Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First Workshop Report (Final)

Authors:

Robert Geddes

Hamish Goldie-Scot

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Cover Image: Scenes from the 1st round of workshops

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Version	**Author(s)**	**Reviewer(s)**	**Date**
Draft	Robert Geddes Hamish Goldie-Scot	Festus Odametey Lucas-Jan Ebels Ronald Isaac Gareth Hearn	2 October 2017
		Paulina Agyekum (AfCAP PMU) Nkululeko Leta (AfCAP PMU)	
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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 Africa Community Access Partnership (AfCAP) is funding the preparation of manuals for Low Volume Roads (LVRs) for three AfCAP member countries in the West Africa sub-region. These are Liberia, Sierra Leone and Ghana. The new manuals will draw on documentation recently developed in other AfCAP participating countries. The preparation of the manuals includes a high level of local stakeholder participation. The manuals are expected to be published by the end of 2018.

Inputs by local experts are being supplemented by inputs by international experts with experience in the development of rural roads documentation in the Africa region. Following a series of country visits in July 2017, a 1-day stakeholder workshop was held in each country during the second half of September. The purpose of these workshops was to consolidate stakeholder engagement in determining, for each manual, the most appropriate scope and style.

In all three countries the basic structure of the manual will be as follows:

- Part A: Geometric Design and Road Safety;
- Part B: Materials, Pavement Design and Construction;
- Part C: Hydrology, Drainage and Roadside Stabilisation;
- Part D: Complementary Interventions (requested by all three countries); and
- Part E: Maintenance (in Liberia and Sierra Leone).

In addition to the general content on Roadside Stabilisation provided in Part C, further Guidelines for roads in hilly and mountainous areas will be prepared for Liberia and Sierra Leone. None of the manuals will provide guidelines for the design of bituminous seals, as this is available in existing documents and is the subject of a ReCAP research project soon to commence in the region.

In Sierra Leone and Liberia there is a significant paucity of mapping and data of soils and road construction materials on a national basis. The collection of such data is beyond the scope of the manuals project. The manuals will therefore focus on the identification of materials on site and obtaining their engineering properties through conventional on-site and laboratory testing.

The level of technical detail in the manuals will reflect the level of detail found in the manuals for LVRs prepared under AfCAP in Ethiopia and Tanzania. A similar level of detail is expected in the manuals for all three countries. It is expected that the manuals will be used to develop curricula for university courses on the design of LVRs, yet retain a practical edge, including through the inclusion where appropriate of process diagrams that will be of particular relevance to practitioners.

Specific findings and recommendations for the three countries are as follows.

- In **Ghana** there is a wealth of existing resource material for low volume roads, but some historical standards have in practice been modified over time, and these adjustments need to be taken into consideration. There is no existing

manual for the design of pavements for low volume sealed roads, including the use of the DCP/DN design method. The new manual will build on the existing documents and international good practice. DFR will need to be proactive in ensuring GHA participation in the manual development process. (participation of the Department of Urban Roads is less critical as the focus of the manual is rural roads).

- In **Liberia** there is an existing manual and specification for feeder roads as well as other relevant documentation for feeder roads. However, these documents all suggest part ownership by development partners and none addresses the design of low volume sealed roads. The new manual will be fully owned by the Government of Liberia.
- In **Sierra Leone** there is no existing manual for low volume roads or feeder roads. The Sierra Leone manual will therefore rely on regional and international standards to a greater extent than the other two countries. It will include guidance on Planning and Prioritisation (of LVRs), Route Selection for LVRs, and Technical Auditing.

In all three countries a working group will be established using WhatsApp. This will allow for interaction between the manual authors and local technical experts during the manual drafting process.

The second project workshop will be held in each country in early 2018. These will be two-day workshops. It is expected that the first draft of the manual will be available to stakeholders ahead of this meeting.

The initial identification of candidates of the peer review group (international national) has started. The peer review will be carried out in March/April 2018.

Key Words
Manuals, Low Volume Roads, Capacity Building, West Africa

Acronyms and Initialisms

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transport Officials
AfCAP	Africa Community Access Partnership
ALCC	Association of Liberian Construction Contractors
ALVRS	Alternative Low Volume Road Surfacing
ASTM	American Standard Test Method
AWARE	A West Africa Response to Ebola
BRRI	Building and Roads Research Institute
BS	British Standard
CBO	Community Based Organisation
CBR	California Bearing Ratio
CCCS	Contractor Classification and Certification System
CDS	Civil Design Solutions
CRIG	Cocoa Research Institute of Ghana
CSIR	Council for Scientific and Industrial Research (R&D group, Ghana)
CSIR	Council for Scientific and Industrial Research (R&D organisation, South Africa)
DC	District Council
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
DFR	Department of Feeder Roads (Ghana)
DN	DCP Number (mm/blow)
DUR	Department of Urban Roads (Ghana)
ECOWAS	Economic Community of West African States
EN	European Standard
EPA	Environmental Protection Authority
ESA	Equivalent Standard Axles
ESOL	Engineering Society of Liberia
EU	European Union
FR	Feeder Road / Forest Reserve
FRAMP	Feeder Roads Alternative and Maintenance Programme
FRP	Feeder Roads Programme
GASIP	Ghana Agricultural Sector Investment Programme
GCEA	Ghana Consulting Engineers Association
GDP	Gross Domestic Product
GHA	Ghana Highways Authority
GhIE	Ghana Institution of Engineers
GIZ	Gesellschaft für Internationale Zusammenarbeit – German Development Agency
GPS	Global positioning system
GRF	Ghana Road Fund
GRFS	Ghana Road Fund Secretariat
ILO	International Labour Organization
JICA	Japanese International Cooperation Agency
KFW	Kreditanstalt für Wiederaufbau - German Development Bank
KTC	Koforidua Training Centre
L-B	Labour-Based
LSFRP	Liberian Swedish Feeder Roads Project
LVR	Low Volume Road

LVSR	Low Volume Sealed Road
LWD	Lightweight Deflection Testing
M&E	Monitoring and Evaluation
MCC	Millennium Challenge Corporation
MDD	Maximum Dry Density
MoFA	Ministry of Food and Agriculture
MLG	Ministry of Local Government
MPBS	Maintenance Performance Budgeting System (Ghana)
MPW	Ministry of Public Works
MRH	Ministry of Roads and Highways
NRSC	National Road Safety Commission (Ghana)
OPRC	Output and Performance based Road Contract
ORN	Overseas Road Note
PI	Plasticity Index
PM	Plasticity Modulus
PIT	Project Implementation Team
PMU	Project Management Unit
PUA	Public Utility Authority (Liberia)
RAI	Rural Access Index
ReCAP	Research for Community Access Partnership
RMFA	Road Maintenance Fund Administration
RMTC	Road Maintenance Training Center
RPM	Road Prioritisation Methodology
RSC	Road Safety Commission
SC	Steering Committee
SCADeP	Smallholder Commercialization and Agribusiness Development Project
SI	Site Investigation
Sida	Swedish International Development Agency
SL	Sierra Leone
SLRA	Sierra Leone Roads Authority
SMTDP	Sector Medium Term Development Plan (Ghana)
SN	Structural Number
SRI	Soils Research Institute
SSD	Single Surface Dressing
TA	Technical Assistance
ToT	Training of Trainers
TRH	Technical Recommendations for Highways
TRL	Transport Research Laboratory (UK)
UK	United Kingdom (of Great Britain and Northern Ireland)
UL	University of Liberia
UN	United Nations
USAID	United Stated Agency for International Development
WAFEO	West African Federation of Engineering Organisations
WB	World Bank
WHH	Welthungerhilfe (Liberia)

Contents

1 Introduction

1.1 Background to the Project

The Africa Community Access Partnership (AfCAP) is seeking to influence future policy in the roads sector by helping ensure that recommendations arising from high quality research established under AfCAP Phase 1 are put into practice. As part of this approach, new design manuals specifically for Low Volume[1] Roads (LVRs) customised to national needs and practice have been, and are being, developed. Such manuals have so far been published under AfCAP in Ethiopia, South Sudan, Malawi and Tanzania. These are based on the results of over 30 years of research on low volume rural roads, both paved and unpaved. Development or updating of existing LVR manuals is also in various stages of completion in Mozambique and Kenya.

1.2 Objectives

The objective of the project is to prepare manuals for low volume roads in Ghana, Sierra Leone and Liberia based on a review, adaption and expansion of previous AfCAP LVR manuals and local manuals that are available in these countries.

The objective of the manuals is to provide, in each country, a relevant resource, based on recognised good practice, that will help build capacity and result in improved sector performance.

1.3 Approach

The approach to the development of manuals has been extended beyond the original scope, which focussed mainly on road design standards. It is accepted that the sustainable provision of low volume rural roads depends on a holistic approach that also recognises the importance of other considerations including design procedures, works specifications, procurement of works and supervision services, construction methods, and quality management. Increasing emphasis is being given to road maintenance as part of rural roads asset management. The approach provides opportunities for local stakeholders to provide their input to the manuals preparation process to ensure that they are relevant to the local context.

[1] Under AfCAP, Low Volume Roads are considered to be those that, over their design life, are required to carry an average of up to about 300 vehicles per day, and are subjected to less than about 1 million equivalent standard axles.

2 Workshop reports

2.1 Workshop Objective

The objective of the 1st Stakeholder Workshops was to reach agreement with stakeholders in the participating countries on the scope of the LVR manual, and receive feedback on issues relevant to the national context.

2.2 Workshop Format

One-day workshops were held in each country in accordance with the requirements of the project Terms of Reference. The workshops were organised by the partner road agencies, who were responsible for inviting the participants and arranging the venue and catering. The structure of the workshops was based on presentations by the technical experts on the CDS team followed by discussion periods. At each workshop a representative of the government presented the current status of low volume roads in the country, recent successes and challenges faced.

2.3 Ghana Workshop

2.3.1 Overview and Programme

As originally envisaged, the Ghana workshop was to have been held at DFR, and to have run from 9 am to 5 pm. However, following a fire at DFR in the morning of the workshop, the DFR building had to be evacuated and the meeting was hastily re-convened in the nearby Ministry of Roads & Highways (MRH) Conference Room. There it was hosted by MRH Chief Director Godwin Brocke, who participated in all the morning sessions. The workshop was chaired by the Director of Feeder Roads Eric Duncan-Williams.

There was a total of 55 participants as detailed in Annex A. The majority of attendees were from DFR, but all key stakeholder groups were represented except for the Contractors' Associations.

To make up for lost time, participants agreed to the Director's proposal for a restructured day, whereby each session was included, but the presentations and feedback fitted around a single break for tea/coffee, with a very late "lunch" provided at the end of proceedings. The content of each of the sessions, the presenter responsible, and the sequence in which they took place remained consistent with the original programme, presented as Figure 2-2.

The result was a series of presentations and lively associated feedback sessions that substantially achieved the primary objective of stakeholder engagement in shaping the purpose, scope and style of the Ghana manual. Nevertheless, in light of the disruption that had occurred, it was agreed that there would be a follow-up meeting with DFR the next day to ensure clarity over issues that had been raised, and next steps in the process of drafting the manual.

The presentations by DFR and the CDS experts were received positively by the participants. The key outcome of the resulting discussions and points of agreement are summarised below.

Figure 2-1: Ghana Workshop in Progress

Time	Activity	Presenter
09:00 to 09:15	Welcoming remarks	Chief Director, DFR & AfCAP
09:15 to 09:30	Introduction, and outline of approach	Hamish Goldie-Scot
09:30 to 10:00	Status of low volume roads in Ghana	DFR
10:00 to 10:30	Preliminary findings	Hamish Goldie-Scot
10:30-11:00	**Tea/Coffee Break**	**All Participants**
11:00 to 11:45	Geometric design and road safety	Ron Isaac
11:45 to 12:30	Materials and pavement design	Lucas-Jan Ebels
12:30-13:30	**Lunch Break**	**All Participants**
13:30 to 14:15	Site investigations and slope stabilisation	Hamish Goldie-Scot
14:15 to 15:00	Hydrology and drainage design	Festus Odametey
15:00-15:30	**Tea/Coffee Break**	**All Participants**
15:30 to 16:00	Key issues arising, and way forward	Hamish Goldie-Scot
16:00 to 16:10	Closure of Workshop	Director of Feeder Roads

Figure 2-2: Workshop Programme, Ghana

2.3.2 Ghana workshop proceedings

MRH Chief Director Godwin Brocke welcomed everyone to the Ministry, expressed appreciation for the work done by AfCAP together with DFR, and stressed the importance of the manual being relevant to the needs of all stakeholders including GHA.

Following further remarks by the Chairman, Director of Feeder Roads Eric Duncan-Williams, and AfCAP Regional Technical Manager Paulina Agyekum, presentations were made by Dr Bekoe on behalf of DFR, and by the CDS experts. These are included in Annex D. In order to help focus discussions, participants were provided with hard copies of the draft contents list for the Ghana manual, as tentatively proposed in the Inception Report following in-country consultations in July 2017.

The following is a summary of the key issues arising during the meeting, together with a record of what was agreed.

Geometric Design Standards and Road Safety

- Participants pointed out that the "current" Ghana design standards as presented came from the GHA 1991 Manual, which is no longer considered as definitive. In practice, adjustments have been made but are not contained in a single reference document. Close consultation with DFR and GHA will be required as such tables are prepared for the manual.
- Carriageway width. DFR currently applies a 6m minimum carriageway width, irrespective of current and potential future traffic, despite the implications for road deterioration and hence maintenance costs. The original reason for this related to road safety and dates back to the 1990s, when the inner side slopes of the side drains on the early labour based road projects was very steep. In discussion it was agreed that many cases exist where current and potential future traffic does indeed justify such a width. But in cases of very low current and potential future traffic there may be a case for the inner slopes of the side drain to be shaped to include part of a nominally 6m wide carriageway. The DFR GIS system includes the demographic and some other data necessary to facilitate a simple screening of which new roads have strong potential for future traffic growth, and which do not. It was agreed that the team would make a proposal about appropriate such standards on such very low traffic roads.
- Width at cross drainage structures. It was agreed that for road safety reasons it is important to avoid situations, such as at relatively long cross drainage structures, where non-motorised traffic could be trapped and, particularly at night, unable to avoid the risk of being struck by motorised traffic.
- "All-weather" roads. There was some discussion about the difference between "all-weather" access (which implies access at all times, including after heavy rain, and "all-season" access (which accepts short term interruptions of service at drifts and vented fords). It was agreed that a well-designed network could contain a mix of the two, on a planned basis.
- It was agreed that the manual should provide guidance on appropriate adjustment to standards when low volume roads pass through villages.
- DFR clarified that the provision of road signs is standard practice in its Feeder Roads.
- Road safety. It was agreed that road safety should where possible be integrated into standard practices, but that a summary overview should also be provided.

Materials and Pavement Design

- There was a discussion about the proposal, based on AfCAP research, to present the DCP-DN method as viable, cost-effective option for LVR pavement design. It was agreed that the justification for adoption of this new method would need to be clearly and convincingly communicated. (The current AfCAP DCP DN and CBR demonstration project currently in progress under the DCP DN Training of Trainers course for Ghana, Liberia and Sierra Leone is part of this process).
- The Director initiated a discussion about the need to ensure value for money by optimising the use of locally available materials, even when not necessarily optimal. This concern was noted, and reference made to the broader need for research into possible alternative methods of stabilising locally available materials that may

otherwise fail to meet the required design criteria. (The forthcoming AfCAP research project on surfacing options will contribute to this process).

