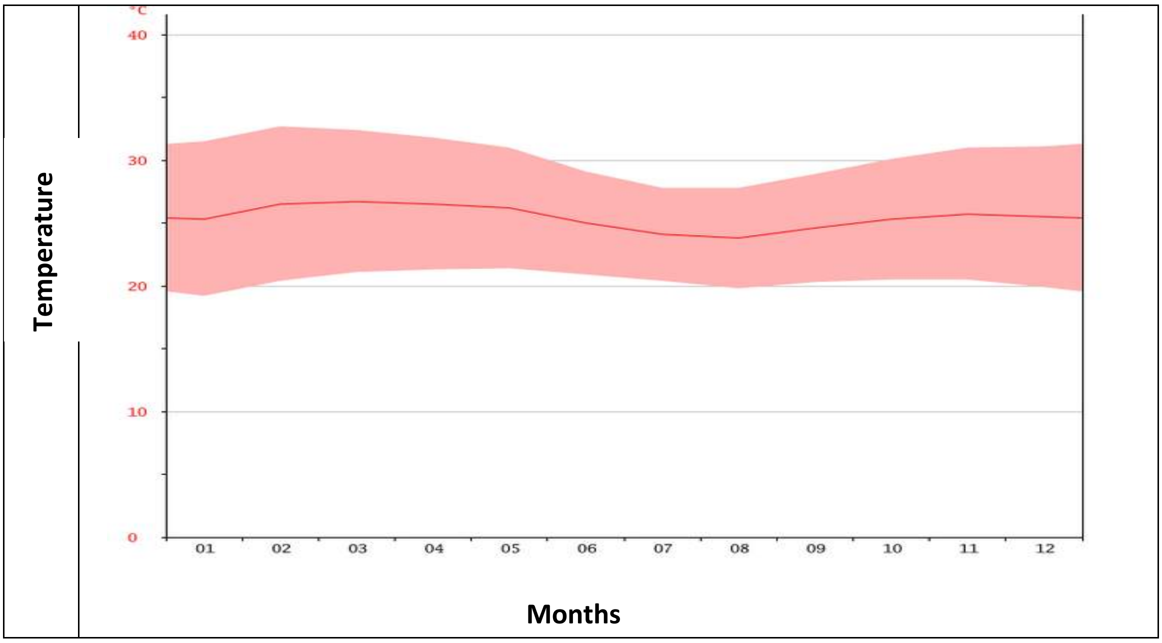



**Figure 25: Climatic graphs (a) rainfall and (b) temperature**

*Source: https://en.climate-data.org; accessed 8June 2017*

Figure 4-18 shows that rainfall is throughout the months of the year with June usually recording the highest rainfall of about 230 mm. High rainfall usually starts in April with the peak month in June and ends in November. March is the hottest month of the year with an average temperature of 26.7°C, whereas August is the coldest month with temperatures averaging 23.8 °C.

The table below presents the rainfall characteristics of the project site.

| Rainfall Data Indicators | |
|---|---|
| Major raining season | May – July |
| Minor raining season | September - November |
| Average annual rainfall (mm) | 1584 |
| Maximum monthly rainfall (mm) | 228 (in June) |
| Minimum monthly rainfall (mm) | 12 (in January) |

At the design stage, the project team will visit the Eastern Region Meteorology Office to obtain the relevant climatic data spanning the period 2006 to 2016. Weather stations closest to the project area would be identified for data sourcing. Rainfall, temperature, and wind at monthly detail level would be collected. Notes of any unusual or severe weather and climatic conditions would captured and analysed.

## 4.5 Erosion and drainage systems

For the expected high rainfall and the road terrain, the provision of a suitable and appropriate drainage system on the steep hill sections in association with the proposed surfacing options would be critical.

Road surface runoff channelled to side drains would have serious erosion effects on the side drains due to high velocities of the flows. Proper and adequate drainage systems with scour checks would be given topmost priority to forestall the expected damaging erosion effects. The sub-surface water seen at some of the sections along the road would be adequately dealt with appropriate counter-measures.

## 4.6 Traffic data

There is no traffic on the Akwasiho–Twenedurase road since it is a new construction. However, the project team intends to identify alternative routes serving the two towns, and carry out applicable traffic surveys to estimate expected generated traffic for the Akwasiho–Twenedurase. In the estimation, trip generation models would be used in which case travel needs of the residents of Akwasiho and Twenedurase would be surveyed. The predominant vehicular travel modes would also be established.

In Nkawkaw district, as was noted during the preliminary reconnaissance survey of the project site, small taxi car popularly known as 'Tico' (Figure 26) are widely used for climbing the Kwahu scarp to settlements such as Obo, Twenedurase, Obomeng, Mpraesu, and others.

**Figure 26: Popular 'Tico' taxis that ply on alternative routes to the project site**

## 4.7 Pavement options

At the kick-off meeting, six pavement options were presented by the project team for discussion and selection. The project team gave an overview of the six pavement options for consideration:

1. Ultra-thin continuously reinforced concrete
2. 14-25 mm single Otta seal
3. Double seal
4. Cobblestones / stones setts
5. Interlocking concrete paving blocks
6. Thin hot-mix asphalt

The DFR raised concerns about excessive loss of gravel on feeder road surfaces resulting in depletion of gravels for low-volume road construction in Ghana. Further discussions revealed that the DFR would prefer cobblestone/stone setts to Otta seal for demonstration purposes, and that the control sections should be given a single seal surface instead of gravel wearing course.It was suggested that Otta seal would be more economical in the northern part of the country owing to the abundance of gravel in the area.

The DFR finally agreed on the following pavement options for demonstration:

- Cobblestone/stone setts
- Innovative interlocking paving blocks

- Cold mix thin asphalt (50 mm thick), replacing thin hot-mix asphalt
- Roller compacted concrete (additional surfacing type to the study)
- Thin mesh reinforced concrete (70 mm thick)

It was noted that RCC is being demonstrated under an AfCAP project on the Akosombo – Jakiti road, at a relatively gentler gradient. In order to compare the performance of RCC on all sections of low-volume roads, it was strongly recommended for demosntration on steeper gradients, hence its inclusion in this study.

## 4.8 Recommended design method

It was observed from the reconnaissance survey that the natural ground appears to provide a strong foundation for the pavement structure. From research works on LVRRs carried in other sub-Saharan Africa countries like Malawi, Mozambique, and Ethiopia, among others, a design concept of the Dynamic Cone Penetrometer (DCP) primarily aimed at achieving a balanced pavement design by optimizing the engineering properties of in situ material would be used.

*Pavement structure and surfacing design:*

The Akwasiho-Twenedurase road is a new construction that requires fresh pavement layers materials. Insitu materials such as the natural gravel with ferruginous stones and the shale rock pieces and other natural occurring materials would be experimentally used to form the designed pavement materials. The concept of the Environmentally Optimised Design concept would be utilised for this purpose. This will ensure judicious use of available local materials while ensuring cost-effectiveness.

*Geometric design:*

The geometric characteristics of the proposed design of the Akwasiho-Twenedurase road, in terms of its horizontal and vertical alignment, will normally be retained. However, it would be reviewed for checks of applicability and conformity to standards as prescribed by manuals and guidelines, e.g. Malawi, Tanzania, etc. No full scale topographical surveys would be carried out for the entire road, rather at the proposed sections for demonstration simple GPS tools would be used. Especially at the critical curves of the road, Total station instruments would be employed to establish proper cross-sections for the appropriate design parameters. It is believed that the AfCAP regional manuals for LVRs would assist the project team in the final design of geometric characteristics of the Akwasiho-Twenedurase road.

*Drainage design:*

The expected major challenges with drainage would be

- the safe discharging of road surface runoff in the side drains without scouring,
- the effects of sub-surface water action, especially around chainage 2+850, and
- containment of the ground water that was seen draining from the cut rock surfaces.

Similar to the geometric design, the AfCAP regional manuals for LVRs would assist the project team in the final design of drainage systems of the Akwasiho-Twenedurase road.

## 4.9 Related matters

The DFR team indicated a desire for the study to include instrumentation (such as traffic counters, underlying pavement material monitors, etc.) to allow the DFR to monitor and evaluate the different pavement options.

The DFR also requested a preliminary cost estimate for the surfacing options to assist them to assess their financial inputs and decision points on procurement. The preliminary cost estimate will be prepared as part of the Draft Design Report and debated in the first stakeholder workshop.