Investigations and Roadside Slope Stabilisation

- There was some discussion about the risk of over-simplification of soils classification during investigations, resulting in a failure to identify specific soil types that could later lead to the road, or associated structures, being undermined or otherwise damaged.
- It was agreed that, although it is relatively rare for roads in Ghana to traverse steep terrain, there are some locations where this does occur, so the manual should include guidance on slope stabilisation and erosion protection measures, both above and below the road. (This could be linked to current AfCAP study on surfacing of steep slopes in Ghana).

Hydrology and Drainage Design

- Participants noted that the DFR drainage design guide is widely used, and considered appropriate. It was agreed that this, and the simple associated software tools, would be the starting point for this part of the manual, and only modified as and when gaps or shortcomings are identified.
- There was a discussion about the costly practice of encasing pipe culverts in mass concrete, when even an unreinforced concrete pipe would be protected by adequate cover. The Ghana experience is that such pipe culverts can indeed be damaged as a result of a combination of excessive loads (such as from timber trucks) and loss of cover due to inadequacies in the design, construction, or maintenance.
- It was agreed that drainage design should be considered as a system not as individual elements, and that a clear basis should be established for the adoption of different return periods when designing different parts of that system.

General Issues

- Stakeholder consultation. Concern was expressed about designs being carried out without consulting the affected / beneficiary communities. The manual may need to include reference to the importance, and nature, of such consultation.
- Environmental protection. There was discussion about whether there should be a stand-alone manual for environmental assessment. Though the consensus was that environmental good practice should wherever possible be integrated into standard processes, it was agreed that where necessary the manual should draw together key aspects of environmental good practice, in order to provide the user with a summary overview, while also pointing where appropriate to more detailed content.
- Management of construction camps. Some participants felt that this topic should be included. It was however noted in this regard that the MLGRD's (arguably underutilised) "Labour Intensive Public Works Manual" may already provide adequate relevant guidance in this regard.
- Data-related opportunities. It was noted that the increasing availability of large volumes of data related to topography, traffic, road condition etc could open the door to innovative IT-supported approaches to some aspects of road design.
- Style of manuals. There was discussion about whether the manual should be a detailed reference document (in the style of the Ethiopia Manuals) or something more practical and readily used by practising engineers. Though no conclusion was reached, it was agreed that in looking at possible sources to fill gaps in existing

resources, the team should not limit itself to the Ethiopia Manual, but also draw where appropriate on a wider range of resources, including manuals that have been developed in Malawi, Tanzania, Bangladesh and Australia. Practical related suggestions included the inclusion where possible within the manual of:
    - Process diagrams providing a ready overview for the reader; and
    - Summary tables, charts and formulae to serve as ready reference resources.
- Revisions to manuals. There was some discussion about the process of revising the manuals, and whether it was wise to issue them in bound hard copy. Alternatives discussed included loose-leaf binders (allowing individual pages to be revised) and soft-copy versions (allowing updates at any stage). It was agreed that the decision about the physical nature of the manual, as well as its division into constituent sub-manuals, should reflect the practical needs of likely users, and that if well designed into separate sub-manuals, a printed version may still be the most appropriate.
- AfCAP research. DFR pointed out that, with AfCAP due to end in 2021, it is important not to delay in identifying specific gaps in knowledge that could potentially be addressed through further AfCAP research.
- DFR expressed interest in the manual including reference to associated computer files, such as drainage design tools, pavement design tools, various apps etc. There was some discussion as to how this could be achieved, possibly through providing a link to a new page on an existing established website from which such tools could be downloaded by registered users. No decision was taken.
- Quality Management of the Design process. It was proposed that the manual should include reference to an underlying quality management system that would give rise to increased confidence in the design process.

Next steps

- It was agreed in the workshop, and subsequently in a meeting with the DFR Deputy Directors, that a small technical working group will be established by DFR. This would facilitate ready informal communication with the authors as and when specific questions or issues arise as the initial draft of the Ghana manual is prepared over the coming 3 months. This could potentially be established as a WhatsApp group, so would not require members to be in the same physical location.
- It was agreed that in order to encourage enhanced engagement of GHA, DFR would approach the GHA Survey and Design Unit and seek their close participation in the process of preparing the manual.
- It was agreed that DFR would continue to communicate about the manual with the Contractors' Associations, neither of which sent a representative to the workshop despite having been invited.
- Regarding the eventual National Peer Review following the event in or soon after February 2018, DFR floated the idea of a retreat at which a small number of key government staff could work closely with a (paid) private sector expert in reviewing the draft in a systematic manner. No decision was taken about the nature of either the workshop, or the subsequent national peer review[2].

[2] The issues that could not be substantively concluded will be addressed through the proposed WhatsApp group.

2.4 Liberia Workshop

2.4.1 Overview and Programme

The workshop was held at the Ministry of Public Works offices in Monrovia on 21st September 2017. It was attended by 44 people representing mainly the Ministry, development partners and local universities. The attendance list is included in Annex B. Most of the participants stayed for the full duration of the meeting.

The workshop was facilitated by Eng. Peter Brooks from the MPW.

Figure 2-3: Liberia Workshop in Progress

Time	Activity	Person Responsible
09:00 - 09:15	Registration/Breakfast	All Participants
09:15 - 09:30	Welcome Remarks	Minister Moore MPW
09:30 - 10:00	Self-Introduction	All Participants
10:00 - 10:45	Workshop Objective and Overview and Summary of Findings of Initial Visit	Robert Geddes
10:45 - 11:15	Status of Feeder Road Sector in Liberia	Asst. Minister Harris MPW
11:15 - 11:45	Session 1: Geometric Design and Road Safety	Ronald Isaac
11:45 - 12:30	Session 2: Material and Pavement Design	Lucas - Jan Ebels
12:30 - 1:30	Lunch Break	All Participants
1:30 – 2:15	Session 3: Site Investigation and Roadside Stabilization	Gareth Hearn
02:15 - 03:00	Session 4: Hydrology and Drainage Design	Festus Odametey
03:00 - 03:15	Tea/Coffee Break	All Participants
03:15 – 03:45	Summary of key Issues Arising and Way Forward	Robert Geddes
04:45 - 04:10	Closing Remarks	Deputy Minister Paye MPW

Figure 2-4: Liberia Workshop Programme

2.4.2 Liberia workshop proceedings

Minister Moore made brief introductory and welcoming remarks before leaving the meeting to attend to other business.

The presentations of Assistant Minister Harris and the CDS experts are included in Annex E.

The presentations of the CDS experts were received positively by the participants and there were a lot of contributions. In several instances a contribution by a participant would prompt a lively debate amongst the group.

The following are the key issues arising during the meeting and agreements made. These were presented by the CDS Team Leader during the final session on "Summary of Key Issues and Way Forward".

Geometric Design Standards and Road Safety

- Experience in Liberia shows that where roads are improved they tend to attract traffic. The estimation of traffic for determining design standards must therefore allow for future traffic growth.
- Superelevation will not be specified for earth and gravel roads as it results in excessive erosion on curves, with rainwater having to travel across the full width of the carriageway to reach the side drain. Superelevation will be allowed for on sealed roads, which have higher vehicle speeds.
- The Ministry of Transport should be invited to participate in the next project workshop as they have responsibility for issues such as road safety.
- It was suggested by a participant that design standards may be required for motorcycle tracks given the huge growth in motorcycle ownership in rural areas. However, there was little support for the idea that motorcycle tracks would be constructed that cannot also accommodate four-wheeled vehicles.

Materials and Pavement Design

- The design of the road pavement must suit the ground conditions that prevail.
- The AfCAP-developed DCP/DN design method for pavement design was proposed, which avoids the need to correlate DCP with CBR.
- There was some discussion around the advantages and limitations of the DCP test, including:
    - DCP tests are cheaper and easier than CBR test and provide an indication of strength to greater depth (80 cm);
    - DCP tests do not require field material sampling, transportation of samples and laboratory testing (except for moisture content tests);
    - DCP results are influenced by in situ moisture conditions, in situ density and type of material.

Investigations and Roadside Slope Stabilisation

- There is a need for cost effective solutions for slope stabilisation on LVRs. These may include bio-engineering and the use of gabion baskets.

- Guidance on route selection is needed in the LVR manual for Liberia as there are mountainous areas and low-lying areas, where road alignment is problematic.
- Expansive soils are not commonly encountered in Liberia, but there are areas with internally eroding soils. Guidance on dealing with these soils should be provided in the manual.
- There is currently insufficient data on type of soils found in different parts of the Liberia that could be referred to in the LVR manuals. (It was suggested that AfCAP management should be approached to support a research project to map soil and material types across the country).

Drainage and Erosion Protection

- The importance of accurate estimation of the slope of river catchments was emphasised.
- It was agreed that the minimum size of culverts on watercourses would be specified as 900mm for ease of cleaning. However, 600mm diameter pipes or (preferably) U-shaped culverts (700mm high x 900mm diameter) may be used for relief culverts or access roads.

General Issues and Way Forward

- Materials and drainage are key issues controlling performance of rural roads in Liberia.
- The LVR manual will cater for both labour-based and machine-based construction but it will not provide detailed guidance on construction methods. Such guidance is widely available from other sources, such as the ILO (for both labour-based, and labour-intensive, construction).
- The new manual for LVRs will be adopted as an update of existing manuals and will be published as an official government document.
- The metric system will be used throughout the manual but conversion tables will be provided for users who may prefer to work in the Imperial system.
- American-English spellings must be used throughout.
- Other volumes could be added to the LVR manual in future, for example the manual on surfacing seals design which is being developed under FRAMP.
- Maintenance of roads is critical in Liberia with the high rainfall environment. The government is still discussing basic arrangements and responsibilities for maintenance especially transition from donor funded project to GOL responsibility. It was agreed that a more comprehensive maintenance manual, such as Part G of the Ethiopia Manual for Low Volume Roads, would be a useful contribution of the project.
- A manual on Complementary Interventions is needed to support community involvement in road works.
- The LVR manual will provide a useful resource for local universities to include the design and provision of LVRs in their curricula.
- It was agreed that more projects are required in Liberia for LVR trials and the demonstration of good practice.
- A WhatsApp group will be established to allow interaction between the manual authors and local technical experts during the drafting process.

- The second project workshop will be held in early 2018. It will be a two-day workshop. It is expected that the first draft of the manual will be available to stakeholders ahead of this meeting.

2.5 Sierra Leone Workshop

2.5.1 Overview and Programme

The workshop was held at the SLRA offices in Freetown on 26th September 2017. It was attended by 44 people representing mainly the SLRA, Road Fund, local consultants and the university. Development partner representatives were invited but none could attend. The attendance list is included in Annex C. About half of the participants stayed only for the morning session. The afternoon session was attended mainly by SLRA technical staff.

The workshop was facilitated by the SLRA Deputy Director for Administration, Mr S Jawara.

Figure 2-5: Sierra Leone Workshop in Progress

Time	Activity	Person Responsible
09:00 - 09:15	Registration	All Participants
09:15 - 09:30	Welcome Remarks	Chairman of SLRA Board
09:30 - 10:00	Self-Introduction	All Participants
10:00 - 10:45	Workshop Objective and Overview and Summary of Findings of Initial Visit	Robert Geddes
10:45 - 11:00	Status of Feeder Road Sector in Sierra Leone	SLRA Deputy Director General
11:00 – 11:30	Tea/Coffee Break	All Participants
11:30 - 12:15	Session 1: Site Investigation and Roadside Stabilization	Gareth Hearn
12:15 - 13:00	Session 2: Geometric Design and Road Safety	Ronald Isaac
13:00 - 14:00	Lunch Break	All Participants
14:00 – 14:45	Session 3: Material and Pavement Design	Lucas - Jan Ebels/ Robert Geddes
14:45 - 15:30	Session 4: Hydrology and Drainage Design	Festus Odametey
15:30 - 16:00	Tea/Coffee Break	All Participants
16:00 – 16:20	Summary of key Issues Arising and Way Forward	Robert Geddes
16:20 - 16:30	Closing Remarks	SLRA Director of Feeder Roads

Figure 2-6: Liberia Workshop Programme

2.5.2 Sierra Leone workshop proceedings

The Chairman of the SLRA made brief introductory and welcoming remarks and participated in the meeting until the lunch break.

The workshop was attended by the AfCAP Regional Technical Manager, Paulina Agyekum, who made some opening remarks concerning the mobilisation of ReCAP-funded projects in Sierra Leone. These include a research project on surfacing seals recently awarded to Aurecon of South Africa, which has direct relevance to the manuals project.

The presentations of the CDS experts were received positively by the participants and there were a lot of contributions from the group. The presentations are included in Annex F.

The following are the key issues arising during the meeting and agreements made. These were presented by the CDS Team Leader during the final session on "Summary of Key Issues and Way Forward".

General Issues (Presentation of the SLRA Deputy Director General)

- There are currently investments in rural roads through SLRA, Ministry of Agriculture, Councils and development partners.
- Some people who were displaced from rural areas to Freetown during the civil war would return to their home areas if the roads in their areas were in better condition.

- The Government is making efforts to improve roads but the work is undermined by the heavy rains in Sierra Leone.
- ILO standards were applied in the past for labour-based road construction.
- Sierra Leone needs its own standards appropriate to local conditions. For example, soils vary considerably across the country and rainfall is high. Where these standards do not already exist how will they be developed and incorporated in the manual? it is noted that specifications for Ghana might not be applicable to SL due to the difference in climatic conditions.

Workshop Objectives (Presentation of the CDS Team Leader)

- There is a new EPA requirement for EIAs on feeder roads projects. The EIA must include a community development action plan. Therefore, there is a need for the Complementary Interventions Manual.
- It was requested that guidance on road planning and prioritisation, route selection, technical audit and design of surfacing seals be incorporated in the new manual. It was noted that the design of surfacing seals will not be included but will be an output of another regional AfCAP project which will soon commence.

Investigations and Roadside Slope Stabilisation

- There are expansive soils in the east of Sierra Leone which are problematic, and dispersive soils in some areas.
- Guidance is need for roads in hilly areas: landslides have been experienced on roads in the Kabala area and on the main road out of Freetown.
- Simple site techniques were requested for assessing the strength of materials for road works. The use of the DCP is one such technique.
- The stockpiling of materials and drainage of the work site should be carried out in a way that avoids contaminating river systems. This will be covered in the manual.
- The manual should include information on the typical soil types found in SL but there is currently very little data on the type of soils found in different parts of the country. Such data may come out of the AfCAP regional materials mapping project[3], but it is recommended that AfCAP should support a new project to map materials types in Sierra Leone. The manual will provide guidance on how to identify materials and test for their engineering properties.

Geometric Design Standards and Road Safety

- Superelevation will not be recommended for unpaved roads as it results in excessive erosion on curves, with rainwater having to travel across the full width of the carriageway to reach the side drain. However, it will be recommended for sealed roads where vehicle speeds are higher.

[3] This project will only be implemented in three countries and might not include Sierra Leone. Furthermore, it does not involve collecting new data on materials characteristics, but rather will create a database of existing information.

- Warning signs are needed on rural roads, including locations where there might be danger of encountering animals.

Materials and Pavement Design

- Rural roads need to be protected against damage from heavy and overloaded trucks. There is no feasible engineering solution to this problem so such vehicles should be prevented from using the roads, especially when the roads are wet. However, this needs clear government policies and political support.
- Mechanical stabilisation through compaction and blending are encouraged for LVR design in order to maximise the potential of local occurring materials. Guidance should be provided in the manual.
- Research on the use of stabilizing chemicals should be included on the forthcoming AfCAP project on surfacing seals. It was recommended that SLRA consult Dr David Jones at the University of California who has conducted research on a range of commercially available products from around the world.
- The DCP is a cost effective and versatile tool for use in subgrade classification, testing borrow materials and site quality control.
- Where there is no effective maintenance of roads it might be necessary to provide more expensive and durable surfacing. However, the importance of establishing effective road maintenance should not be ignored.
- Training will be required for engineers in the use of the LVR manual. Training is not part of the current TORs of the consultant team.

Drainage and Erosion Protection

- Drains are needed to intercept water from outside the road and direct it away from the road, as well as to collect water running off the road.
- Guidance is needed for drainage of roads in flat areas and across swamps.
- U-culverts are an alternative to pipe culvert where there is limited cover. They are more cost effective to construct than box culverts and provide better hydraulic performance due to the curve channel shape.
- Downstream effects must be considered in culvert design. They may be more severe than upstream effects.
- Digital elevation models are preferred to topographical mapping sheets for the assessment of catchments for flow estimation.
- Recent studies have shown that Rational Method is accurate up to catchment area of $10km^2$.
- Modern computer based methods are preferred to nomographs for sizing culverts. However, the nomographs will be retained in manual for users who prefer to use manual methods. The danger with computer methods is that there may be a tendency to believe the output without assessing whether it is realistic.
- Design methods for bridges not relevant for LVRs. There are existing manuals available for the design of bridge, for example AASHTO.

- There are no gauging stations on rivers in Sierra Leone and very little rainfall data. It is necessary to develop a method to convert daily rainfall data from the few weather stations to create IDF curves. Factors will be required to convert this data from one part of the country to another. IDF curves are needed for implementation of the Rational Method of flow estimation.

Way Forward

- A WhatsApp group will be established to allow interaction between the manual authors and local technical experts during the drafting process.
- The second project workshop will be held in early 2018. It will be a two-day workshop. It is expected that the first draft of the manual will be available to stakeholders ahead of this meeting.

Annex A. Workshop Participants - Ghana

S.N.	NAME	POSITION	INSTITUTION
1	G. J. BROCKE	CHIEF DIRECTOR	MINISTRY OF ROAD AND HIGHWAYS
2	E. DUNCAN-WILLIAMS	DIRECTOR	DEPARTMENT OF FEEDER ROADS
3	CHARLES AWUAH BARFOUR	CHIEF ENGINEER	GHANA HIGHWAYS AUTHORITY
4	MADAM JANICE O.F. OFORI	Manager (RSU)	GHANA HIGHWAYS AUTHORITY
5	E.A GBADAG	PRINCIPAL ENGINEER	MINISTRY OF ROAD AND HIGHWAYS
6	GEORGE K. ADDISON	PRINCIPAL ENGINEER	MINISTRY OF ROAD AND HIGHWAYS
7	KWABENA BADU-YEBOAH	AG. DIRECTOR	ENVIRONMENAL PROTECTION AGENCY (EPA)
8	VICTOR KOJO BILSON	PLANNIING OFFICER	NATIONAL ROAD SAFETY COMMISSION (NRSC)
9	A.K.B DEYANG	DIRECTOR	MOFA
10	CHARLES A. ADAMS	MANAGER RTEP (KNUST)	KNUST
11	DANIEL OBENG	LECTURER	KNUST
12	MR. EVANS TUTU AKOSAH	SENIOR ENGINEER	ABLINCONSULT
13	MR. CHELKAN BARAJEI	NATURAL INFRASTRUCTURAL MANAGER	GASIP
14	PETER K. YAWSON	COUNTRY DIRECTOR (AFCAP)	AFCAP
15	JOSEPH ODDEI	CHAIR CIVIL DIVISION	GHIE
16	MICHAEL RIBEIRO	ENGINEER	KTC
17	FESTUS ODAMETEY	HYDROLOGY /DRAINAGE	CONSULTANT - CDS
18	RON ISAAC	GEOMETRICS & ROAD SAFETY	CONSULTANT - CDS
19	DR. LUCAS EBELS	PAVEMENT DESIGN & MATERIALS	CONSULTANT - CDS
20	HAMISH GOLDIE-SCOT	GHANA TEAM LEADER, WAM	CONSULTANT - CDS
21	DR. K.O. AMPADU	DEPUTY DIR. PLANNING	DEPARTMENT OF FEEDER ROADS
22	R. O. OTOO	DEPUTY DIR. MAINTENANCE	DEPARTMENT OF FEEDER ROADS
23	BERNARD BADU	DEPUTY DIR. DEVELOPMENT	DEPARTMENT OF FEEDER ROADS
24	JONATHAN OFOSUHENE	SENIOR ENGINEER	DEPARTMENT OF FEEDER ROADS
25	LANQUAYE WELLINGTON	CHIEF ENGINEER	DEPARTMENT OF FEEDER ROADS
26	NII SARPEI - NUNOO	CHIEF ENGINEER	DEPARTMENT OF FEEDER ROADS
27	PETER K. YAWSON	CHIEF ENGINEER, PLANNING	DEPARTMENT OF FEEDER ROADS
28	DAVID BROBBEY	CHIEF ENGINEER	DEPARTMENT OF FEEDER ROADS

S.N.	NAME	POSITION	INSTITUTION
29	JOSEPH A.M. IDUN	CQS/CM	DEPARTMENT OF FEEDER ROADS
30	K.N. AKOSAH - KODUAH	C.E.M	DEPARTMENT OF FEEDER ROADS
31	MR. LAWRENCE ABBEW	CQS	DEPARTMENT OF FEEDER ROADS
32	DR. PATRICK AMOAH BEKOE	SENIOR ENGINEER	DEPARTMENT OF FEEDER ROADS
33	ALEXANDER GOGOE	SENIOR ENGINEER	DEPARTMENT OF URBAN ROADS
34	MR. EMMANUEL NORGAH	SENIOR QUANTITY SURVEYOR	DEPARTMENT OF FEEDER ROADS
35	NATHAN N. ODJAO	BRIDGE MTCE ENGINEER	DEPARTMENT OF FEEDER ROADS
36	BUGAPEH CHARLES	ENG. (MRO)	DEPARTMENT OF URBAN ROADS
37	MR. BEN NELSON K. ABLEDO	PRINCIPAL QUANTITY SURVEYOR	DEPARTMENT OF FEEDER ROADS
38	MR. GILBERT APAU	QUANTITY SURVEYOR	DEPARTMENT OF FEEDER ROADS
39	MR. KIA AKOBOTSE	QUANTITY SURVEYOR	DEPARTMENT OF FEEDER ROADS
40	MR. BERNARD AMOAH	REG, MTCE MANAGER	DEPARTMENT OF FEEDER ROADS
41	MR. SALIFU HARDI	ASST. DEVELOPMENT PLANNER	DEPARTMENT OF FEEDER ROADS
42	MR. AKWASI ASAMOAH	PRINCIPAL ENGINEER	DEPARTMENT OF FEEDER ROADS
43	DON F. KUUBETERZIE	PRINCIPAL ENGINEER	DEPARTMENT OF FEEDER ROADS
44	DOKU STEPHEN	NSP	DEPARTMENT OF FEEDER ROADS
45	MR. MAWUSI JOSEPH ADEKPONYA	ASSISTANT ENGINEER	DEPARTMENT OF FEEDER ROADS
46	FRANK AMOFA AGYEMAN	ASSISTANT ENGINEER	DEPARTMENT OF FEEDER ROADS
47	KWABENA OWUSU AFRIFA	ASSISTANT ENGINEER	DEPARTMENT OF FEEDER ROADS
48	MARTIN HMENSA	ASSISTANT ENGINEER	DEPARTMENT OF FEEDER ROADS
49	EMMANUEL OPON TUTU	ASSISTANT ENGINEER	DEPARTMENT OF FEEDER ROADS
50	ABOAGYE EMMANUEL	ASSISTANT ENGINEER	DEPARTMENT OF FEEDER ROADS
51	JAMES N.N. ODONKOR	ASSISTANT ENGINEER	DEPARTMENT OF FEEDER ROADS
52	SAMUEL N. Y. BUATSI	ASSISTANT QUANTITY SURVEYOR	DEPARTMENT OF FEEDER ROADS
53	MR. ERIC ANYIDOHO	TECH ENGINEER	DEPARTMENT OF FEEDER ROADS
54	STELLA ARTHUR	TECH. ENGINEER (CIVIL)	DEPARTMENT OF FEEDER ROADS
55	CECIL AUTHUR	TECH. ENGINEER (QS)	DEPARTMENT OF FEEDER ROADS

Annex B. Workshop Participants - Liberia

S.N.	NAME	POSITION AND INSTITUTION
1	HON. W. GYUDE MOORE	MINISTER /MPW
2	HON. JACKSON J. PAYE	DEPUTY MINISTER/RURAL DEV. & COMM. SERVICES
3	HON. ROLAND L. GIDDINGS	DEPUTY MINISTER /ADMINISTRATION - MPW
4	HON. SUMOIWUO Z. HARRIS	ASSISTANT MINISTER/ RURAL ROAD - MPW
5	HON. MARGARET SARSIH	ASSISTANT MIN./PLANNING & PROGRAMMING - MPW
6	DR. FREDRICK HIGENI	CHIEF OF PARTY - FRAMP
7	RICHMOND HARDING	PROJECT COORDINATOR -FTHRP
8	ULRICH THÜES	PROJECT DIRECTOR GIZ
9	ALIBABA K. KPAKOLO	CHIEF OF FEEDER ROAD
10	LAHAISON WARITAY	RESIDENT ENGINEER -MONTSERRADO COUNTY
11	SOLOMON GARPUE	RESIDENT ENGINEER - BOMI COUNTY
12	ANTHONY G. SIAWAY	RESIDENT ENGINEER - GRD. CAPE MOUNT
13	HASSAN Z. FAHNBULLEH	RESIDENT ENGINEER - MARGIBI COUNTY
14	WILMOT WILLIAMS	RESIDENT ENGINEER - GRAND BASSA COUNTY
15	BILL M. S. WESSEH	FEEDER ROAD ENGINEER
16	CHRISTOPHER M. BLAMONH	FEEDER ROAD ENGINEER
17	DAVE MCARTHUR LORMIE	FEEDER ROAD ENGINEER
18	MELVIN SAYE	FEEDER ROAD ENGINEER
19	DECKONTEE H SARTOE	FEEDER ROAD ENGINEER
20	OPHELIA BEDELL	FEEDER ROAD ENGINEER
21	ELVIS S. K. MENSAH	FEEDER ROAD DESIGN ENGINEER
22	DOMINIC ARYEETEY	FEEDER ROAD ENGINEER
23	PETER G. BROOKS	FEEDER ROAD ENGINEER
24	WILLY JOHNSON	FEEDER ROAD ENGINEER
25	ERICSSON ZARDEE	FEEDER ROAD ENGINEER

26	YALLAH M. KORHENE	FEEDER ROAD ENGINEER
27	MAMADUO BALDE	WELTHUNGERHILFE(WHH)
28	BESTMAN TEAH	FEEDER ROADS ENGINEER /MPW
29	EMMANUEL JOHNSON	INFRASTRUCTURE IMPLEMENTATION UNIT/MPW
30	AARON W. JOBOE	RESIDENT ENGINEER – GBARPOLU COUNTY/MPW
31	WENNIE V. DUYEWKU	ASSOC. OF LIBERIAN CONSTRUCTION CONTRACTORS (ALCC)
32	MICHEAL S.K. KPAKOLO	INFRASTRUCTURE IMPLEMENTATION UNIT/MPW(IIU)
33	JOHNNY W. JACKSON	DIRECTOR – MONITORING & EVALUATION/MPW
34	AMANDU T. GOMEZ	STELLA MARIS POLYTECHNIC TECHNICAL DEPARTMENT(SMP)
35	DOMINIK ARYEETEY	FEEDER ROADS ENGINEER/MPW
36	ALASCA WAH CUMMINGS	ENGINEER-HIGHWAY MAINTENANCE DIVISION/MPW
37	JOHN L. BOIMAH, PE	UNIVERSITY OF LIBERIA CIVIL ENGINEERING DEPARTMENT
38	AMOS Y. BARCLAY	UNIVERSITY OF LIBERIA CIVIL ENGINEERING DEPARTMENT
39	DAVID M. JALLAH	UNIVERSITY OF LIBERIA CIVIL ENGINEERING DEPARTMENT
40	ROB GEDDES	TEAM LEADER - CDS
41	DR. LUCAS EBELS	PAVEMENT DESIGN & MATERIALS - CDS
42	RON ISAAC	RURAL ROADS EXPERT - CDS
43	GARETH HEARN	GEOTECHNICAL EXPERT - CDS
44	FESTUS ODAMETEY	HYDROLOGIST/DRAINAGE EXPERT - CDS

Annex C. Workshop Participants – Sierra Leone

S.N.	NAME	POSITION	INSTITUTION
1	MRS JOSEPHINE MAC THOMPSON	BOARD DIRECTOR	SLRA
2	ABDUL RICHARD FOFANAH	ENGINEER	CRGS
3	RANSFORD LUBE METZGER	REPORTER	AYU TELEVISION
4	CHRISTIAN A THOMAS	CAMERA OPERATOR	AYU TELEVISION
5	EMERIC SMITH	CAMERA OPERATOR	SLBC
6	ROB GEDDES	TEAM LEADER	CDS
7	RON ISAAC	RURAL ROADS EXPERT	CDS
8	GARETH HEARN	GEOTECHNICAL EXPERT	CDS
9	FESTUS ODAMETEY	HYDROLOGIST/DRAINAGE EXPERT	CDS
10	GEORGE NYUMA	DIRECTOR OF FEEDER ROADS	SLRA
11	MELVIN B. O. SCOTT	SENIOR ENGINEER HYDROLOGICAL DESIGN	SLRA
12	EMMANUEL A TARAWALLI	DGM	SLRA
13	ALBERT SOVULA	SEIC	SLRA
14	PAUL DEMBY	SEIC BU	SLRA
15	KAI KAMANDA	SEIC PORT W/O	SLRA
16	HAMID A. BANGURA	ENGINEER	SLRA
17	DR KELLEH G MANSARAY	DEAN OF FACULTY OF ENGINEERING AND ARCHITECTURE	FBC
18	TAMBA YONGA	CRG KEREM	SLRA
19	JOSEPH E KARGBO JNR	EIC WESTERN REGION	SLRA
20	SAMUEL J MACAULEY	ENGINEER FRD	SLRA
21	ANDREW M. JUSU	PA TO DG	SLRA
22	PETER S KOME	C ENG	SLRA
23	ALEXANDER K. P. GEORGE	SNR ADMIN OFFICER	SLRA
24	IBRAHIM A. MUSTAPHA	CHIEF AUDITOR	SLRA
25	ALIE M FORNA	SC ENGINEER	RMFA
26	RUGIATU KOROMA	HEAD OF M&E	RMFA
27	YASSIN BANGURA`	TRAINEE ENGINEER	RMFA
28	LAURETTA DUMBUYA	SENIOR ENGINEER	SLRA
29	LUCY T ESSA	SENIOR ENVIRONMENTAL OFFICER	SLRA