- With respect to the road selected for the study, the following matters were observed:
    - Road is already awarded to a contractor. Preparation of road foundation was underway.
    - Based on the nature of the terrain, lined trapezoidal drains are proposed for the experimental sections of the road as a substantial volume of water is expected on the road.
    - No as-built data orinformation on the road is available.
    - No field and laboratory tests had been carried out.

# 5 Summary: Progress of Work

## 5.1 Project Task 1

Task 1 is the core of the project inception phase. The main goal was to review all documents identified for the study, select the experimental site and develop a research matrix to be followed in the project. This task is 100% complete (Section 2 and Section 3 of this report).

## 5.2 Preliminary information gathering

At the outset, the project team contacted the relevant authorities to obtain information pertinent to the project inception phase (i.e. protocols, guidelines, reports, manuals, technical reports). The following local road authorities were consulted:

- Ministry of Roads and Highways (MRH)
- Department of Feeder Roads (DFR)
- Eastern Regional Office of the DFR

A need for the availability of historical data on performance of steep sections to assess the results of the demonstration sites was discussed. DFR was to assist the project team with available and relevant data on design and construction of steep sections. Not all information requested are ready at this stage. A request to the DFR has already been made, and consultations are underway to procure all data requested by the project team.

## 5.3 Key experts

The key experts remain the same as proposed in the CSIR tender. The availability of the experts to undertake the contract was confirmed at the project inception.

## 5.4 Mobilisation

Mobilisation of the research team and the counterpart staff from the DFR was debated during the kick-off meeting. Based on these deliberations, the CSIR confirmed to the AfCAP PMU by means of a mobilisation report (dated 24 February 2017) that both the project team and the DFR have been mobilised to start the project. It is assumed that the contractor for construction and the DFR supervision consultants are mobilised as demonstration sections will be located on roads that have already been included in awarded contracts.

## 5.5 Kick-off meeting

The kick-off meeting was held on 22 February 2017 at the offices of the Department of Feeder Roads (DFR) in Accra, Ghana. The meeting was successfully held as all project team key experts and 20 DFR staff members were present. The purpose of the meeting was to introduce the key players in the project, and to discuss the agenda circulated by the project team leader ahead of the kick-off meeting. The importance of the project to the DFR, their role in facilitating knowledge transfer and capacity building, and the need to expedite preparations for the design and construction of the demonstration sections were emphasised. Key highlights of discussions during the meeting are included in the project mobilisation report (project milestone deliverable) that was submitted to AfCAP on 24 February 2014.

## 5.6 Meeting with AfCAP PMU

The meeting was held on 3 March 2017 at the offices of the AfCAP Technical Manager for West Africa (Dr Paulina Agyekum). The objective of the meeting was to provide feedback from the site visits/selection, and share thoughts on meetings held between the project team and stakeholders. Key discussion points were on the selected demonstration site and the alternative surfacing options for the study. Dr Agyekum was informed that the DFR preferred the four surfacings for the study to be 70 mm ultra-thin reinforced concrete, double Otta seal, interlocking concrete paving blocks, and 50 mm thin hot-mix asphalt. With respect to the exclusion of Cobblestones/stone setts from the list, the AfCAP Technical Manager indicated that she would discuss with the DFR and Mr John Asiedu (MRH RSIM) on this surfacing option if it can replace Otta seals in the study.

The AfCAP Technical Manager was informed that the selected road is already under a contract implying that major contractual processes are already completed. Dr Paulina indicated that she will confirm from the DFR about the eligibility of the selected road.

The project team was advised to ensure the technical capacity of the Contractor with respect to the various surfacing options that need to be studied. The AfCAP Technical Manager indicated that the Contractor training should be taken seriously on this project. Furthermore, she also advised that, the Contractor will have to be closely monitored during construction to avoid confusion in terms of the design and construction requirements of the different surfacing options. It was indicated that the DFR was optimistic of the cooperation of the Contractor, and his ability to deliver as expected. Dr Agyekum reiterated her commitment to the project, and on behalf of AfCAP, she will provide full support to ensure the success of the project.

## 5.7 Meeting at the Ministry of Roads and Highways

### *5.7.1 Meeting with the directorate - RSIM*

The project team had a meeting at the Directorate of Research, Statistics and Information Management (RSIM) of the Ministry of Roads and Highways (MRH) on 9 March 2017. The Director of Research (Mr John Asiedu) was briefed about the progress of activities since the commencement of Phase 2. Matters discussed include the findings that emerged from the site reconnaissance of the proposed sites, follow-up meeting with the DFR staff members for the selection of demonstration site, and the choice of the pavement options for the study (i.e. ultra-thin concrete, Otta seal, thin asphalt and interlocking concrete paving block). Mr Asiedu was of the view that Otta seals can be replaced with stones (cobblestone/stone setts), especially as Otta seals had already been experimented in the western and central regions of Ghana.

Mr Asiedu also nominated a representative from the MRH as a counterpart staff member to the project as required. To ensure maximum participation from MRH staff, Mr Asiedu suggested that some of the workshops and training programmes be held at the MRH premises. He pledged the Ministry's full support for the project.

### *5.7.2 Meeting at central materials laboratory – GHA*

A second meeting was held between the project team and the Central Materials Laboratory (CML) of the Ghana Highway Authority (GHA) on 9 March 2017. The purpose of this meeting was to assess the laboratory personnel for proficiency and availability to render the laboratory services as recommended by the DFR. The objectives and an overview of the project were presented to the CML management. The Director of the CML (Nana Kwesi Agyapong) assigned a Principal Engineer (Mrs Olivia Mante Soli) to liaise with the project team on all research activities in which the CML will be involved. The Director also advocated for the inclusion of dedicated CML staff members in the field testing activities.

## 5.8 Site identification

A two-day site visit to identify candidate roads for the construction of the demonstration and control sections was undertaken on 1 and 2 March 2017. Prior to the site visit, there was a meeting between the project team and the staff of the DFR Eastern Region. A detailed site survey was presented in Section 2.7.

## 5.9 Selection of demonstration site

A decision was reached in a meeting at the DFR offices on 6 June 2017 to conduct the study on Akwasiho – Twenedurase road. The gradients of the site vary between 12 and 22% over a total length of 1.9 km of steep sections on a 3.5 km road. Thus, the site can conveniently accommodate five demonstration sections including RCC and two control sections with a minimum length of 275 m each. Details of the selection of the demonstration site was presented in Section 3.

This site was selected after it was found that the initial proposed project site (Akosombo-Jakiti road) did not meet criteria to demonstrate all five surfacing options.

## 5.10 Preparation of inception report

The first version of the Inception Report was submitted for comments from the AfCAP PMU on 20 March 2017. Following the change of project, the second version of the Inception Report was submitted for further comments from the AfCAP PMU on 15 May 2017.

# 6 Project Planning

## 6.1 Revision of overall project plan

The project plan for three critical tasks — site investigation, draft designs and final designs has been adjusted due to the change in project site. Also, the inclusion of the roller RCC surfacing in the study has increased the quantity of materials testing work on the project. Consequently, milestone deliverable dates for Tasks 2, 3, and 4 have been pushed back two to three months depending of the activities involved. However, the overall plan to undertake the assignment over a period of 36 months remains unchanged.

No additional major changes to the project plan are anticipated at this time. Revisions in activities will be made as the project progresses. Any such revisions will be discussed and agreed with the AfCAP PMU and DFR. For instance, the programme will be reviewed immediately after the first stakeholder workshop to provide a more detailed programme for the construction management, second stakeholder workshop, technical monitoring and training tasks (Tasks 5, 6, 7 and 8).

## 6.2 Plan for next milestone deliverable

A number of activities to be undertaken under Task 2, 3 and 4 (following the inception phase) are described in this section. These tasks comprise activities that cover site investigation, technical designs and tender documentation, and the first stakeholder workshop. Traffic data collection have been included in Task 2 as part of the pavement design procedure. While the activities are to be undertaken largely by the local project team comprising of the Local Civil Engineer and the two Civil Engineering Technicians, their activities would be guided by the Team Leader from the CSIR. The outputs of Task 2 would form the basis for Task 3 and a draft design will be prepared and debated during the first stakeholder workshop.

The strategy for Task 2 is to draw up a detailed plan of activities for thorough discussion with the DFR for review and agreement.

The DFR is responsible for the planned activities summarised in Table 16.

**Table 16 Responsibilities of the DFR – Task 2, 3 and 4**

| Item Description | DFR Responsibilities/ Action Points | Date |
|---|---|---|
| Counterpart staff | • DFR to provide final list of counterpart staff to the project team.<br>• If possible, counterpart staff should be selected across the agencies of the MRH, taking into consideration gender representation. | 5 September 2017 |
| Technical information / documentation on the Akwasiho-Twenedurase road | • DFR to supply the project team with the following documents:<br>○ climatic data of demonstration site<br>○ traffic data on all alternative routes. This will assist in accurate estimation of expected traffic on the experimental sections (a new road)<br>○ all other supporting documentation shall be provided by the DFR | 15 September 2017 |
| Materials testing | • DFR through the contractor should supply all materials for laboratory testing and designs; | 30 August 2017 |

| | | |
|---|---|---|
| | ○ emulsion<br>○ cement<br>○ stones<br>○ lime<br>○ others as required<br>• Special materials (e.g. cement type, emulsion type, etc.) must be supplied in consultation with the local research counterparts on the project (BRRI). | |
| Contractor | • DFR should clarify deviations from current norms and standard approach of feeder roads construction to the contractor, and highlight research as key component in this project.<br>• DFR in consultation with the project team should enforce all obligations of the contractor, e.g.<br>○ materials sourcing<br>○ making available the list of key project staff (Resident engineer, materials technician/ supervisor, foreman, and surveyor) equipment holding for capability assessment. This would also guide the project team in the development of training materials for the project.<br>○ detailed programme of works for construction (**after 1st Workshop**)<br>○ contract documents | 15 October 2017 |
| Logistics | • Provision of office for the project team<br>• Provision of land transport for the project team to site and laboratories | As and when needed (Project team to give at least one week notice) |
| 1st stakeholder Workshop | • DFR to<br>○ invite participants/ stakeholders (Note: Contractor and key staff must attend the workshop). In addition, key DRF contractors should be invite to this workshop)<br>○ arrange for venue<br>○ provide projector/accessories<br>○ arrange for refreshment and lunch | The week of 16 October 2017 (tentative, TBA) |

As part of Task 2, the project team will visit the project site to undertake the following field activities:

- A second site visit to make a detailed assessment of the project site (i.e. the Akwasiho-Twenedurase road) and to select the exact locations of the demonstration and control sections.
- Road infrastructure surveys to obtain measurements of road alignment, profiling of the existing pavement layers, assessment of the existing drainage structures (culverts, side drains, mitre drains, catchwater drains) for adequacy of opening (size, shape, etc.) and outlet conditions (ponding, silting, erosion, etc.).
- A survey of available road materials to establish appropriate engineering properties for material types and design procedures/guidelines for various pavement options.

- An effort to collect as much data as possible for the pavement designs and construction. (Preliminary investigations and draft designs may not be completed in the second visit because inputs of other external experts will be required).
- The collection of road environment data and the sourcing of data on hydrology, geology, topography, meteorology of the project catchment area.
- Traffic surveys that will entail manual vehicular counts at designated points on the main road corridor and supplementary traffic observations on ancillary roads that act as spokes to the main villages along the Akwasiho-Twenedurase road.
- Limited laboratory and field tests to check the uniformity of existing pavement structures and the quality of materials from all demonstration and control sections.
- Socio-economic baseline survey of the project catchment area.
- Sending of samples from burrow pits, quarry sites, rock outcrops, existing road materials, construction materials (e.g., bitumen and cement), and from identified suppliers to the GHA CML and BRRI laboratories for testing.

In consultation with the DFR, the project team will finalise the equipment required and the names of the laboratories to include in the study. It should however be noted that the successful completion of the above activities depends strongly on the progress achieved on the project site.

### 6.2.1 Detailed plan for next tasks/activities task

Table 17 presents a scope of activities to be carried out to accomplish Tasks 2, 3 and 4. The resource that may be required is also captured.

A Gantt chart for a suggested work plan, and the inputs and outputs of Tasks 2, 3, and 4 is presented in Figure 27.

**Table 17: Scope of activities for next project tasks**

| Activity | Scope of Activity | Sources of Information | Identified Resources | Responsibility |
|---|---|---|---|---|
| Consultations with DFR | Discuss all Task 2 activity-related issues, e.g.<br>• Agreement on programme of activities for Task 2;<br>• Introduction of local project team to Contractor facilitated by DFR;<br>• Request for as-built designs and technical specifications, historical road maintenance works, etc. | DFR staff on the project, e.g. Dr Bekoe, Eng. Quaye | Voice calls to relevant persons;<br>visit to DFR Head Office, Accra;<br>visit to project site | Local Researcher/ Counterpart |
| Interaction with Contractor | • Present overview and aim of the project to Contractor.<br>• Assess Contractor's key personnel.<br>• Evaluate the technical data (proposed road geometrics and pavement designs) on the Akwasiho – Twenedurase road. | Contractor, and his key personnel | Interviews with Contractor's key personnel | Local Researcher/ Counterpart |
| Assessment of project site | • Establish existing pavement structures and layers based on the DCP survey carried out on designated sections for a minimum of 800mm depth and 5 points per control/test section.<br>• Assess road geometrics and safety considerations.<br>• Capture in detail all surface defects and drainage structures:<br>- *Culverts*: Adequacy of opening (size, flooding, length of culvert). Outlet conditions (ponding, silting, erosion, headwalls). Structural strength (condition of concrete or other materials).<br>- *Low-level structures* (causeways, drifts, etc.): Adequacy of existing structure to cope with floods.<br>- *Surface drainage*: Standing water due to rutting, etc.<br>- *Drainage channels*: Adequacy of side drains (shape of drain, ponding, silting, erosion). Catchwater drains and cut-off drains (shape of drain, ponding, silting, and erosion). Mitre drains (frequency, shape of drain, ponding, silting, and erosion). | Field surveys and field tests of Akosombo-Jakiti road project site | Field tests, equipment and manpower, e.g. DCP and trial pits | Local Researcher/ Counterpart |

| | | | | |
|---|---|---|---|---|
| Capturing and assessment of project environment data | • Collect hydrological and geological maps, topographical data of the project environment.<br>• Establish and assess the appropriateness of drainage systems. | Meteorological office; Survey department in Eastern Region; project site | Structured interviews; physical measurement with GPS tools; analyses of road design data | Local Researcher/ Counterpart |
| Mapping of construction materials | • Identify all key construction materials sources, characteristics and properties, etc. | Project site; material deposit (burrow pits); suppliers' establishment | Interviews with Contractor, DFR staff, indigenes, material suppliers, etc. | Local Researcher/ Counterpart |
| Sample field materials for testing | • Identify and characterise the nature of available road materials.<br>• Establish engineering properties of materials from burrow pits, deposits, rock outcrops, suppliers' samples.<br>• Develop modified test protocols. | Project site; material deposit (burrow pits) | | Local Researcher/ Counterpart |
| Traffic data collection | • Perform screenline counts of vehicular traffic, including non-motorised traffic on market and non-market days.<br>• Observe two master locations on main road corridor for 12-hour day traffic.<br>• Observe supplementary traffic at four spokes identified in the project catchment area. | Akosombo-Jakiti road corridor; adjoining feeder roads | Enumerators, field sheets, traffic counters, safety gear | Local Researcher/ Counterpart |
| Socio-economic survey | • Identify project catchment area.<br>• Administer structured questionnaire to selected respondents from the communities<br>• Include females, the aged, and the physically challenged to establish baseline indicators such as livelihoods of indigenes, demographics, etc. | Project site and adjoining spatial environs | | Local Researcher/ Counterpart |
| Laboratory testing of sample materials | • Undertake basic material characterisation of existing pavement sub-surface layers.<br>• Undertake basic soil characterisation of gravel borrow pits, including grading, specific gravity, Atterberg limits, compaction, CBR, etc.<br>• Undertake basic aggregate characterisation of marginal materials identified for use, | Project site, material deposits (e.g. burrow pits, rock outcrops, etc.) | | Local Researcher/ Counterpart |

| | | | | |
|---|---|---|---|---|
| | including Los Angeles abrasion, aggregate crushing value, aggregate impact value, 10% fines, water absorption, elongation, flakiness, etc.<br>• Undertake basic bituminous material characterisation of existing pavement surface layer.<br>• Establish engineering properties of all materials tested as enumerated above.<br>• Prepare modified test protocols for consideration in the development of specifications and guidelines. | | | |
| Stakeholder workshop | • Workshop presentation and discussion | | MRH/DFR | Team Leader /Local Researcher/ Counterpart |