S.N.	NAME	POSITION	INSTITUTION
30	SHEKU M KANNEH	DIRECTOR OF FINANCE	SLRA
31	FRANCIS S BOCKARIE	C/E DEV	SLRA
32	ALHAJI M KALLAH	DISTRICT ENGINEER	WARD-SLRA
33	OMAR DAVIES	SNR GZC MAKENI	SLRA
34	JULDEH A BARRIE	CIVIL ENGINEER	ICS
35	ABDULAI ANSUMANA	DIRECTOR OF MAINTENANCE	SLRA
36	ALPHA J. A. BANGURA	PLANNING ENGINEER	FIMET BETON-VILLA
37	JOSEPH R. SANDY	PROJECT MANAGER	SECOM (SL) LTD
38	PAULINA AGYEKUN	TECHNICAL MANAGER	AFCAP
39	SAMUEL MORGAN	TRANSPORT ECONOMIST	MTA
40	JAMES A. LEBBIE	CHIEF ACCOUNTANT	SLRA
41	ABDUL E BAIROH	DIRECTOR	MSU/SLRA
42	SIDIE M JAWARA	DEPUTY DIRECTOR, ADMINISTRATION	SLRA
43	VICTOR A. T. KABU	IT MANAGER	SLRA
44	MOHAMED J ZOMBO	COMMUNICATIONS AND PUBLIC RELATIONS	SLRA

Annex D. Presentations made - Ghana

Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First project workshop for Ghana

19th September 2017

Workshop Programme

Time	Activity	Presenter
09:00 to 09:15	Welcoming remarks	Chief Director, DFR & AfCAP
09:15 to 09:30	Introduction, and outline of approach	Hamish Goldie-Scot
09:30 to 10:00	Status of low volume roads in Ghana	Director of Feeder Roads
10:00 to 10:30	Preliminary findings	Hamish Goldie-Scot
10:30-11:00	Tea/Coffee Break	All Participants
11:00 to 11:45	Geometric design and road safety	Ron Isaac
11:45 to 12:30	Materials and pavement design	Lucas-Jan Ebels
12:30-13:30	Lunch Break	All Participants
13:30 to 14:15	Site investigations and slope stabilisation	Hamish Goldie-Scot
14:15 to 15:00	Hydrology and drainage design	Festus Odametey
15:00-15:30	Tea/Coffee Break	All Participants
15:30 to 16:00	Key issues arising, and way forward	Hamish Goldie-Scot
16:00 to 16:10	Closure of Workshop	Director of Feeder Roads

2

INTRODUCTION & OUTLINE OF APPROACH

- Objectives
- Approach & Methodology
- Existing Resources
  - Ghana
  - Elsewhere

STATUS OF LOW VOLUME ROADS IN GHANA

- Progress to date
  - Consultations and field visit
  - General recommendations
  - Specific findings for Ghana
- Proposed structure of manual
- Timeline

3

Objectives

Objective of the project:

To prepare manuals for low volume roads in Ghana, Sierra Leone and Liberia based on a review, adaption and expansion of previous AfCAP LVR manuals and local manuals that are available in these countries.

Objective of the manuals:

In each country, to provide a relevant resource, based on recognised good practice, that will help build capacity and result in improved sector performance

Objective of the 1st Stakeholder workshop:

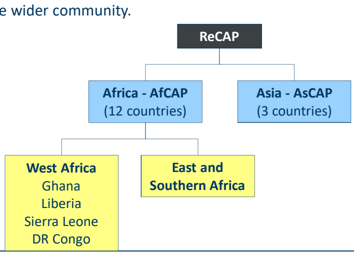
To reach agreement on the scope of the LVR manual, and receive feedback on issues relevant to the national context

4

Context: Research for Community Access - ReCAP

- Programme of applied research and knowledge dissemination for the rural transport sector in Africa and Asia (2014 to 2020)
- Funded by UK Aid.

Overall aim: to promote safe and sustainable rural access in Africa and Asia through research and knowledge sharing between participating countries and the wider community.



5

Approach and Methodology

Approach

Draw on local stakeholder input to help ensure that the manual is relevant to the local context:

Methodology

- Initial visit with ***stakeholder consultation***;
- ***First workshop***;
- Preparation of drafts of each chapter
- ***Second workshop***;
- Preparation of revised drafts;
- ***Formal Peer Review***;
- Preparation of final versions.

6

Existing Ghana LVR Guides and Manuals (1 of 4)

Pocket Books:

2005: Site Supervision

2007: Road Maintenance

Road Maintenance

2004: Routine & Recurrent Maintenance

Existing Ghana LVR Guides and Manuals (2 of 4)

EPA Guidelines

Existing Ghana LVR Guides and Manuals (3 of 4)

Compilation Guides:

2006: Concrete Properties

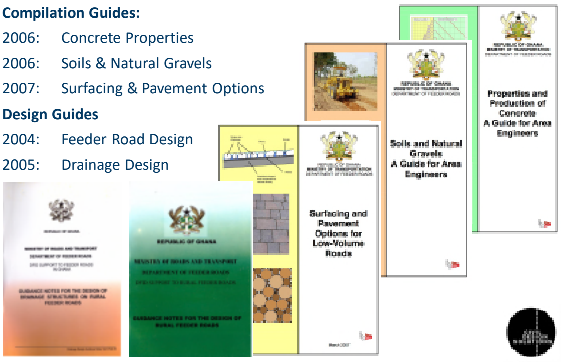
2006: Soils & Natural Gravels

2007: Surfacing & Pavement Options

Design Guides

2004: Feeder Road Design

2005: Drainage Design



Existing Ghana LVR Guides and Manuals (3 of 3)

Standard Specifications

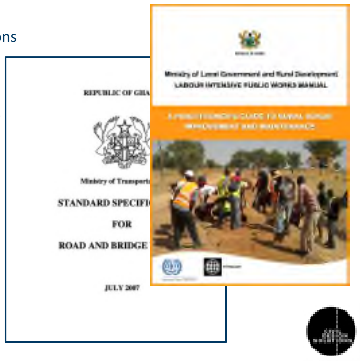
2007: Standard Specifications for Road & Bridge Works

Other

2014: Guide to Rural Roads Improvement & Maintenance

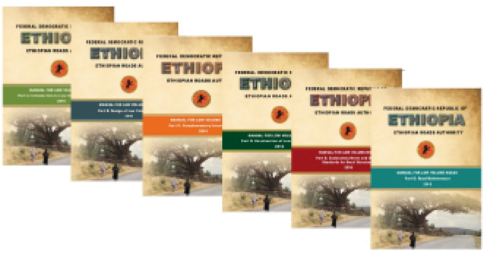
Road Prioritisation RPM

Various Tech Memos



Approach and Methodology

International benchmark for Low Volume Road Manuals: Ethiopia Manual for Low Volume Roads (2016).



Workshop Programme

Time	Activity	Presenter
09:00 to 09:15	Welcoming remarks	Chief Director, DFR & AfCAP
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15:00-15:30	Tea/Coffee Break	All Participants
15:30 to 16:00	Key issues arising, and way forward	Hamish Goldie-Scot
16:00 to 16:10	Closure of Workshop	

Progress to date – consultations and field visit

17th to 21st July: Stakeholder meetings and field visit:

- Association of Road Contractors
- **Department of Feeder Roads**
- Environmental Protection Authority
- Forestry Commission
- Consulting Engineers Association
- **Ghana Highway Authority**
- Ghana Institution of Engineers
- Road Fund Secretariat
- Koforidua Training Centre
- Ministry of Food and Agriculture
- **Ministry of Roads and Highways**
- Progressive Road Contractors' Association
- Road Safety Commission

Recommendations arising from the initial round of visits

- Develop the Ghana version first and use it as a basis for the Liberia and Sierra Leone versions.
- Draw on relevant aspects of Ethiopia Manual for Low Volume Roads (2016).

Findings from the initial visit to Ghana

- Relatively mature road network;
- Extensive Standard Specifications;
- Maintenance Management System;
- Existing Guidance and reference documents; but
- Existing Guides not used consistently; and
- Some gaps need to be addressed.

Proposed Structure of the Manual

Four Parts:

Part A: Introduction to LVRs, Geometric Design and Road Safety

Part B: Materials and Pavement Design

Part C: Hydrology, Drainage and Roadside Stabilisation

Part D: Complementary Interventions

Timeline

Aug 2017	Inception Report
Sep 2017	First Workshop (one day)
Feb 2018	Second Workshop (two days)
Jun 2018	Final draft MS Word version
Nov 2018	Launch of Manual

Workshop Programme

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09:00 to 09:15	Welcoming remarks	Chief Director, DFR & AfCAP
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16:00 to 16:10	Closure of Workshop	

AfCAP Worskshop

Status of Department of Feeder Roads in Ghana, Recent Successes and Challenges

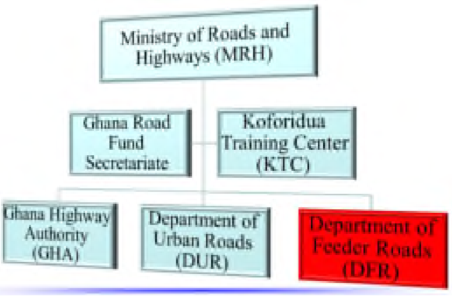
Presented by: Ing. Dr. Patrick Amoah Bekoe
On behalf of
Director of D.F.R

Date: 19th September, 2017

Order of Presentation

- ✓DFR in Perspective
- ✓Mission, Vision
- ✓Broad Objectives
- ✓Organogram
- ✓Recent Successes
- ✓Challenges
- ✓Way Forward

DFR in Perspective



MISSION & VISION

VISION

To ensure that 80% of rural communities in Ghana can access a feeder road within 2Km radius at optimum cost under a decentralized system by 2020.

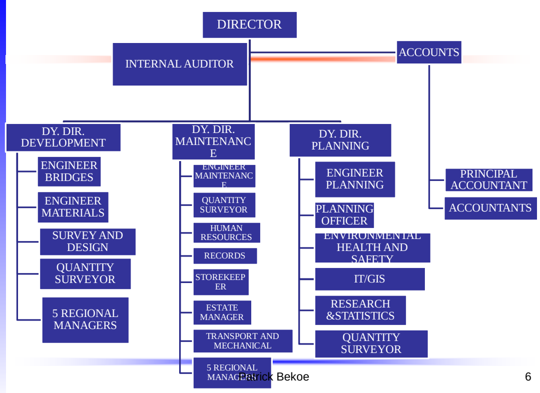
MISSION

The Department of Feeder Roads exists to ensure the provision of safe all weather accessible feeder roads at optimum cost to facilitate the movement of people, goods and services and to promote socio-economic development, in particular agriculture

BROAD OBJECTIVES

- ✓ The key objectives of the DFR in pursuance of its Mission Statement are:
- ✓ To provide improved access for the movement of people and goods to facilitate the promotion of economic activities and access to social services in rural communities;
- ✓ To protect investments made on improved roads through adequate maintenance system;
- ✓ To provide employment opportunities for the rural poor by encouraging a greater use of labour-based road construction technology;
- ✓ To use sound economic principles as decision criteria for feeder road investment for rehabilitation and construction activities;
- ✓ To improve the institutional capacity of DFR to sustain feeder road programmes;

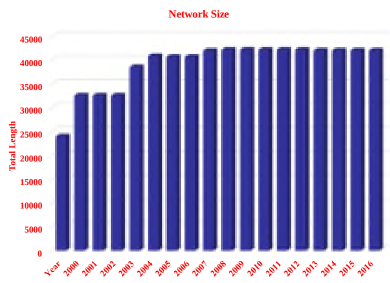
DFR ORGANIZATIONAL STRUCTURE



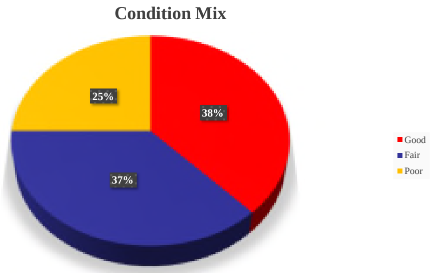
Recent Successes

Network Growth

Year	Network Size
2000	23999
2001	32597
2002	32597
2003	32597
2004	38561
2005	40862
2006	40671
2007	40671
2008	42010
2009	42194
2010	42210
2011	42190
2012	42190
2013	42190
2014	42045
2015	42045
2016	42045
2017	42045

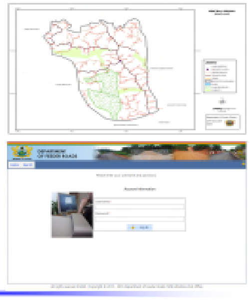


Condition Mix



Increase in Usage of I.C.T

- ✓ Developed a Geographical Information System (G.I.S.)
- ✓ Developed a Contract Management Software
- ✓ Computerization of our basic operations (e.g. IPCs, etc)

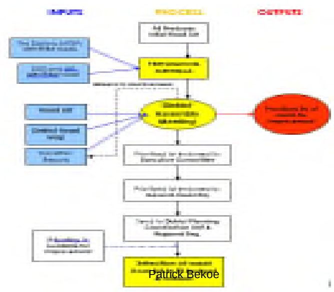


Stakeholder Engagement

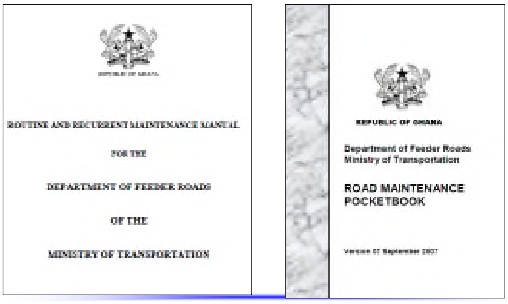
- ✓ Selection of Project
- ✓ Feedback on road conditions
- ✓ Feedback on ongoing projects
- ✓ Complaints

Embedment of DFID Legacy

- ✓ Road Prioritization Methodology

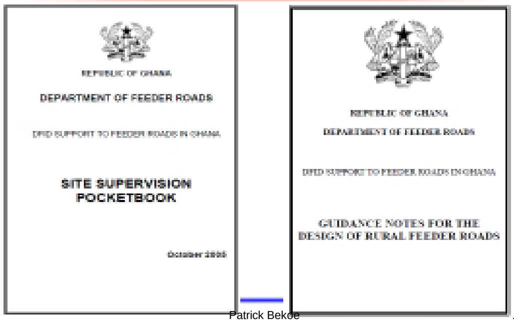


Embedment of DFID Legacy



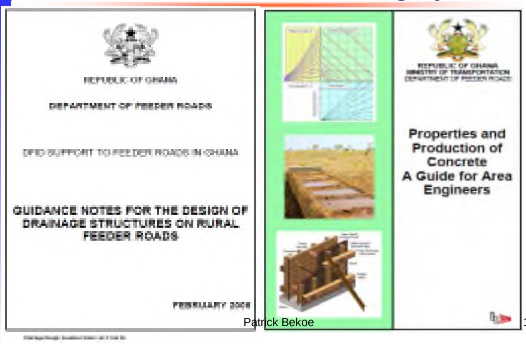
Patrick Bekoe 13

Embedment of DFID Legacy



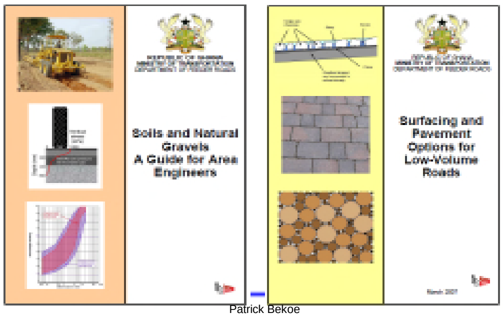
Patrick Bekoe 14

Embedment of DFID Legacy



Patrick Bekoe 15

Embedment of DFID Legacy



Patrick Bekoe 16

Labour Based Technology

- ✓ Trained Selected Contractors in Construction of roads up to Subbase Level
- ✓ Awarded contracts in Various regions
- ✓ Currently with the assistance of JICA, the Department is undertaking a study on the use of Labour Base Technology for Bituminous Surfacing (Cold Mix Asphalt)

Patrick Bekoe 17

African Community Access Programme

- ✓ Training in DCP DN Design Method
- ✓ Training of ToT's in DCP DN Design Method -(Ongoing)
- ✓ Alternative Surfacing for Steep Hills Ph.1
- ✓ Alternative Surfacing for Steep Hills Ph.2-(Ongoing)
- ✓ Use of Roller Compacted Mass Concrete (RCC)-(Ongoing)
- ✓ Rural Transport Diagnostics
- ✓ Identification of Hazardous Spots
- ✓ Gender Mainstreaming
- ✓ Development of Design Manuals for Low Volume Roads (Ongoing)

Patrick Bekoe 18

Decentralization

- The Local Government Act 1993, Act 462, Act 936, provides for the decentralization of 22 departments at the district level, among them was DFR.
- All District Officers of the Department of Feeder Roads were transferred to the various MMDAs by December 2013.
- MRH is about transfer identified roads to the District Assemblies.

Patrick Bekoe 19

Challenges

Patrick Bekoe 20

Implementation of Decentralization

- ✓ DFR has been subsumed under the works Department of the DA's. A stand alone DFR at the District Level will be better, giving the importance of roads to socio-economic development.
- ✓ Decentralization of DFR through Deconcentration will be a better option than through Devolution

Patrick Bekoe 21

Low Staffing

- ✓ High Attrition Rate
  - Retiring of Staff
- ✓ Moratorium on Employment

Patrick Bekoe 22

Funding

- ✓ High Budget Deficit
- ✓ Road fund budget able to take care of only about 45% of our Maintenance Needs

Patrick Bekoe 23

Standardization

- ✓ Customization of MRH Specification for DFR Operations
- ✓ Lack of Standardized Design Software

Patrick Bekoe 24

Way Forward

- ✓ Lobbying Government to allow DFR to engage for staff
- ✓ Lobbying Government to allow DFR to stand alone under the Decentralized system.
- ✓ Increasing the use of Labour Based Technology for road works
- ✓ Alternative source of funding to improve the payment regime
- ✓ Timely payment for executed works
- ✓ Embedment to Research findings in to DFR's Operations

Thank you for listening. Any questions?

Workshop Programme

Time	Activity	Presenter
09:00 to 09:15	Welcoming remarks	Chief Director, DFR & AfCAP
09:15 to 09:30	Introduction, and outline of approach	Hamish Goldie-Scot
09:30 to 10:00	Status of low volume roads in Ghana	Director of Feeder Roads
10:00 to 10:30	Preliminary findings	Hamish Goldie-Scot
10:30-11:00	Tea/Coffee Break	All Participants
11:00 to 11:45	Geometric design and road safety	Ron Isaac
11:45 to 12:30	Materials and pavement design	Lucas-Jan Ebels
12:30-13:30	Lunch Break	All Participants
13:30 to 14:15	Site investigations and slope stabilisation	Hamish Goldie-Scot
14:15 to 15:00	Hydrology and drainage design	Festus Odametey
15:00-15:30	Tea/Coffee Break	All Participants
15:30 to 16:00	Key issues arising, and way forward	Hamish Goldie-Scot
16:00 to 16:10	Closure of Workshop	

Geometric Design

Outline of Presentation

- Introduction
- Road Classification
- How the Standards will be used
- Factors affecting Geometric Standards
- Design Speed and Geometry
- Road Cross Section
- Typical Cross Sections
- Horizontal Alignment
- Vertical Alignment
- Harmonisation of Horizontal and Vertical Alignment
- Summary of Geometric Standards for each Class of Road
- References
- Questions

Introduction

- Purpose of Roads:

  To provide traffic mobility between centres and areas, and to provide access to adjoining land and properties.

- Definition of Geometric Design:

  The process whereby the layout of the road through the terrain is designed to meet the needs of ALL road users.

- Objectives of Geometric Standards:

  To provide acceptable levels of safety and comfort for drivers through provision of adequate sight distances, coefficients of friction, road space for manoeuvres, and to minimise earthworks to reduce construction costs.

- Objectives of the Geometric Design Chapter in the new LVR Manual:

  To provide Geometric Design principles, recommendations, guidance and standards to enable the low volume road designer to meet the safety and comfort standards appropriate to the local environment for roads carrying less than 300 vehicles per day.

Road Classification

- LVR's generally carry relatively low volumes of traffic, typically less than 300 vpd and make up a significant proportion of the road network.
- LVR's provide the only form of access to rural communities and provide basic access to essential services.
- In Ghana the road network is divided into 5 main classes according to their function in the road network:
  - National Roads
  - Regional Roads
  - Inter-Regional Roads
  - Metropolitan/Municipal Roads
  - Feeder Roads (LVR's)
- Feeder Roads are further divided into 3 main categories:
  - Access/Spur Feeder Roads
  - Connector Feeder Roads
  - Inter-District Feeder Roads

How The Standards Will Be Used

- Design Procedure
  - Steps will be provided for selecting the appropriate standards to be used in the geometric design process including a flow diagram.
- Scenario 1: Upgrading an Existing Road
  - Basic alignments already exist and spot improvements may be required to meet the required design standards.
- Scenario 2: Upgrading an Existing Track
  - Sub-standard alignments already exist and improvements will be required to meet the required design standards.

  Alternatively appropriate traffic calming measures can be used to reduce speed to avoid costly realignment where upgrades are required.
- Scenario 3: New Roads
  - Requires viability and route determination investigations prior to road design.

Factors Affecting Geometric Standards

The following factors that affect the geometric standards will be discussed in greater detail in the new LVR Manual:

- Cost
  - Costs associated with road construction, operation and maintenance is directly related to the geometry standard adopted.
- Level of Service (LOS)
  - LOS is directly associated with traffic volume and increases with increase in road class.
- Traffic Volume
  - Geometry standards are justified in accordance with traffic volume and increase with increase in traffic volume.
  - For LVR's the design control is Average Annual Daily Traffic (AADT) in the 'design year' incl. distribution by vehicle type.

Factors Affecting Geometric Standards (Continued)

- Traffic Composition
  - Geometry standards depend on the type of vehicles expected to use the facility i.e. lower standards can be used for smaller vehicles.
- Terrain
  - Geometry standards are dependant on the terrain i.e. flat terrain can accommodate higher geometry standards, whilst hilly or mountainous terrain will only support lower standards.
  - 3 categories have been defined i.e. Flat, Rolling, Hilly or Mountainous.
- Roadside Population
  - Geometry standards are required to be modified to ensure good access and enhance safety through populated areas.

Factors Affecting Geometric Standards (Continued)

- Pavement Type
  - Surfaced (concrete, asphalt, seal or gravel) or unsurfaced (earth).
  - Surfaced roads provide higher traction or friction for vehicles as opposed to unsurfaced roads thus geometry standards are required to be higher for unsurfaced roads than for surfaced roads.
- Soil type and Climate
  - Problem soils can be mitigated through geometric design such as flattening road embankments where unstable soils are encountered.
  - The impact of problematic wet climates can be mitigated through geometric design such as increasing road slopes to increase precipitation runoff.
- Safety
  - One of the main objectives in geometric design and will be discussed in a separate Chapter of the presentation.

Factors Affecting Geometric Standards (Continued)

- Construction Technology
  - Labour abundant countries are required to maximise the use of labour rather than rely on equipment-based methods of road construction, thus geometric design needs to take this into consideration.
- Administrative Function
  - The administrative functional of a road may control the standards to be adopted irrespective of levels of traffic.
- Environmental
  - The location and design of the road should maximise positive effects and minimise negative effects on the environment.
  - Dust pollution, uncontrolled quarry operations, environmental degradation arising from logging activities due to increased access to remote areas are the major concerns.
  - Environmental impact assessments should be carried out for every road design.

Design Speed and Geometry

The following aspects of geometric design will be discussed in greater detail in the new LVR Manual:

- Design Speed
  - Maximum safe travel speed which can be maintained over a specific section of road under free flow conditions to which Geometric Standards are related.
  - Higher design speeds require higher Level of Service (LOS) and consequently are more costly to construct.

GHANAIN RECOMMENDED DESIGN SPEEDS

Terrain	Access/Spur (km/h)		Connector (km/h)		Inter-District (km/h)	
	Gravel Surface	Bituminous Surface	Gravel Surface	Bituminous Surface	Gravel Surface	Bituminous Surface
Flat	50	60	60	80	60	80
Rolling	40	50	50	60	50	60
Mountainous	20	30	30	30	30	30

- Sight Distance
  - Length of roadway ahead, clear of objects, required to visible to the driver and is the most important influence on road safety and efficient operation.
  - Sufficient sight distance is to be provided both longitudinally and laterally.

Design Speed and Geometry (Continued)

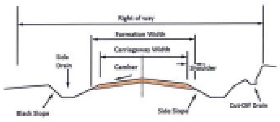
- Stopping Sight Distance
  - Distance a vehicle requires to stop safely upon viewing an object in the road and is used for the basic geometric design of the road alignments.
- Intersection Sight Distance
  - Same as for stopping however based on the object viewed being another vehicle entering the road from an intersecting side road.
  - A table reflecting these distances will be included in the manual.
- Passing Sight Distance
  - Distance a vehicle requires to overtake another safely and is used for design of passing opportunities and no-overtaking sections of roadway.

GHANAIN RECOMMENDED SIGHT DISTANCES

Design Speed (km/h)	20	30	40	50	60	70
Min. Stopping Distance (m)	20	30	50	60	80	100
Passing Sight Distance (m)	115	170	230	290	350	420

Road Cross Section

The following elements relating to road cross section will be discussed in greater detail in the new LVR Manual:



- Road Widths:
  - Ideally roadway widths are required to be wide enough for 2 vehicles to pass safely without having to use the verge.
  - LVR's normally operate as single lane roads where vehicles drive in the centre of the road, and on the rare occasion that vehicles meet, they are able to slow down or stop in order to pass.
  - Generally the LVR road element widths are standardised based on whether these are surfaced or unsurfaced and may be influenced by the type of terrain in some cases.
  - Standard road widths for LVR's are included at the end of the Section.

Road Cross Section (Continued)

- Shoulders
  - Surfaced or unsurfaced edge supports to contain the road carriageway.
  - Protects road pavement structure from surface runoff ingress.
  - Provides safe space for non-motorised travellers, emergency vehicle breakdowns etc. where sufficiently wide enough.
- Camber
  - Facilitates the drainage of the roadway by shedding stormwater runoff to the side drains.
  - For unsurfaced roads this is generally 5 - 7% however 6% has been suggested for LVR's.
  - For surfaced sections this can be reduced to 2 to 3%.
  - Road slope changes introduced to counteract centrifugal forces of a vehicle negotiating a horizontal curve is referred to as superelevation and will be discussed later in the Chapter.

Road Cross Section (Continued)

- Roadside drains
  - Introduced to convey stormwater runoff from the road surface to suitable discharge points to avoid saturation of the pavement layers.
  - Flat bottomed drains are recommended for LVR's as V-shaped drains formed of earth develop erosion lines easily.
- Clearances
  - Minimum lateral clearance from the carriageway = 0,25m – 0,5m
  - Minimum vertical clearance above carriageway = 5m
  - Clear zones or verge areas to be kept clear of obstacles which may be hazardous to vehicles which leave the roadway.
- Side Slope
  - Slope of earthworks cut and fill embankments generally affected by stability characteristics of the natural soil.

Road Cross Section (Continued)

- Right-Of-Way (ROW)
  - Area reserved for the roadway, drainage systems, signage, services, clear zones, non-motorised travellers, and for accommodating future upgrading requirements.
  - In Ghana ROW widths vary as sandy soils require larger side drains that required for good soil conditions.
- Passing Opportunities
  - Where road widths are very narrow i.e. <3m, it may be necessary to install passing opportunities.
  - Generally required every 300m to 500m for road widths <3m.
  - Can be installed as widened shoulders where 2 vehicles are unable to pass or where slower moving vehicles obstruct following vehicles from safely overtaking e.g. on steep inclines.

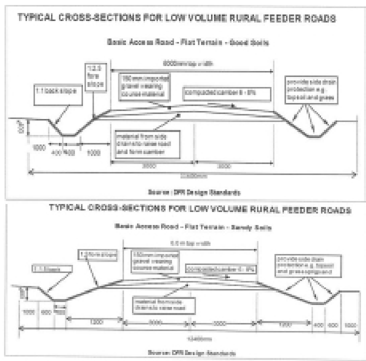
Road Cross Section (Continued)

GHANAIN RECOMMENDED ROAD CROSS-SECTION STANDARDS

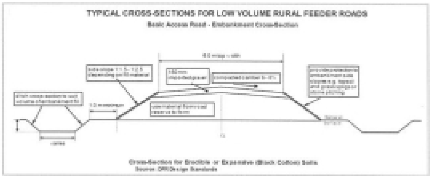
Road Classification			Access/Spur			Connector			Inter-District		
Terrain Classification			F	R	M	F	R	M	F	R	M
Design Speed (km/h)	GS		50	40	20	60	50	30	60	50	30
	BS		60	50	30	70	60	30	70	60	30
Width	Carriage Way	GS	6m			7m			7m		
		BS	6m			7m			7m		
	Shoulder	GS	-			1m			1m		
		BS	-			1m			1m		
	Median Strip		Minimum of 2,5m applicable in towns only with adequate reservation								
Camber (%)	GS		5 - 7%			5 - 7%			5 - 7%		
	BS		3%			3%			3%		

Note: GS = Gravel Surface BS = Bituminous Surface F = Flat Terrain R = Rolling Terrain M = Mountainous Terrain

Typical Cross Sections



Typical Cross Sections (Continued)



Horizontal Alignment

The following elements of horizontal alignment design will be discussed in greater detail in the new LVR Manual:

- Straights or Tangent Sections
  - Beneficial in flat terrain however less in rolling or mountainous terrain.
  - Provides good visibility and greater passing opportunities.
  - However increases danger from excessive speeding and headlight glare.
  - Generally straights should not exceed 4km in length.
- Superelevation
  - It is proposed that superelevation be excluded from unsurfaced LVR's as this increases the path length stormwater runoff has to travel over the roadway potentially leading to erosion of the earth or gravel surface.
  - Can potentially create ponding at points where the superelevation development is flat or crosses over.