## 6.3 Planning and Deliverables for Tasks 2, 3 and 4

| Task | Task Group / Activity | Days | ETC |
|---|---|---|---|
| *Task 2.0* | *Site Investigation* | | |
| **2.1** | **Preliminary consultations with DFR** | **8** | **08/06/2017** |
| 2.1.1 | Discuss and agree on programme of activities for Task 2 | 2 | 05/06/2017 |
| 2.1.3 | Review of as-built designs, technical specs & maintenance works | 6 | 08/06/2017 |
| **2.2** | **Interaction with contractor and opinion leaders** | **4** | **13/06/2017** |
| 2.2.1 | Meeting - Local research team/DFR/Contractor & team | 1 | 11/06/2017 |
| 2.2.3 | Assessment of Contractor's key personnel | 1 | 12/06/2017 |
| 2.2.4 | Evaluate Contractor's work programme | 1 | 12/06/2017 |
| **2.3** | **Collect technical data on demonstration road** | **10** | **22/06/2017** |
| 2.3.1 | Profile existing road using DCP tests and test pits | 5 | 19/06/2017 |
| 2.3.2 | Assess road geometrics and safety considerations | 3 | 18/06/2017 |
| 2.3.3 | Capture surface defects and drainage structures | 3 | 18/06/2017 |
| 2.3.4 | Identify and investige potential erosion spots | 2 | 18/06/2017 |
| 2.3.5 | Review of appropriate mech. stabilisation & constructon techniques | 5 | 22/06/2017 |
| 2.3.6 | Evaluation of maintenance requirements & techniques | 2 | 22/06/2017 |
| **2.4** | **Collect environment data** | **2** | **11/06/2017** |
| 2.4.1 | Hyrological, geological maps, topograghical data, etc | 2 | 11/06/2017 |
| **2.5** | **Materials sourcing** | **3** | **21/06/2017** |
| 2.5.1 | Identify source of materials at/close to demonstration site | 3 | 21/06/2017 |
| **2.6** | **Sampling of materials for testing** | **7** | **26/06/2017** |
| 2.6.1 | Materials from quarry, burrow pits, deposits, rock outcrops | 4 | 18/07/2017 |
| 2.6.2 | Samples of cement, bitumen, etc from suppliers | 2 | 26/07/2017 |
| 2.6.3 | Review of natural lateric materials processing/screening | 3 | 26/07/2017 |
| **2.7** | **Collect traffic data and analyse** | **10** | **18/07/2017** |
| 2.7.1 | 12hrs/7 days traffic count (manual) | 7 | 18/07/2017 |
| 2.7.2 | Traffic data analysis and reporting | 3 | 20/07/2017 |
| **2.8** | **Conduct socio-economic survey** | **3** | **26/07/2017** |
| 2.8.1 | Conduct interviews, administer questionnaire | 2 | 20/07/2017 |
| 2.8.2 | Analyses of socio-economic survey data | 2 | 26/07/2017 |
| **0.0** | **Trip to Ghana: Project Team Leader** | **1** | **10/08/2017** |
| **2.9** | **Laboratory testing of sample materials** | **35** | **10/09/2017** |
| 2.9.1 | Soils from exiting road layers, burrow pits, etc | 10 | 27/08/2017 |
| 2.9.2 | Agreggates, stones, rocks, etc | 10 | 03/09/2017 |
| 2.9.3 | Bitumen, cement, pozzolana, others | 5 | 09/09/2017 |
| 2.9.4 | Analyses of laboratory test results | 5 | 09/09/2017 |
| 2.9.5 | Develop design procedures/guidelines for pavement options | 5 | 10/09/2017 |
| *Task 3.0* | *Design of Experimental Sections & Procurm't of Works* | | |
| **3.1** | **Structural and material designs of road sections** | **15** | **20/09/2017** |
| 3.1.1 | Structural design of pavement options | 5 | 13/09/2017 |
| 3.1.2 | Additional laboratory tests on optimised materials | 7 | 17/09/2017 |
| 3.1.3 | Material designs | 5 | 14/09/2017 |
| 3.1.4 | Economic analysis | 2 | 16/09/2017 |
| **3.2** | **Geometric designs of road sections** | **2** | **20/09/2017** |
| 3.2.1 | Review proposed/working geometric designs of Contractor | 2 | 20/09/2017 |
| **3.3** | **Preliminary specifications for optimised materials** | **10** | **22/09/2017** |
| 3.3.1 | Review existing standard specifications | 5 | 20/09/2017 |
| 3.3.2 | Draft revised standard specifications | 5 | 20/09/2017 |
| **3.4** | **Procurement of the works** | **5** | **22/09/2017** |
| 3.4.1 | Prepare BoQ of research works to revise original contract | 5 | 22/09/2017 |
| **D3:** | **Project Milestone Deliverable (Draft Design Report)** | **1** | **29/09/2017** |
| **0.0** | **Trip to Ghana: Project Team Leader** | **1** | **16/10/2017** |
| *Task 4.0* | *1st Stakeholder Workshop & Final Design* | | |
| 4.1 | Organise and hold first workshop | 2 | 18/10/2017 |
| 4.2 | Final design & outocomes of workshop | 20 | 25/10/2017 |
| **D4:** | **Project Milestone Deliverable (Final Design Report)** | **1** | **30/10/2017** |

**Figure 27: Activity/Inputs and outputs for Tasks 2, 3 and 4**

## 6.4 As planned milestones

It is anticipated that the project will be delivered as planned and stipulated in the contract. Detailed milestone deliverables and dates are presented in Table 18.

**Table 18: Milestone deliverables and due dates**

| No. | Milestone Deliverable | Due Date | Proposed Due Date |
|---|---|---|---|
| 1 | Mobilisation | 24 February 2017 | No change in date |
| 2 | Inception report | 20 March 2017 | |
| 3 | Draft design report | 26 June 2017 | 29 September 2017 |
| 4 | Final design report including the outcomes of the first workshop | 24 July 2017 | 30 October 2017 |
| 5 | Construction progress report | 16 October 2017 | 22 December 2017 |
| 6 | Construction progress report including the outcomes of the second workshop | 08 January 2018 | 05 March 2018 |
| 7 | Final construction report including baseline survey | 05 February 2018 | 02 April 2018 |
| 8 | Training and capacity building report | 05 March 2018 | 07 May 2018 |
| 9 | Economic analysis report | 02 April 2018 | 04 June 2018 |
| 10 | 1st performance monitoring report | 06 August 2018 | No change in date |
| 11 | 2nd performance monitoring report | 04 February 2019 | |
| 12 | 3rd performance monitoring report | 05 August 2019 | |
| 13 | Draft final report including the 4th performance monitoring for presentation at the stakeholder (third) workshop | 23 December 2019 | |
| 14 | Final report | 03 February 2020 | |

## 6.5 Identified external factors

The time required to complete the activities will depend on various factors, some of which identified at inception phase are external to the contract.

1. Although a contractor has been appointed on the road earmarked for the study, it is likely that project delivery may be affected by the construction of the sections. This is because the contractor may not have the requisite skill in the new pavement technologies that are being introduced in the project or in the associated construction techniques.

2. The delivery of site works is highly dependent on and paramount to daily progress on the site. Progress may slow down if contractors have insufficient resources to carry out the construction activities as planned.

3. Eastern Region of Ghana including where the demonstration sections will be constructed (Akwasiho-Tweneduraseroad) experiences its rainy season from April to mid-November (May, June, July are peak rainfall months). Inclement weather could be a major hindrance to work

progress and it may eventually delay deliverables. Obviously, construction activities cannot be carried out during the wet season.

4. The availability of resources to both the contractors and the DFR can influence progress on sites. The project team was informed that this is a common problem that is faced by the construction industry in Ghana as a whole. Efficiency of payments to contractors could affect progress of work. Sometimes work is abruptly suspended on project sites as a result of delayed payments.

The above factors may cause delays in project delivery, which can necessitate an extension of the time allowed for the project.