Horizontal Alignment (Continued)

- Horizontal Curves
  - Must be appropriately designed for design speeds >50km/h
  - Avoid sharp curves for obvious reasons.
  - Current recommended minimum curve radii are indicated below.
  - New minimum curve radii will need to be developed as current recommendations are based on superelevation slopes.
  - For small changes of direction it is however desirable to use large radius curves to improve appearance and reduces the tendency for road users to cut corners.
  - Curve lengths should be kept to a minimum as overtaking on curves is generally difficult and often difficult to maintain adequate sight distance.

GHANAIN MINIMUM RADII OF CURVATURE

Terrain		Access/Spur			Connector			Inter-District		
		Speed	Absolute	Desirable	Speed	Absolute	Desirable	Speed	Absolute	Desirable
Flat	GS	50km/h	85m	150m	60km/h	130m	220m	60km/h	130m	220m
	BS	60km/h	130m	220m	80km/h	230m	420m	80km/h	230m	420m
Rolling	GS	40km/h	50m	100m	50km/h	85m	150m	50km/h	85m	150m
	BS	50km/h	85m	150m	60km/h	130m	220m	60km/h	130m	220m

Note: GS = Gravel Surface BS = Bituminous Surface

Horizontal Alignment (Continued)

- Minimum length of horizontal curve

GHANIAN MINIMUM LENGTH OF HORIZONTAL CURVE

Design Speed (km/h)	20	30	40	50	60	70
Min. Curve Length (m)	40	50	70	80	100	120

- Curve Widening
  - To be applied where tight curves are unavoidable to allow for the swept paths of large vehicles and to allow drivers to manoeuvre when approaching oncoming vehicles.
  - Generally applied to the inside of the curve.
  - The following table reflecting widening recommendations based on curve radius will be included in the manual.

GHANAIN RECOMMENDED CURVE WIDENING

Curve Radius (m)	16 - 19	19 - 21	21 - 26	26 - 32	32 - 45	45 - 60	60 - 90	90 - 160
Increase in Width (m)	2.00	1.75	1.50	1.25	1.00	0.75	0.50	0.25

Vertical Alignment

The following elements of vertical alignment design will be discussed in greater detail in the new LVR Manual:

- Gradient
  - Grades should be kept as low as possible and consideration should be given to alternative surfacing options on high grade sections or hairpin bends in mountainous terrain.
  - Minimum gradient recommended is 0,5% (1:200) to assist with side drain conveyance of stormwater runoff.

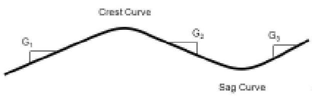
GHANAIN RECOMMENDED MAXIMUM GRADIENTS

Design Speed (km/h)	20	30	40	50	60	70
Max. Vertical Grade (%)	12	10	7	6	5	4

- Vertical Curvature
  - Parabolic curves defined by length unlike radius for horizontal curves.
  - Minimum length is defined by L = K x G where L = length of curve; G = algebraic difference in grade (%); K = relationship of design speed and safe stopping sight distance.

Vertical Alignment (Continued)

- Crest Curves
  - Based on daylight safe stopping sight distance and thus related to design speed as well as minimising driver discomforting forces.
- Sag Curves
  - Based on night-time vehicle headlight illumination distance limitations.



GHANAIN RECOMMENDED K VALUES & MINIMUM VERTICAL CURVE LENGTH

Design Speed (km/h)	40	50	60	70
K Values for Crest Curves	4	8	14	30
K Values for Sag Curves	5	7	10	18
Min. Vertical Curve Length	35m	40m	50m	70m

Harmonisation of Horizontal and Vertical Alignment

The following recommendations should also be considered when designing the road alignment and will be discussed in greater detail in the new LVR Manual:

- Avoid horizontal curves with changing radius that generally come as a surprise to road users.
- Avoid isolated curves connected with long tangents may come as a surprise to road users particularly if the curve is close to the minimum radius.
- Long curves are problematic to road users as they are difficult to negotiate as opposed to shorter length curves.
- Inappropriate combinations of horizontal and vertical alignments, e.g. a sharp horizontal curve located beyond a pronounced vertical crest curve, is not desirable.
- Avoid skew intersections and cross-intersections – stagger rather.
- Staggered intersections should not be located minimum 40m apart.
- Good visibility of intersections are required from both directions.
- Avoid steep grades at intersections which lead to longer vehicle acceleration and deceleration distances.

Summary of Geometric Standards for Each Class of Road

It is proposed that all the various geometric design standards be contained in a single matrix table for each class of road as shown in the example below.

Design Element	Unit	Flat	Rolling	Mountain	Escarpment	Populated areas
Design speed preferred	km/h	70	60	50 (2)	25 (2)	50
Road width	m	7.0 (4)	7.0 (4)	7.0 (2)	7.0 (2)	7.0 (3,4)
Max. desirable gradient	%	4	6	6	6	4
Maximum gradient	%	6	9	9	9	6
Minimum gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum super-elevation	%	6	6	6	6	6
Normal cross-fall (5)	%	6	6	6	6	6
Minimum stopping sight distance	m	125	95	70	25	70
Maximum super elevation	%	6	6	6	6	6
Minimum horizontal radius Super elevation = 4%	m	245	175	110	25	110
Minimum horizontal radius Super elevation = 6%	m	215	155	100	20	100
Minimum crest vertical curve	K	34	19	11	2.5	11
Minimum sag vertical curve	K	5	3.5	2.2	1	2.2

References

- Ghana DFR Design of Rural Feeder Roads (2004)
- Ghana DFR Design of Drainage Structures on Rural Feeder Roads (2005)
- Ghana DFR Routine & Recurrent Maintenance Manual (2004)
- Ghana DFR Site Supervision Pocketbook (2005)
- Ghana DFR Road Maintenance Pocketbook (2007)
- Ghana DFR Soils and Natural Gravels (2006)
- Ghana DFR Properties and Production of Concrete (2006)
- Ghana DFR Surfacing and Pavement Options for Low Volume Roads (2007)
- Ghana DFR Design Standards (2009)
- Ghana EPA Environmental Impact Assessment Guideline (2011)
- Ghana MoLGRD Practitioners Guide to Rural Roads Improvement and Maintenance (2014)
- Ghana HA Road Design Guide (1991)
- Ghana HA Traffic Calming Design Guideline (2007)
- Ghana MoT Standard Specification for Road and Bridge Works (2007)
- Ethiopia RA Manual for Low Volume Roads (2016)

Questions?

Road Safety

Outline of Presentation

- Introduction
- Traffic Signs
- Road Markings
- Traffic Calming
- Safety Barriers
- Safety Audits
- References
- Questions

Introduction

- Road accident statistics common with many African countries show that death rates from road accidents are 30 to 50 times higher than in Western countries.
- Economic analysis has also shown conclusively that a high level of road accidents has very significant economic consequences for a country.
- There are a number of key principles of design that can considerably improve road safety:
  - Consider ALL road users including non-motorised travellers,
  - Provide adequate warning signage where potential hazards exist,
  - Encourage appropriate speeds through design,
  - Reduce conflicts if possible,

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Introduction (Continued)

- Objectives of the Road Safety Chapter in the new LVR Manual:
  To provide Road Safety design principles, recommendations, guidance and standards to enable the low volume road designer to meet the safety standards appropriate to the local environment for roads carrying less than 300 vehicles per day.
- Some general safety considerations:
  - Prevent accidents e.g. provide adequate drainage of road surface.
  - Reduce the severity of accidents e.g. through provision of flat roadside slopes.
  - Separating vulnerable road users from motorised traffic e.g. through provision of road shoulders or footways.

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Traffic Signs

The following types of road signs will be discussed in greater detail in the new LVR Manual:

- Regulatory Signs
  - Indicate legal requirements of traffic movement.

- Warning Signs
  - Indicate conditions that may be hazardous to road users.

- Information Signs
  - Convey information of use to road users.

- Marker Posts
  - Guideposts intended to make road users aware of potential hazards e.g. drainage structures located on the road verge.
  - Kilometre posts generally only required on higher order roads.

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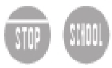
Road Markings

The following types of road markings will be briefly covered in the new LVR Manual due to it's appropriateness to surfaced roads and not unsurfaced:

- Regulation Markings and Symbols
  - Indicate legal requirements of traffic movement.

- Warning Markings and Symbols
  - Indicate conditions that may be hazardous to road users.

- Information Markings and Symbols
  - Convey information of use to road users.



- Object Markers
  - Hazardous objects in the clear zone impractical to be removed should be adequately painted by use of high-visibility material.
- Road Studs
  - Reflective devices installed to demarcate the road centreline at night.

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Traffic Calming

- The following various methods of improving road safety through the implementation of traffic calming measures will be discussed in greater detail in the new LVR Manual:
- Road Alignment Controls
  - Manipulation of the road alignment or road features, such as reducing width, to cause road users to slow down e.g. chicanes.
- Warning Devices
  - Installation of artificial road texture on sealed road sections that causes considerable tyre noise and vehicle vibrations to warn road users of hazardous conditions and cause them to slow down e.g. rumble strips.
- Speed Reduction Humps and Cushions
  - Most common method used to slow traffic.
  - Generally preceded by road warning devices.
  - Unlike road warning devices these are higher and potentially hazardous if not designed correctly.
  - Humps extend the full width of the road whilst cushions have considerable gaps to allow bicycles and motorcycles to pass through.

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Traffic Calming (Continued)

- The 'Village Treatment' concept of traffic calming introduced in Ethiopia has proven to be successful.
- Using a combination of the traffic calming devices, pedestrian sidewalks, and busbays, a perception is created for the driver that the approaching village is a low speed environment with the aim to encourage him to reduce speed.

- The 'Village Treatment' is made up of 3 zones:
  - The approach zone - prior to entry of village where driver is made aware that the open road speed is no longer appropriate (80 – 50km/h),
  - The transition zone - gateway to core zone and first speed humps (50km/h)
  - The core zone - centre of village and activity zone with humps (40km/h)

Private and confidential 36

Safety Barriers

The following aspects of safety barriers will be briefly discussed in the new LVR Manual due to it's appropriateness to higher order roads:

- Segregating Vulnerable Road Users
  - Provision of physical separation between motorised vehicles in opposing directions and also with non-motorised travellers i.e. pedestrians and cyclists e.g. by means of crash barriers.
- Crash Barriers
  - Prevents vehicles traveling in opposite directions from colliding with each other head on.
  - Primarily used on LVR's to prevent vehicles from leaving the road where hazardous conditions exist e.g. at the top of high fills.

Safety Audits

- Road safety is complex by nature, and although many unsafe practices are glaringly obvious, there are many situations where it is difficult to identify what is likely to be unsafe, especially in the case of a new road where one is working from drawings.
- Road safety improvements mostly rely on reliable historic data much of which is never recorded or analysed using road accident characteristics.
- Professional road safety auditing is the next best practice and should be regularly undertaken on every road project particularly for road projects in populated areas.
- The new LVR manual will provide greater detail on this subject.

References

- Ghana HA Traffic Calming Design Guideline (2007)
- Ethiopia RA Manual for Low Volume Roads (2016)

References

- LVR roads in Ghana

ReCAP

Questions?

Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First Stakeholder Workshop

Materials and Pavement Design

Accra - Ghana

19 September 2017

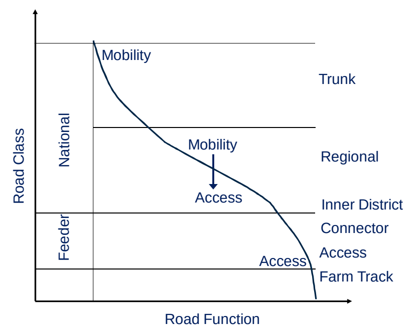
Outline of Presentation

- Road classification
- Principles of Low Volume Road pavement design
- Site physiography
- Traffic
- Materials
- Pavement design
- Quality Assurance & Quality Control

Road Classification

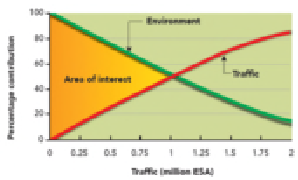
- Functional road classification in Ghana:
  - Primary / National / Trunk roads (highways)
  - Secondary / Regional roads:
    - Major
    - Minor
  - Feeder Roads:
    - Inter-district feeder roads
    - Connector feeder roads
    - Access / spur feeder roads
  - Metropolitan / municipal roads

Road Classification



Principles of LVR pavement design

- Low volume road :
  - ≤ 300 vpd (middle design life)
  - ≤ 1 million cumulative ESA's
- Performance more dependent on environment than traffic

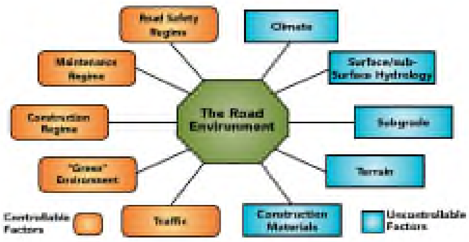


- Budgets for maintenance, rehabilitation and improvements are constrained
- Conventional planning, design, construction and maintenance philosophies for higher volume roads do not apply

Principles of LVR pavement design

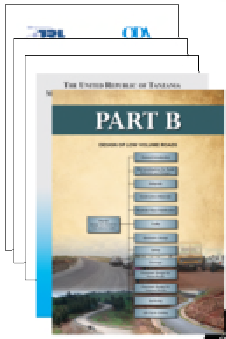
- Multiple structural layers seldom warranted for unpaved roads
- Considerations for design:
  - Raise formation and gravel wearing course above NGL
  - Allowance and provision for cross drainage
  - Treatment of unsuitable subgrade material
  - Maintenance capacity and frequency
  - Phased construction, possible future upgrade to surfaced standards
- Low Volume Paved Roads vs Unpaved Roads
  - Surface dressing
  - Alternative surfacing
  - Gravel roads
  - Earth roads (un-engineered, semi-engineered)

Principles of LVR pavement design



Principles of LVR pavement design

- Reference documents:
  - TRL: Overseas Road Note 31
  - MRH: Design Standards for DFR
  - MRH: Standard Specifications
  - LVR Manuals various other AfCAP countries:
    - Tanzania
    - Ethiopia



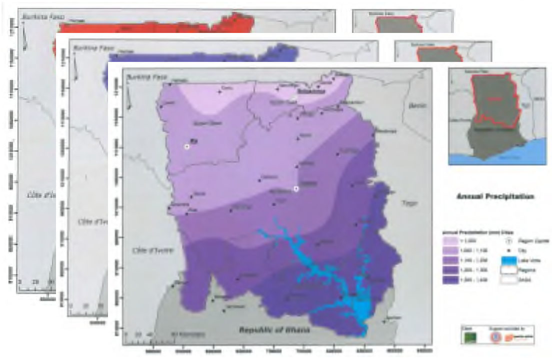
Principles of LVR pavement design

1. Design Principles
   - Road category
   - Design Period
   - Site Physiography
2. Traffic Design
   - Traffic volumes
   - Traffic loading
   - Traffic class
3. Design Investigations
   - Subgrade Characterisation
   - Material Selection
4. Structural Design
5. Economic Analysis

Site physiography

- Topography:
  - Flat < 6%
  - Rolling / hilly ≥ 6 % and < 9%
  - Mountainous ≥ 9 %
- Geology
- Soils and vegetation
- Climate:
  - Temperature
  - Rainfall

Site physiography

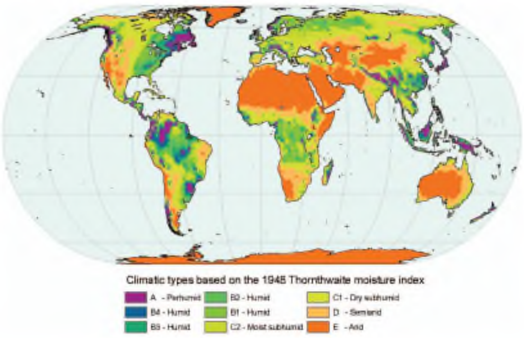


Site physiography

- Climatic indicator, e.g.:
  - Thornthwaite Moisture Index
  - Weinert N-value

Thornthwaite	Climatic region	Weinert	Climatic Region
< -40	Arid	> 5	Dry
-40 to – 20	Semi-arid		
-20 to 0	Dry sub-humid	3 To 5	Moderate
0 to 20	Moist sub-humid		
20 to 100	Humid	< 3	Wet
> 100	Perhumid		

Site physiography

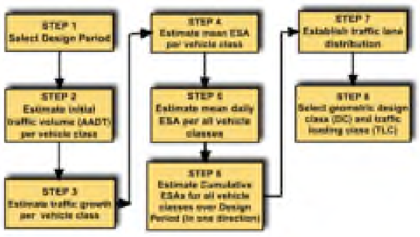


Traffic

- Traffic surveys:
  - Classified traffic counts
    - Motorised vs. NMT
    - Stationary vs Moving Observer Count (WB method)
  - O-D surveys
  - Axle load surveys
- Potential variations:
  - Seasonal (wet vs. dry)
  - Daily (market vs. non-market day)

Traffic

- Method of determining cumulative traffic loading is well documented
- Typical process:



Traffic

- 3 No. Traffic Load Classes proposed for pavement design:

Traffic Load Class	Cumulative traffic load during design life (million ESAs)
TLC 1.0	0.3 – 1.0
TLC 0.3	0.01 – 0.3
TLC 0.01	< 0.01

Design Investigations

- Materials investigation:
  - New road; focus on:
    - Subgrade
    - Available materials for road construction
  - Existing road:
    - Also determine strength existing road structure
- Subgrade characterisation:
  - Material sampling and testing (grading, indicators, CBR)
  - DCP testing (DN, CBR)
  - LWD testing (Emod)

Design Investigations

- Proposed subgrade classes for pavement design:

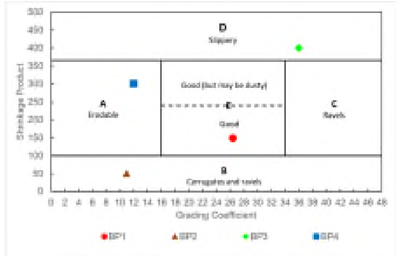
Subgrade Class	CBR Range [%]	Treatment and typical usage
S1	< 3	Special treatment required
S2	3 – 7	Suitable as fill
S3	7 – 15	Suitable as fill
S4	> 15	Suitable as improved subgrade / subbase

Materials

- Material classifications as per Standard Specifications
- Wearing course materials (TRH20):
  - Zone A: Fine grained material prone to erosion
  - Zone B: Non-cohesive materials that lead to corrugations and ravelling / material loss
  - Zone C: Poorly graded materials that are prone to ravelling
  - Zone D: Fine plastic material prone to slipperiness and excessive dust
  - Zone E: Optimum materials for best performance
- Type of surfacing:
  - Traditional surfacings
  - Non-traditional surfacings and stabilisers

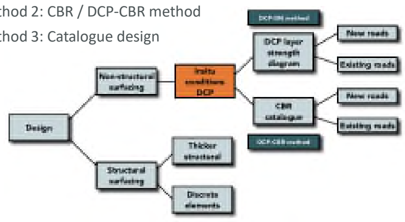
Wearing Course Material

- Selection of wearing course material:
  - Shrinkage Product SP = LS x $P_{0.425}$ 100 – 365 (240)
  - Grading Coefficient = $(P_{26.5} - P_{2.0}) \times P_{4.75} / 100$ 16 - 34

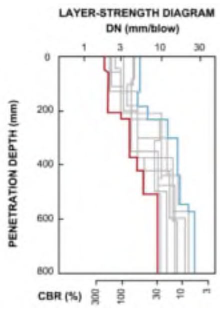


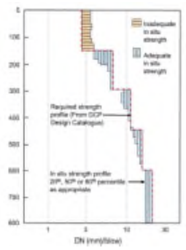
Pavement Design

- Current design method DFR:
  - Paved roads: ORN 31
  - Gravel roads: Table with standard wearing course thickness
- Proposed:
  - Method 1: DCP-DN method
  - Method 2: CBR / DCP-CBR method
  - Method 3: Catalogue design



Pavement Design





Pavement Design

- Gravel wearing course thickness
  - Typical gravel loss:

Material Quality Zone [1]	Material Quality	Typical gravel loss (mm/yr/100vpd)
Zone A	Satisfactory	20
Zone B	Poor	45
Zone C	Poor	45
Zone D	Marginal	30
Zone E	Good	10

  - Wearing course thickness : regravelling frequency x annual gravel loss
  - HDM-4 gravel loss formula (TRL Ghana study, 2006)

Quality Management System

- Quality Plan
  - Provide guidance on the contractual specification for quality management and a quality plan
- Quality Assurance
  - Method statements
  - Work instructions
  - Control forms
  - Check lists
  - Measurement & Monitoring
- Quality Control
  - Production Control
  - Acceptance Control

Quality Management System

- Example of materials sampling and testing plan:

Material	Frequency of the sampling and testing requirements
Tests on Soils	• Samples shall be collected from each stockpile. • Collect 6 samples from different parts of each stockpile. • Each sample shall be 50kg or more. • Collect 2 samples per stockpile if the material is sand.
Grading tests	• Two sieve analyses per material source.
Atterberg limits	• 2 tests for each sample.
Determination of laboratory dry density and optimum moisture content	• Mix the material for each stockpile and carry out at least 2 similar tests, separate tests on the mixed material to check for accuracy of the test results.
Determination of CBR or DN value (soaked, OMC and 0.75 OMC optional)	• Carry out 2 similar tests on the mixed samples for each stockpile.
Tests for concrete	
Slump test on fresh concrete	• One test for every 3 batch mixes.
Cube strength tests	• Six cubes for every pour (every lift or continuous pour).
Test on aggregate in the laboratory	• Samples shall be collected from 3 or more different positions in the truck or stockpile and the samples shall be tested separately.
Grading	• Minimum of 3 tests and plot a grading envelop for each delivery on site.
ACV	• Minimum of 3 tests and record and take an average of the values.
10% FACT	• Minimum of 3 tests and record and take an average of the values.
Water absorption	• Minimum of 3 tests and record and take an average of the values.

Private and confidential 25

Questions?

Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First Stakeholder Workshop

Ghana

19th September 2017

Investigations & Roadside Stabilisation

Contents

Route selection
Geological and subgrade investigations
Investigations for construction materials
Roadside slope stabilisation

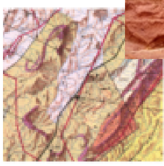
Roads in hilly and mountainous terrain

Route Selection

- Principal factors
  - Engineering
  - Cost
  - Environmental
- Methods of route investigation
- Methods of route comparison and selection

Investigations

- Geological investigations
- Role of geology in LVR engineering
  - Rock types
  - Weathering profiles and soil types
    - In situ weathered soils
    - Colluvial soils
    - Alluvial soils
- Desk study data sources
  - Published maps
  - Remote sensing

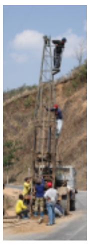


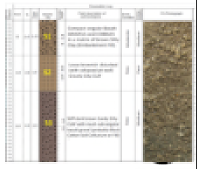
Investigations

- Problematic soils
  - Soft compressible soils
  - Expansive soils
  - Collapsible soils
  - Dispersive soils
  - Soils prone to erosion

Investigations

- Sub-grade investigations
- Importance of sub-grade condition
  - For embankments and pavements
  - For foundations to bridge abutments and other structures
- Techniques of investigation
  - Field mapping
  - Trial pitting
  - In situ testing
  - Drilling investigations
  - Laboratory testing

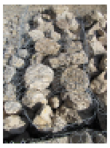




Gareth Hearn (Presented by Hamish Goldie-Scot)

Investigations

- Construction materials: prospecting for borrow pits and rock quarries
  - Capping layer
  - Fill material
  - Subbase-base material
  - Sand, aggregate, rock fill etc


Investigations

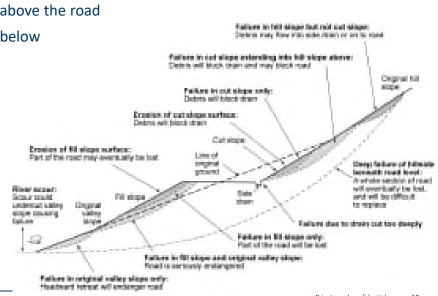
- Construction materials continued –
- Prospecting techniques
  - Desk study
    - -Topographic maps
    - -Geological maps
    - -Remote sensing
  - Field investigations – borrow pits
    - -Surface mapping
    - -Trial pitting
    - -Sampling & laboratory testing
    - -Survey of designated source areas
  - Field investigations – rock quarries
    - - Geological mapping
    - - Drilling investigations
    - - RQD


Investigations

- Construction materials continued –
- Borrow pit operation and restoration
  - Control of runoff
  - Stockpiling and control of erosion
  - Restoration
    - Landscaping
    - Re-topsoiling
    - Replanting


Roadside slope stabilisation

- Mechanisms of slope instability and erosion
- Instability in natural slopes
- Instability in cuts and fills
- Instability above the road
- Instability below



Roadside slope stabilisation

- Design, stabilisation, mitigation
- Cut slope geometry (rock/soil vs height vs angle)
- Slope stabilisation measures (earthworks, drainage, retaining walls)
- Slope protection measures (erosion control, netting, retention walls)




Roads in hilly and mountainous terrain

- Route selection and alignment design
- Choice of cross-section
- Earthworks design and spoil disposal
- Slope stabilisation and erosion control
- Cross-drainage

ReCAP Research for Community Access Partnership

UKaid from the British people

Hydrology/Drainage

Festus Odametey

UKaid from the British people

Outline

UKaid from the British people

1. *Introduction*

i. General

Water is often the cause, whether directly or indirectly of roadway destruction or pavement failure. Poor drainage is a major contributing factor to failure of road pavement structure.

ii. Purpose

To equip the Design Engineer with the need knowledge, tools and techniques for effective design of drainage structures on Low Volume Roads.

iii. Scope

- cover extensively the steps required to design storm drainage structures to minimize or eliminate flooding of Low Volume Rural Roads (LVRR).
- ensure that Low Volume Rural Roads are motorable all year round by providing adequate drainage structures across and along the road corridor to keep surface free of surface runoff after heavy downpours.

UKaid from the British people

- Three main stages involved in the design of drainage structures, namely:
  - Data collection
  - Hydrological studies (estimation of peak flows)
  - Hydraulic analysis (estimation of capacities of drainage structures)

iv. Summary of Standards

- Design Return Periods

Type of Drainage Structure	Designed Return Period, years	Maximum Return Period, years
Unlined side drains	2	5
Lined Side drains	5	10
Drifts	2	5
Vented Drifts	5	10
U and Pipe Culverts	10	25
Minor Box Culverts	10	25
Major Box Culverts	25	50
Small Bridges, Span < 50m	25	50
Major Bridges, Span >= 50m	50	100

UKaid from the British people

- Minimum Culvert Size
  - A minimum size of 900 x 1200 diameter U-Culvert or 900 mm diameter pipe culvert is recommended for watercourse culvert.
  - A minimum culvert size of 700 x 900 diameter U-Culvert or 600mm diameter pipe culvert is recommended for access culvert
- Minimum and Maximum Velocities
  - Velocities in the range of 1.0m/s (min.) to 3.0m/s (max.) tend to have fewer operational problems than culverts that produce velocities outside of this range.
- Multiple Cell/Barrel Culvert
- Culvert Material Selection
- End Treatment (Inlet & Outlet)
- Outlet Protection

UKaid from the British people

- Culvert Alignment and Grade
  - It is recommended that culverts be placed on the same alignment and grade as the natural streambed, especially on year-round streams.
- Sections of Drains
  - *Open – Trapezoidal*

    Minimum bottom width: 30cm

    Side Slope Unlined: 1:2 to 1:4

    Side Slope Lined: 1:1, 1:1.5, 1:2

  - *Circular/Pipe Culverts*

    Minimum Diameter: 900mm for cross culverts and 600mm for accesses/junctions

    Maximum Diameter: 1500mm/2000mm

    Minimum Cover: 0.6m

- *Rectangular Culvert*
  Minimum Height 1.0m
  Minimum Width 1.0m

- *U-Culverts*
  Minimum Height 0.7m
  Minimum Width 0.9m

- *Carrying capacity of drains:*
  Manning's roughness coefficient, n.