# 7 Conclusions and Recommendations

## 7.1 Conclusions

The work done during the inception phase and conclusions made are summarised as follows:

- Five surfacing types including roller compacted concrete (RCC) instead of four as per the contract requirement will be demonstrated in this study. These are; cobblestones, interlocking concrete paving blocks, cold mix asphalt, roller compacted concrete and ultra-thin reinforced concrete.
    - RCC is being demonstrated under an AfCAP project in Ghana on a road with a relatively gentler gradient. It was strongly recommended for demonstration in this project to compare its performance on steeper gradients. Costs of the inclusion of RCC in the project— relatively insignificant—will be submitted to the AfCAP PMU for a consideration of an addendum to the original contract.
    - In a meeting with the project team on 24 May 2017, the DFR expressed concerns about the inclusion of thin hot-mix asphalt (50 mm thick) in the surfacings for demonstration. These concerns are related to production and construction (e.g. scarcity of mobile asphalt plants and limited commercial asphalt plants in Ghana, long haulage distances to the project site, and the need for expensive construction equipment). It was agreed that the thin hot mix should be replaced by cold mix asphalt for demonstration.
- Although whole life cycle cost analysis indicated that a single Otta seal surfacing is economically feasible for use on the steep hill sections of feeder roads, the DFR and Ghana Ministry of Roads and Highways (MRH) were of the view that since Otta seals had already been trialled in the western and central regions of Ghana, they would prefer cobblestone /stone setts to be demonstrated with the other four surfacings.
- Suitable road (project site) with gradients varying between 12 and 22% has been identified for the study. The total length of the road is 3.5 km with 1.9 km of steep hilly sections. The road can conveniently accommodate five demonstration sections and two control sections with a minimum length of 275 m each.
- Majority of pavement structures proposed for the alternative surfacing involve a three-layer system. Based on the work done in Malawi, it is possible to design a two-layer pavement system in which the existing natural subgrade is "proof-rolled" and overlaid with a natural gravel base and surfaced with the proposed surfacing options.
- Based on the lab assessments, materials testing will be conducted at both the BRRI Lab in Kumasi and GHA Central Materials Laboratory (CML) in Accra. The two Labs complement each other in terms of the testing programme proposed for the study. The overall laboratory testing programme will however, be led and managed by the BRRI.
- Outcomes of the study will be used to initiate the development of guidelines and specifications for steep hill sections of low-volume roads in Ghana. The final guideline/specification will draw on the outputs of the laboratory and field works carried out in the project, and ultimately

aligned with the AfCAP West African sub-regional project on the development of low-volume roads manual for Ghana, Sierra Leone and Liberia. It is suggested that a single document instead of individual documents be developed for the five surfacing types. This will further be discussed with the AfCAP PMU as the project progresses.

- Since the DFR will use an already existing contract for the demonstration sites, the DFR should clarify deviations from current norms and standard approach of feeder roads construction to the contractor, and highlight research as key component in this project. Selected contractor should have good background /experience in the construction of the proposed surfacings. Preferably, a contractor who has paved similar roads in the country should be nominated for this project.

- The proposed protocol for monitoring is designed to be in line with the AfCAP regional protocol for experimental sections on low-volume roads. Since the DFR is not familiar with this type of monitoring the counterpart staff will be trained in the use of the protocol. Detailed step-by-step procedures of the protocol will be provided during the project training. It is anticipated that this training in the use of the protocol will involve practitioners from Sierra Leone and Liberia.

- For effective knowledge transfer and capacity building, it was emphasised at the inception meeting that the participation of DFR staff should be a continuous process. It is expected that after the contract period of three years the trained staff from the DFR would have acquired the prerequisite skills and knowledge to continue with the monitoring and evaluation of the demonstration sections.

- A detailed work plan for the implementation of site investigation, draft designs and final designs of the demonstration sections is provided in this report with detailed activities and timelines.

- No major concerns were raised at the inception stage and thus, a successful implementation of the project is anticipated.

## 7.2 Recommendations

Based on the findings and issues highlighted in this report, the following recommendations are made:

- Due to concerns raised by the DFR, it is recommended that cold-mix asphalt be accepted to replace the thin hot-mix asphalt (50 mm).

- The project has already experienced a challenge of site selection, and that has impacted some deliverables. To avoid further delays, the DFR should request the nominated contractor to produce a detailed programme of works two weeks after the first stakeholder workshop.

- The DFR team indicated a desire for the study to include instrumentation (such as traffic counters, underlying pavement material monitors, etc.) to allow the DFR to monitor and evaluate the different pavement options. Introduction of appropriate instrumentation in this project is recommended, albeit it is contingent to the ability of the DFR to fund them.

- The BRRI laboratory should coordinate and collaborate with GHA CML to conduct all materials testing. The DFR in consultation with the BRRI should facilitate the process to appoint GHA CML as there could be potential delays.

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# Appendix A: Assessment of Laboratories for Materials Testing

**Table 19: Laboratory capacities for testing**

| Material | Tests Required | Test Method | GHA CML | GHA, Koforidua | DFR, Koforidua | BRRI Lab |
|---|---|---|---|---|---|---|
| Subgrade | Sieve analysis (dry and wet sieving) | | YES | YES | YES | YES |
| | Plasticity Tests (liquid limit, plastic limit and linear shrinkage) | GHA S6 | YES | YES | YES | YES |
| | Compaction (maximum dry density and optimum moisture content) | | YES | YES | YES | YES |
| | CBR & Percent Swell | | YES | YES | YES | YES |
| Gravel | Plasticity Tests (liquid limit, plastic limit and linear shrinkage) | GHA S6 | YES | YES | YES | YES |
| | Compaction (maximum dry density and optimum moisture content) | | YES | YES | YES | YES |
| | CBR | | YES | YES | YES | YES |
| | Triaxial tests | | YES | NO | NO | YES |
| | Aggregate strength tests | | YES | YES | NO | NO |
| Course aggregates | Particle size distribution | BS EN 933-1 | YES | YES | YES | YES |
| | Clay, silt and dust in aggregate | BS 812-103.2 | YES | YES | YES | YES |
| | Flakiness index | BS EN 933-3 | YES | YES | YES | YES |
| | Relative density- water absorption bulk density | BS EN 1097-6 | YES | NO | NO | YES |
| | Voids and bulking moisture content | BS EN 1097-3 | YES | NO | NO | YES |
| | Aggregate crushing value | BS 812-109/BS 812-110 | YES | YES | NO | YES |
| | Organic impurities in sands | AASHTO T 21 | NO | NO | NO | YES |
| | Los Angeles Abrasion | AASHTO T 96/ASTM C 131/ C 135 | YES | YES | NO | NO |
| | | ASTM C 535 | YES | YES | NO | NO |
| | Sand equivalent | AASHTO T 176 | YES | NO | NO | NO |
| | 10% Fines aggregate crushing value | BS 812-111<br>AASHTO T:238 | YES | NO | NO | NO |
| Asphalt/ Bitumen | Mix design (Marshall method) | AASHTO T245, | YES | NO | NO | NO |
| | Moisture sensitivity test(TSR) | ASTM D 4867 | YES | NO | NO | NO |
| | Saybolt /universal furol viscosity | AASHTO T59(ASTM | YES | NO | NO | NO |

| Material | Tests Required | Test Method | GHA CML | GHA, Koforidua | DFR, Koforidua | BRRI Lab |
|---|---|---|---|---|---|---|
| | | D244) | | | | |
| | Specific gravity ofbitumen | AASHTO T228(ASTM D 70) | YES | NO | NO | NO |
| | Flashandfire pointtest | ASTM D92 | YES | NO | NO | NO |
| | Penetration test | ASTM D5 | YES | NO | NO | NO |
| | Distillation test (Cutback /emulsified bitumen) | ASTM D 402/ASTM D6997 | YES | NO | NO | NO |
| | Extraction test | ASTM D2172 | YES | NO | NO | NO |
| | Maximum theoretical specificgravity($G_{mm}$) | ASTM D 2041 /AASHTO T209 | YES | NO | NO | NO |
| | Softeningpoint | ASTM D36 | YES | NO | NO | NO |
| | Rollingthinfilmoventest | AASHTO T 240/ASTM D 2872 | YES | NO | NO | NO |
| | Kinematic viscosity | ASTM D2170 / D2170M | YES | NO | NO | NO |
| | Viscosity | ASTM D 4402 | YES | NO | NO | NO |
| | Bulk specific gravity of asphaltic concrete cores | ASTM D 2726 /AASHTO T166 | YES | NO | NO | NO |
| | MarshallStabilityandflow | ASTM D6927 | YES | NO | NO | NO |
| Sand-stone concrete | Mix design | | YES | NO | NO | YES |
| | Slump test | BS EN 12350 | YES | YES | YES | YES |
| | Compressive strength test | BS 1881 P116:1983 | YES | YES | YES | YES |
| | Schmidt hammer | | YES | NO | NO | YES |
| | Flexural strength on concrete | | YES | NO | NO | NO |
| Cement | Fineness and Consistency | | NO | NO | NO | YES |
| | Initial setting and final setting | EN 206 P1:2000, IS 4031 1988 | NO | NO | NO | YES |

**Table 20: Key personnel of four laboratories**

| No. | Laboratory | Name | Qualification | Section | Position | Years of Experience |
|---|---|---|---|---|---|---|
| **1** | GHA Central Material Laboratory, Accra | Frederick Acquah | Certificate | Soils/ aggregates laboratory | Principal technical officer | 15 |
| | | Nancy Crentsil | Higher National Diploma Civil Engineering | Soils/ aggregates laboratory | Technical officer | 7 |
| | | Mensah Enoch Laryea | GCE O Levels | Soils/ aggregates laboratory | Principal technical officer | 9 |
| | | Rachel Lamptey | High School | Soils/ aggregates laboratory | Senior technical officer | |
| **2** | GHA Koforidua | George Laryea | Higher National Diploma Civil Engineering | Soils/ aggregates laboratory | Technician | 15 |
| **3** | DFR Koforidua | AsieduMintah | CTC III | Materials Lab | Principal technician, head of laboratory | 24 |
| **4** | BRRI Kumasi | Bernard Ofosu | MSc GIS with Remote Sensing | Geotechnical division | Senior research scientist, head of laboratory | 15 |
| | | Kwame Sarpong | BSc Civil Eng. | Geotechnical division | Principal technical officer | 15 |
| | | TheresahOsei | BSc Chemistry | Chemistry laboratory | Chief technician, head of laboratory | 7 |

# Appendix B: Guideline of Materials Testing for Monitoring

**Table 21: Monitoring of experimental sections—bituminous materials testing**

| Material properties | Test method | Construction | Post-construction |
|---|---|---|---|
| Binder recovery and content | ASTM D2172 | ✓ | ✓ |
| Penetration (original, before and after RTFOT & recovered binder) | ASTM D5 | ✓ | ✓ |
| Softening point | ASTM D36 | ✓ | ✓ |
| Dynamic viscosity (at 60°C and 135°C) | ASTM D4402 | ✓ | ✓ |
| Ash content (recovered binder) | ASTM D482 | ✓ | ✓ |
| Density of binder (before RTFOT) | ASTM D70 | ✓ | |
| Aggregate grading | ASTM C136 D546 | ✓ | |
| Aggregate shape properties (flakiness, fractured faces, particle index test) | ASTM D5821, ASTM D3398 | ✓ | |
| Unit weight of aggregate | AASHTO T19 | ✓ | |
| Void content of fine aggregates | AASHTO T 304 | ✓ | |
| Sand equivalent | AASHTO T 176 /ASTM D 2419 | | |
| Average least dimension (ALD) | --- | ✓ | |
| Methylene blue test in case of micro-surfacing | ASTM C1777 | ✓ | |
| Bulk relative density (asphalt core) | ASTM D 2726 /AASHTO T166 | ✓ | |
| Theoretical maximum relative density (cores) | ASTM D 2041 /AASHTO T209 | ✓ | |
| Core thickness | No specific method | ✓ | |
| Indirect tensile strength (production mix/cores) | ASTM D 6931 | ✓ | |
| Moisture resistance (production mix) | ASTM D 4867M | ✓ | |

**Table 22: Monitoring of experimental sections—concrete materials testing**

| Parameter | Property | Test method | Pre-construction | Construction |
|---|---|---|---|---|
| Aggregate | Grading | BS EN 933-1 | ✓ | ✓ |
| | Grading (dust content) | BS 812-103.2 | ✓ | ✓ |
| | 10 % FACT Dry/Wet | BS 812-111 AASHTO T: 238 : Part 9: Clause 2.5 | ✓ | ✓ |
| | Aggregate Crushing Value (ACV) | AASHTO T: 238 : Part 9: Clause 2.5 | ✓ | ✓ |
| | Fineness Modulus | BS 812-109/BS 812-110 | ✓ | ✓ |
| | Flakiness Index | BS EN 12620:2013 | ✓ | ✓ |
| | Water Absorption | BS EN 933-3 | ✓ | |
| | Sand Equivalent | BS EN 1097-6 ; ASTM C128 | ✓ | ✓ |
| | Organic Impurities | | ✓ | ✓ |
| | Soundness | ASTM D2419 | ✓ | |
| | Chloride content | AASHTO T 21; ASTM C40 | ✓ | ✓ |
| | Soluble salt-Sulphates | BS 812-121-1989 | ✓ | ✓ |
| | Clay Content | ASTM D1411 | ✓ | ✓ |
| Concrete Mix | Max water/cement ratio | BS EN 206:2013+A1:2016 | ✓ | ✓ |
| | Min cement content | BS EN 206:2013+A1:2016 | ✓ | ✓ |
| | Slump of freshly mix concrete | BS EN 12350-2:2009 | ✓ | |
| | Compressive strength | BS EN 12390-4:2000 | ✓ | ✓ |
| | Air content | BS EN 12350-7:2009 | ✓ | ✓ |
| | Flexural Strength | | ✓ | |

**Table 23: Monitoring of experimental sections—granular materials**

| Parameter | Property | Test method | Pre-construction | Construction |
|---|---|---|---|---|
| Granular Soil/Aggregate | Grading | GHA S6 | ✓ | ✓ |
| | Grading Modulus | GHA S6 | ✓ | ✓ |
| | Atterberg limits:<br>• Plasticity Index<br>• Liquid Limit<br>• Plastic Limit<br>• Linear Shrinkage | GHA S6 | ✓ | ✓ |
| | Sand equivalent | AASHTO T 176 | | ✓ |
| | DCP | BS 1377-4:1990 | ✓ | ✓ |
| | Maximum dry density (MDD) | BS 1377-4:1990 | ✓ | ✓ |
| | Optimum moisture content (OMC) | BS 1377-4:1990 | ✓ | ✓ |
| | Unconfined compressive strength | BS 1377-7:1990 | ✓ | |
| | Field density | BS 1377-9:1990 | | ✓ |

## Appendix C: Traffic Tallying Form

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Traffic Tallying Form** | | | | | | | **Project:** | | | | | | | | |
| **Area/Town:** | | | **Road:** | | | | **Count made by:** | | | | | **Date:** | | | |
| **Location/Chainage of Count Section** | | | | | | | **Day:** | | | | | **Sheet** | | **of** | |
| **VEHICLE CLASS \ HOUR** | **6 - 7** | **7 - 8** | **8 - 9** | **9 - 10** | **10 - 11** | **11 - 12** | **12 - 13** | **13 - 14** | **14 - 15** | **15 - 16** | **16 - 17** | **17 - 18** | **COUNT** | **FACTOR** | **TOTAL** |
| **Passenger Cars** | | | | | | | | | | | | | | | |
| **Light Goods Vehicle (Pick Ups, Small Bus, Vans, Small Trucks)** | | | | | | | | | | | | | | | |
| **Medium Bus** | | | | | | | | | | | | | | | |
| **Coach (eg. Salem Bus)** | | | | | | | | | | | | | | | |
| **Medium Truck (2 Axle)** | | | | | | | | | | | | | | | |
| **Heavy Truck (2 Axle)** | | | | | | | | | | | | | | | |
| **Heavy Truck (3 Axle)** | | | | | | | | | | | | | | | |
| **Heavy Truck (4 Axle)** | | | | | | | | | | | | | | | |
| **Articulated Trucks** | | | | | | | | | | | | | | | |
| **Tractor and Agric Vehicles** | | | | | | | | | | | | | | | |
| **HOUR TOTAL** | | | | | | | | | | | | | | | |

## Appendix D: Tables from ILO (2013)

The table below provides a guide of task rates for various dressed stone paving works

**Table 8-23: Productivity norms for dressed stone paving**

| TASK/DESCRIPTION | METHOD | AVERAGE TASK RATE [44] |
|---|---|---|
| **Quarry work** | | |
| Quarrying of 0.15 to 0.25 $m^3$ blocks from granite rock mass in benches up to 0.50 cm high, with many wide cracks. | Use of crowbar. Team of 3 workers who, using the crowbar as a lever, detach blocks from the rock mass and help load them onto a hand cart. | 4 $m^3$/day, that is 1.3 $m^3$/wd |
| Quarrying of 0.25 to 0.40 $m^3$ blocks from compact granite rock mass with benches from 0.50 to 1 m high. No cracks in benches. | Use of plug and feathers, rock drill and drill bit. Work carried out by 2 workers with one rock drill. Blocks detached from rock mass, then split if necessary before loading. | 1.8 $m^3$/day, that is 0.9 $m^3$/wd |
| Quarrying of 0.25 to 0.40 $m^3$ blocks from compact granite rock mass with benches 0.30 to 1 m high. | 2 workers make wedge-holes manually using grooving-chisel and club-hammer. Split blocks once more if necessary. | 1 $m^3$/day, or 0.50 $m^3$/wd |
| Boring using pneumatic drill: diameter of drill-hole ¢ 34 mm. Compact rock. | 2 workers work in shifts at drilling. | 2 50-cm deep wedge-holes per hour |
| Boring holes for quarry wedges. | 1 worker with grooving-chisel and club-hammer. | 3 holes/hour |
| Boring holes for quarry wedges using pneumatic hammer drill. | 2 workers work in shifts using hammer drill. | 7 holes/hour |
| Quarrying of 0.50 to 1 $m^3$ blocks from compact granite rock mass with benches over 1 m high. | Use of calmmite or black powder explosive. Drilling of blast-holes using pneumatic drill. 2 workers. One blasting officer for placing and firing explosives or placing and covering calmmite. | 6 $m^3$/day, or 2 $m^3$/wd |
| Cutting of 0.50 to 1 $m^3$ blocks to make 0.25 to 0.40 $m^3$ blocks. | Use of quarry wedges. Wedge-holes bored using hammer drill. Two workers in shifts. | Team cuts 3 $m^3$/day, or 1.5 $m^3$/wd |
| | Use of quarry wedges. Wedge-holes made manually. One worker. | Volume cut: 1 $m^3$/wd |
| **Dressing** | | |
| Secondary cutting stage of 0.25 to 0.40 $m^3$ blocks into 14 cm thick slabs. | Use of quarry wedges. Drilling of wedge-holes using hammer drill. Two workers in shifts. | 2.5 $m^3$/day, or 1.25 $m^3$/wd |
| | Use of quarry wedges. Manual boring of wedge-holes. One worker. | 0.8 $m^3$/wd |
| Dressing of large paving-blocks from 14 cm thick slabs. | Use of pneumatic hammer drill fitted with chisel end. Edges dressed by means of chisel. One worker. | 40 paving-blocks/wd |
| | Manual method: grooves cut using grooving-chisel and club-hammer. Edges dressed by means of chisel. One worker | 20 paving-blocks/wd |
| Dressing of edging curbstones. | Edges dressed using chisel, faces corrected using grooving-chisel. One worker. | 4 lm/wd |
| Clearing, over radius of 50 m, of stone debris resulting from squaring of paving-blocks. | Transported by wheelbarrow, loaded by 8-pronged fork. | 1 worker for 20 paving-block masons |
| **Handling** | | |
| Loading and transporting blocks. | Team made up of:<br>· 4 unskilled workers<br>· 1 gang leader | Handling and transport, over 10-20 m, approx. 2 $m^3$/wd |
| Transport of paving-blocks 50 m from dressing site to storage area. | Transported by wheelbarrow. Paving-blocks stacked in piles at storage site. | 400 paving-blocks/wd |

The table below provides a summary of labour based sealing types, specifications, indicative costs, advantages, disadvantages and productivities.

**Table 8-25: Sumary of labour based sealing types**

| Seal Type | Specifications | Indicative costs (US$) | Advantages | Disadvantages | Daily Productivity |
|---|---|---|---|---|---|
| Otta Seal | - Binder – MC 3000 cutback bitumen, or; 150/200 Penetration grade, 135 - 180oC at spray rate of between 1.8 to 2.0 litres/ m² (depending on properties of aggregates used)<br>- Graded aggregates: 16mm - 2mm<br>- Plant/Equipment:<br>o Bitumen tanker<br>o Pneumatic roller<br>o Chippy spreader<br>o Set of handtools | 2.5 - 3.0/ m² (single seal, excluding prime) | • Durable (+/- 14mm compacted thickness single seal, proven 9 -11 years' service life with single sand cover seal)<br>• High labour content<br>• Does not require priming (except to prevent base damage by traffic)<br>• Same day re-open to traffic (at controlled speed) helping compaction<br>• Relaxed aggregate strength, grading, dust content, particle shape, binder adhesion requirements.<br>• Accommodates use of locally available natural aggregates. | • Hot bitumen poses potential health & safety hazard.<br>• Application requires bitumen tankers<br>• Requires long stretches of formed base which may be damaged by traffic<br>• May be looked upon as inferior seal during first 4 months of construction due to unappealing look (use of natural gravel appears as dirt road).<br>• Screening of aggregate from natural material is expensive.<br>• Prolonged and expensive after-care | • 90m²/wd (Group task with team of 60 completing 5,500m² in spotting and spreading of aggregates) |
| Sand Seal | - Binder - Cationic spray grade emulsion (65% bitumen and 35% water) sprayed at 60 oC. Spray rate of 1.6litre/m²<br>- Sand with grading between 6.7 and 0.15 mm at 0.007./m²<br>- Plant/Equipment:<br>o Motorised hand sprayer<br>o Pedestrian vibratory roller<br>o Set of handtools | 1.5 - 2.0/ m² (excluding prime at 0.6litre/m²) | • High labour content<br>• Seal as you go with small plant & machinery<br>• Relatively simple and inexpensive to construct depending on the availability of sand.<br>• Carpet thickness can easily be increased with successive applications.<br>• Maintenance is simple yet must be monitored attentively.<br>• Affords some protection to surface and other pavement layers. | • Single sand seal not very durable. Requires a second seal after 2 years.<br>• Requires priming at additional cost<br>• Can only be opened to traffic until after about one week.<br>• Requires an efficient motorised hand sprayer with controllable delivery. | • 150m²/wd (Group task with team of 20 completing 3,000m² in spotting and spreading of sand |
| Modified Otta seal | - Prime rate: 0.5 - 0.6 litres/m² anionic emulsion.<br>- Binder: 60% emulsion at 50oC in two application spray rates: 0.6 – 0.7 litres/m² as tack coat and remaining balance as per calculated binder content, as penetration spray.<br>- Commercial Aggregates: 9.5mm<br>- 0.075mm<br>- Plant/Equipment:<br>o Motorised hand sprayer<br>o Chippy spreader<br>o Pedestrian roller<br>o Set of Handtools | 2.0 - 2.5/ m² (single seal, excluding prime) | • Durable (+/- 14mm compacted thickness)<br>• High labour content<br>• More labour-friendly than Otta seal. (Seal-as-you-go).<br>• Same day re-open to traffic (at controlled speed) helping compaction.<br>• Requires less aggregates application than Otta seal<br>• Does not require hot bitumen and tanker distributer<br>• Does not require long and expensive after-care | • Requires an efficient motorised hand sprayer with controllable delivery.<br>• Requires only graded commercial aggregates. (Cannot use natural gravel).<br>• Requires high technical design and construction inputs in ensuring correct rate of:<br>o binder application.<br>o aggregates application. | • 90m²/wd (Group task with team of 16completing 3,000m² in spotting and spreading of aggregates |

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| Cold Mix Asphalt | - Tack coat : 60% Anionic stable grade emulsion.<br>- Emulsion binder: 65% Cationic premix grade (Tosas KMS 65).<br>- Aggregates : 9.5 – 0.075 mm<br>- Mix proportions (litres) :<br>Mix Volume: 80, 60<br>Aggregate: 80, 60<br>Emulsion: 12, 9<br>Water (litres): 2.5, 1.5<br>- Plant/Equipment:<br>o Concrete mixer, or<br>o Steel trays<br>o Pedestrian vibratory roller<br>o Set of handtools | 4 - 5/m² (excluding prime at 0.6lit/m²) | • High labour content<br>• Seal as you go with small plant & machinery (avoids damage to base)<br>• Suitable for steep sections<br>• Self-sealing of cracks<br>• Durable (thicker layer ~ +/- 18mm compacted)<br>• Minimal handling and health hazards.<br>• Open to traffic same day<br>• Good riding quality with adequate bearing capacity and tyre contact stress transfer.<br>• Easy on-site production - does not require high technical supervision<br>• Affords easy transport of binder to site in 210 litre drums and eliminates all challenges associated with the use of heavy bitumen tankers. | • Higher material transport costs | • 70m²/wd (Group task - Each team of 14 completing 1,000m² in batching, mixing, placing, and screeding the asphalt). With more mixing trays and teams employed, the daily output can be multiplied many times. |
| Segmented Paving Blocks | - Strength: 50 MPa<br>-Thickness: 60mm<br>- Bedding Sand: 20mm thick Grading: 4.75 – 0.075mm<br>- Jointing sand: Grading:1.18 – 0.075mm<br>- Plant/Equipment:<br>o Flat plate vibratory roller<br>o Set of handtools | 12 - 15/m² | • Can use labour to manufacture blocks on site<br>• Laying/placing done by hand<br>• Cost savings in base layer as pavement also act as base layer.<br>• Easy maintenance – remove, patch and replace.<br>• Long durability<br>• Reduced maintenance and lower maintenance costs | • High initial costs (compensated for by thicker layer as base, and durability).<br>• Noisy for high speed traffic;<br>• Require attention to ensure positive drainage of the bedding sand layer | • 15 -20m²/wd (Group task - Each team of 10 completing 150 - 200m² in laying sand bed and, placing paving blocks). |
| Ultra Thin Reinforced Concrete | - 50 mm layer of 30 MPa (1:1.5:3) concrete,<br>- 200 x 200mm grid welded mesh (reinforcing, placed in the centre layer.<br>- Plant/Equipment:<br>o Concrete mixers<br>o Vibrating screed beam or truss.<br>o Movable bridge for placing and screeding concrete<br>o Bass texture broom<br>o construction joints saw<br>o Sealing joints equipment<br>o Set of handtools | 8 - 10/m² | • Lower whole life cost for comparable design<br>• Does not rut, shove or pothole<br>• Reduced maintenance and low maintenance costs<br>• Labour friendly and therefore suitable for LBM<br>• Skills acquired are not limited to road construction but are transferable to the wider building and construction industry<br>• Existing subgrade and alignment can be used<br>• Only simple inexpensive equipment needed | • Possibly increased initial cost<br>• Increased material transport costs in remote areas<br>• Cracking potential during construction<br>• Some concrete skills needed | • 20m²/wd (Group task - Each team of 20 - 25 completing 400 - 500m² in batching, placing and screeding concrete). |

# Appendix E: Guidelines for Labour-Based Construction

- **Labour based construction of single seal**
  - Should the base not be primed it will need to be swept before the operation can commence. This process will be the same as for the priming operation. The binder content needs to be increased slightly to allow for a percentage to be absorbed into the base layer to create the bond required between the granular base and wearing course layers.
  - To ensure that the operation is not slowed down while chip spreaders are re-supplied with stone chippings, small stockpiles can be deposited along the road side at intervals of about 50m to reduce the distance to be travelled as the stone chippings are wheeled to the chip spreaders.
  - Spray applications should only be applied during the day and only in good weather conditions.
  - The emulsion can be sprayed directly from the 200 L drums if the hand pulled cart is used.
  - Tack coat or 1st First Spray operation using a hand lance
    - The piping should be checked for leaks and the motor, where present, for correct operation, having no leaks, with pulley sufficiently tight and having sufficient oil and fuel.
    - Nozzles should be cleaned with diesel, if necessary, away from the road surface.
    - The area to be sprayed from a given quantity of binder should firstly be established and marked out to assist in achieving the correct application rate.
    - Spraying should be carried out in wide sweeping movements of the hand lance with 1/3 overlaps between successive applications. The actual spray rate should be continuously checked by comparison of the area covered and the area marked.
    - The spray operation should not advance too far ahead of the chipping operation.
  - Stone application
    - The stone application must commence as soon as practically possible to ensure the stone aggregate falls onto the unbroken emulsion. The chip spreaders are pushed by three workers plus an operator who will ensure that the chipping operation takes place along the correct line.
  - Rolling operation
    - No severe turns should be made on the surface itself until the stone aggregate is well bedded down and the emulsion broken
  - Back chipping
    - The back chipping operation of sweeping off excess stone aggregate and adding chippings to the spots where there are insufficient stones lean will take place between the roller passes.
  - Fog spray
    - A diluted emulsion fog spray can be applied after 2 – 3 weeks once all the stone aggregates have bedded down well and all excess stone aggregates have been swept to the side of the road surface either by vehicular traffic or brooming.
  - Traffic control
    - Seals need approximately four to eight hours to set properly
    - Traffic must not be allowed onto the seal until such time as it is fully set

- **Construction 0f a 50 mm ultra-thin reinforced concrete pavement (UTRCP)**
  - Requirements of support layer
    - The support layer should be constructed to levels to accommodate the concrete within 5 mm of designed level. In order to facilitate this it is strongly recommended that levels are established at every 10 meters.
  - Erection of shutters
    - The side shutters should be of 50 x 50 mm steel box sections with a minimum of 3 lugs per section.
    - In placing and fixing the side shutters care must be taken to ensure that no bumps are built into the surface
    - Once the side forms have been placed, the levels must again be checked by placing the straight edge across the tops of the side forms and taking dip readings to ensure that the thickness of the concrete will be within tolerance.
    - The formwork must be cleaned and oiled before use to ensure that it is easily removed.
    - In order to achieve a uniform vertical curve it is recommended that the length of the side forms should not exceed 2 meters. One meter side forms should be used to accommodate horizontal curves and bends in the road.
    - Side forms should not be removed before the concrete has hardened sufficiently to prevent damage being done to the sides and not earlier than 6 hours after completion of the slab.
  - Treatment of surface
    - Before commencing with the placing of the mesh reinforcing for the UTRCP, all loose material must be removed from the surface and a diluted stable grade anionic emulsion. A course broom can be used to evenly distribute the emulsion. The broom must be dipped in water at frequent intervals to prevent the build-up of bitumen.
  - Placing of the welded wire mesh
    - The welded wire mesh reinforcing must be Reference 200 (100 x 100 x 4mm).
    - The cover to the mesh should be 25 mm and the mesh shall be laid butt jointed in both the longitudinal and transverse direction and the overlap achieved by splicing the individual bars of the mesh with a splice bar 400mm long of the same diameter as the mesh.
    - The continuity of the mesh must continue through any construction joints
  - General and description
    - The concrete pavement shall be as follows:

      a. Thickness: 50mm (Tolerance -5mm)

      b. Strength: specified 30 MPa after 28 days

      c. Aggregate: 9 mm nominal stone and sand from an approved commercial source
  - Mixing of concrete
    - Concrete should be mixed on site, using a suitably sized concrete mixer.
  - Placing of concrete
    - The concrete shall be uniformly placed by wheelbarrow, with care being taken not to walk on or disturb the mesh reinforcing
    - Where a section of concrete is to be cast against a section of previously cast concrete a 2-3 mm thick galvanized sheet approximately 300 mm wide should be placed on the top

    - In the case where the layer below the concrete pavement is an Emulsion Treated Base (ETB) the timing of placing the concrete pavement will depend on the time required for the emulsion in the ETB to break.
    - In order to prevent "drying out" of the concrete the concrete shall at all times be covered with a suitable canopy.
    - "Starter" and "end" beams, must be provided for the thin concrete pavement at the commencement and end of the paving. The mesh must be folded down into the beams
    - Walking on the mesh reinforcing or newly placed concrete is not acceptable.
    - The finishing of the concrete pavement layer should be done by a bull float
    - Broom the surface with a bristle broom at right angles to the edge of the pavement
    - The broom must be dipped in water at frequent intervals to prevent the build-up
- Construction joints
    - Construction joints should only be provided to provide a clear, neat joint at the end of a day's work As the mesh reinforcing is to be laid continuously, special attention must be given to the construction joints
    - It is recommended that the formwork be removed as soon as the concrete has set sufficiently so as not to cause spalling of the concrete +/- 1 hour after casting the concrete.
    - Before proceeding with casting the concrete for the next shift, the surface (face) of the joint must be cleaned of any laitance, lightly roughened and treated with cement slurry.
- Longitudinal joint
    - A longitudinal joint shall be formed along the centerline of the road by casting the second member against the first, sawing and sealing with a cold poured bitumen rubber sealant. Before proceeding with the concrete for the second member the road, the surface (face) of the joint must be cleaned of any laitance and lightly roughened.
- Curing of concrete
    - The exposed surfaces, including the sides of the pavement slab, must be protected, with plastic sheeting, as soon as possible after the required texturing of the surface has been effected.
    - Care must be taken to ensure that the bags holding down the plastic sheeting are not placed on the "wet" concrete. This plastic sheeting must be kept in place for as long as is feasible but for a minimum of 7 days.
- Sealing of concrete joints
    - The construction joints and longitudinal joint shall be sawn 10mm wide to a depth of 13mm and sealed with a bitumen rubber compound.