Material in the drain	Roughness coefficient
Concrete lined channel.	0.013 – 0.015
Sandcrete block	0.015 – 0.020
Masonry	0.017 – 0.030
Earth (new)	0.018 – 0.030
Earth (existing)	0.022 – 0.060

- *Flow Velocities in Drains*

Minimum Velocities in all drains	0.60 m/s
Maximum Velocities;	
i. Open Earth Drains (no lining)	1.7 m/s
ii. Block / Masonry lined	2.5 m/s
iii. Reinforced Concrete	2.5 – 3.0 m/s

- *Freeboard*

Open Drains	0.30m
Culverts	0.67m

v. General Considerations
- Environmental Considerations
- Safety Considerations

vi. Terminologies

2. *Hydrological and Drainage Studies*

i. Administrative Processes
- Collection of Existing Documents and Desk Studies
- Field Data Collection

ii. Classification of LVR Drainage
- Surface Drainage
- Subsurface Drainage
- Slope Drainage
- Drainage of Structures

iii. Catchment Characteristics
- Land Use
- Soil Type
- Slope
- Stream Length
- Catchment Area

iv. Estimation of Peak flow

a. Field Observation Methods
- Direct Observation of the size of the Stream Channel or Watercourse
- Direct Observation of Erosion and Debris
- History and Local Knowledge
- Replicating Successful Practice

b. Rational Method –
- Gives satisfactory discharge results only on small catchments areas i.e. < 2.0 square kilometers.
- It is assumed that the intensity of the rainfall is the same over the entire catchment area.

c. Modified Rational Method -
- Use for larger catchment i.e. > 2.0 square kilometers.
- Areal Reduction Factor (ARF)

d. WinTR 20
- Subarea Parameters
- Stream Parameters
- Structure Data
- Design Return Period

3. *Choice of Drainage Structure*

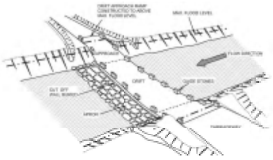
i. Side Drains
- Rectangular (U-Shaped) concrete lined –Recommended at settlement areas along the road corridor
- Trapezoidal Earth Channel
- Trapezoidal Stone Pitched
- Trapezoidal Concrete Lined
- Triangular (V-Shaped) Earth Channel

ii. Culverts
- Watercourse Culverts: Usually pipe and box culverts will be used.
- Relief Culverts: Pipe and U-Culverts will be recommended
- Access Culverts: U-Culverts will be recommended at accesses to withstand traffic load.

iii. Small Bridges
- Will be recommended where stream depth is greater than 4.0m

iv. Drifts and Vented Drifts or Causeways

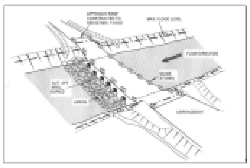
- Drifts are suitable for shallow water courses with a gentle gradient and at sites where raising the road over a culvert would require the transport of large quantities of earth



Typical features of a drift

A Hand Packed drift

- Vented drift is a combination of a culvert and a drift. They are suitable for carrying roads across water courses which have a base water flow for most of the year and which have large flows for less than three days after heavy rains.



Typical features of a vented drift

A typical vented drift / causeway

4. *Hydraulic Analysis*

i. Introduction

Hydraulic design is aimed at minmizing or eliminating their occurrence of Overtopping and washing out of embankment; scouring; erosion; etc.

ii. Side Drains

- Longitudinal ditches
- Mitre drains (Turn-outs)
- Catch water drains (Cut-off ditches/drains)

Design Methods:

- The flow capacities of side drains can be determined from the simple expression:

$$Q = VA \text{ i.e. Manning's formula}$$
$$V = 1/n\ R^{2/3}\ S^{1/2}$$

where,

Q = Peak flow, m^3/s
V = Velocity of Flow, m/s
A = Catchment Area, m^2
R = Hydraulic Radius = A/P, P = wetted Perimeter, m
S = Slope, m/m
n = Roughness Coefficient

- The flow capacities of side drains can again be determined using the computer based software, HY-22 for open channel analysis.
  - Select channel type: rectangular, circular, trapezoidal
  - Input data :
    1. Channel slope, m/m
    2. Bottom Width, m
    3. Side Slopes
    4. Manning's Coefficient
    5. Designed Discharge, m^3/s
    6. Depth, m
  - Analyze

Mitre Drain (Turn-outs):

- Generally rule, provided every 25 metres
- At least one at every 100 metres.
- Maximum distance normally be 200 metres.

Mitre Drain (Turn out Spacing)

Longitudinal/ Side drain Gradient, S (%)	Spacing (m)
$1 \le S \le 2$	200
$2 < S \le 4$	100
$4 < S \le 6$	50
$6 < S \le 8$	40
$8 < S \le 10$	25
$10 < S \le 12$	20

Source: DFR Site Supervision Pocketbook, 2004

iii. Culverts

- Cross Drainage Structures (Stream Culverts, Relief Culverts)

  Relief culverts may be required at intermediate points where a side drain carries water for more than about 200m without a mitre drain or other outlet.
- Access Culverts

Recommended Spacing between Relief Culverts

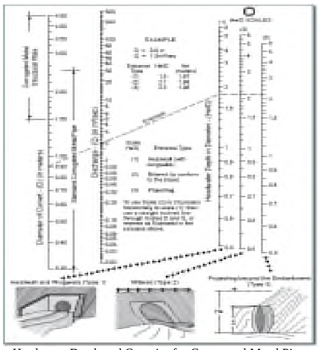
Longitudinal Gradient of Road/ drain, %	Recommended Interval of cross drainage, m
$2 \le S < 3$	200
$3 \le S < 5$	150
$5 \le S < 6$	135
$6 \le S < 7$	120
$7 \le S \le 8$	100
$8 < S \le 10$	80
$10 < S \le 12$	60

Design Methods:

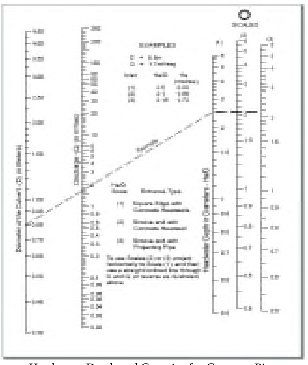
a. Culvert opening is estimated using the nomograms for:
- corrugated metal pipes
- concrete pipes
- concrete box culverts.

b. Using HY-8 Culvert Analysis software

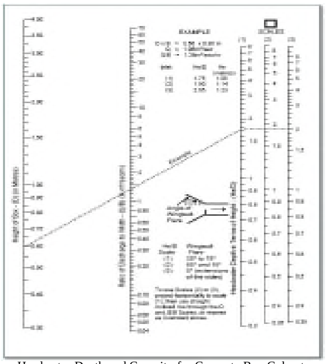
Input Data:
- ➢ Crossing Properties (Discharge Data, Tailwater Data, Roadway Data)
- ➢ Culvert Properties
  - Culvert Data (Slope, Material, Manning's n)
  - Site Data (Culvert Invert Data or Embankment Data)
- ➢ Overtopping Analysis



Headwater Depth and Capacity for Corrugated Metal Pipe Culverts with Inlet Control (Adapted from FHWA, 1998)

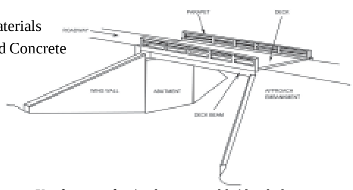


Headwater Depth and Capacity for Concrete Pipe Culverts with Inlet Control (Adapted from FHWA, 1998)



Headwater Depth and Capacity for Concrete Box Culverts with Inlet Control (Adapted from FHWA, 1998)

iv. Small Bridges
- Bridges are generally the most expensive type of road structure requiring specialist engineering advice and technically approved designs.
- Bridge Materials
- ✓ Reinforced Concrete
- ✓ Steel
- ✓ Timber



Key features of a simply supported bridge deck

- If the crossing is to be used by pedestrians, proper protected footways should be designed on both sides of the carriageway.
- Reinforced concrete parapets are preferred rather than steel guard rails.

5. Sedimentation and Erosion Control

- Sedimentation Control
  - ✓ A factor of safety of 2 (in terms of water flow capacity) in flat terrain.
  - ✓ Slope/fall should be 3-5%. to minimize silting and deposition of debris in the culvert.

Siltation in cross culvert

- Erosion Protection
- Scour Checks for Erosion Control

Scour check Spacing

Drain Gradient , S (%)	Scour Check Spacing, m
<5	Not needed
5≤ S < 7	15
7≤ S < 10	10
10≤ S < 12	7
≥12	5

Source: DFR Site Supervision Pocketbook, 2004

6. Design of Drainage Structures

- Scour
- Foundations
- Concrete slab
- Aprons
- Headwall & Wingwalls
- Rip-rap
- Gabions

7. Construction Materials

- Stone Masonry
- Brick and Block Masonry
- Timber
- Plain and Reinforced Concrete

8. Construction Methods

- Preparatory Work
- Site Work
- Site Administration

9. References

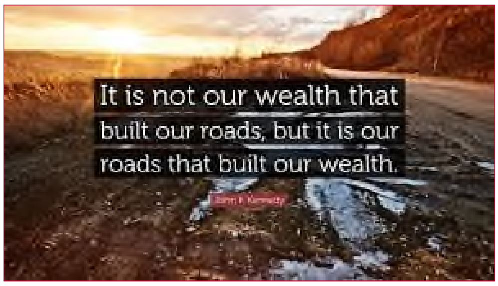
i. Ethiopian Manual for Low Volume Roads (2016)
ii. Tanzania Ministry of Works, Transport and Communication, Low Volume Roads Manual (2016)
iii. Ghana DFR Guidance Notes for the Design of Rural Feeder Roads (2004)
iv. Ghana DFR Site Supervision Pocketbook (2004)
v. Hydrological & Drainage Design: Design Guidelines, Criteria and Standards by Bureau of Design
vi. Ghana Highway Authority Road Design Guide (1991)
vii. Ghanaian Practitioners Guide to Rural Roads Improvement and Maintenance (2014)
viii. Ghana MoT Standard Specification for Road and Bridge Works (2007)
ix. Liberian Feeder Roads Design Manual and Specifications (2016)
x. Sierra Leone National Rural Feeder Roads Policy Document (2011)

Annex E. Presentations made – Liberia

Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First project workshop for Liberia

21st September 2017



Outline of Presentation

- Workshop Programme
- Objectives of the Project, the Manual and the Workshop
- Approach and Methodology for Implementation of the Project
- Findings of Initial Visit
- Recommendations from the Initial Visit.

Workshop Programme

Time	Activity	Person Responsible
09:00 - 09:15	Registration/Breakfast	All Participants
09:15 - 09:30	Welcome Remarks	Minister Moore MPW
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03:15 – 03:45	Summary of key Issues Arising and Way Forward	Robert Geddes
04:45 - 04:10	Closing Remarks	Deputy Minister Paye MPW

Objectives

Objective of the project:

*To prepare manuals for **low volume roads** in Ghana, Sierra Leone and Liberia based on a review, adaption and expansion of previous AfCAP LVR manuals and local manuals that are available in these countries.*

Objective of the manuals:

In each country, to provide a relevant resource, based on recognised good practice, that will help build capacity and result in improved sector performance.

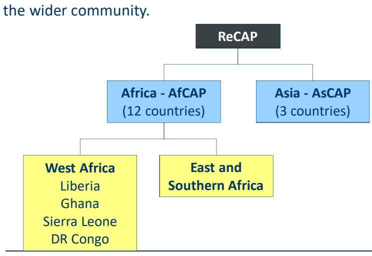
Objective of the 1st Stakeholder workshop:

To reach agreement on the scope of the LVR manual, and receive feedback on issues relevant to the national context.

Research for Community Access - ReCAP

- Programme of applied research and knowledge dissemination for the rural transport sector in Africa and Asia (2014 to 2020)
- Funded by UK Aid.

Overall aim: to promote safe and sustainable rural access in Africa and Asia through research and knowledge sharing between participating countries and the wider community.



ReCAP Activities in Liberia

- Project Scoping Study for Sierra Leone and Liberia (July 2016)
- Training of trainers for DCP/DN pavement design method
- Participation in regional AfCAP events
- **LVR Manual project** (first AfCAP project in Liberia)
- Research on seals for LVRs
- ???

Manual Project - Approach and Methodology

Approach

Provide opportunities for local stakeholder input to ensure that the manual is relevant to the local context.

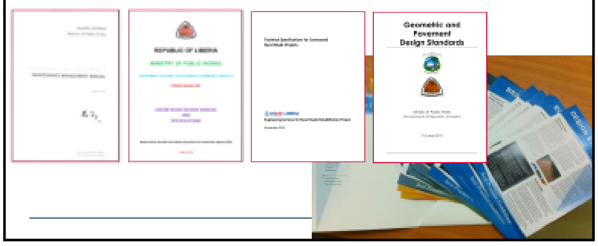
Methodology

- Initial visit with ***stakeholder consultation***;
- ***First workshop*;**
- Preparation of drafts of each chapter
- ***Second workshop*;**
- Preparation of revised drafts;
- ***Formal Peer Review*;**
- Preparation of final versions.

Approach and Methodology

Build on existing material, especially existing local standards:

- LSFRP Feeder Roads Manual and Specifications (2016)
- Maintenance Management Manual (*ILO/ADB*- 2009)
- Best Practice Guidelines (2014)
- Geometric and Pavement Design Standards (2017)



Approach and Methodology

AFCAP-supported manuals for Ethiopia, Tanzania, Malawi, Mozambique, South Sudan.

Initial Visit

Stakeholder meetings and field visit in Liberia

3rd to 7th July 2017

- Ministry of Public Works
- Engineering Society of Liberia
- Swedish International Development Agency
- University of Liberia
- Cardno/USAID
- GIZ
- Welthungerhilfe.

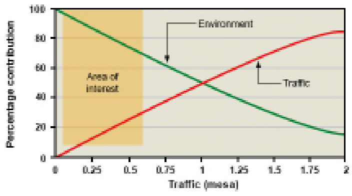
Initial Visit

Field Visit to Bong County

Findings from the initial visit to Liberia

- Relatively undeveloped road network and low traffic levels;
- Dependence on international donors and NGOs;
- No Standard Spec for Roads and Bridges - standards for LV rural roads have been defined through LSFRP;
- More guidance/specs needed on design of LV sealed roads;
- Maintenance management systems still being developed (is L-B maintenance effective?);
- Low capacity for materials testing;
- Lack of clarity on metric versus imperial systems;
- Test methods – AASHTO/ASTM;
- University curricula focuses on highway design;
- Road standards are dictated by extreme rainfall conditions.

Traffic versus Environment



Low volume roads carry:
- Less than about 300 VPD.
- Less than about 1 million esas over the design life.

Environmentally Optimised Design

Recommendations arising from the initial visit

- Each country will have unique manual – existing standards will be used wherever possible;
- Draw on relevant aspects of other AfCAP manuals particularly Ethiopia Manual for Low Volume Roads (2016) and Tanzania LVR Manual (2016);
- Provide a relatively high level of detail in the manual;
- Technical working group in each country.

Structure of the Manual

Five Parts:

Part A : Geometric Design and Road Safety

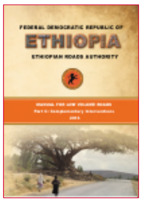
Part B : Materials, Pavement Design and Construction

Part C : Hydrology, Drainage and Roadside Stabilisation

Part D: Complementary Interventions (?)

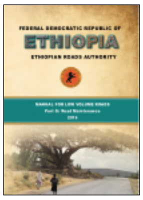
Part E: Road Maintenance (?)

Complementary Interventions



- Community participation in roads projects
- Small community infrastructure
- Planning and identification of complementary interventions
- Contract provisions to support complementary interventions
- Supervision, monitoring and enforcement.

Road Maintenance



- The Purpose of Maintenance
- Maintenance Activities
  - Regular (Routine) Maintenance
  - Occasional (Periodic) Maintenance
- Prioritisation
- Planning and Productivity
- Maintenance of Bridges & Structures
- Specifications for Maintenance of Low Volume Roads

Maintenance Activities

Table G.6.1: Roadside Activities

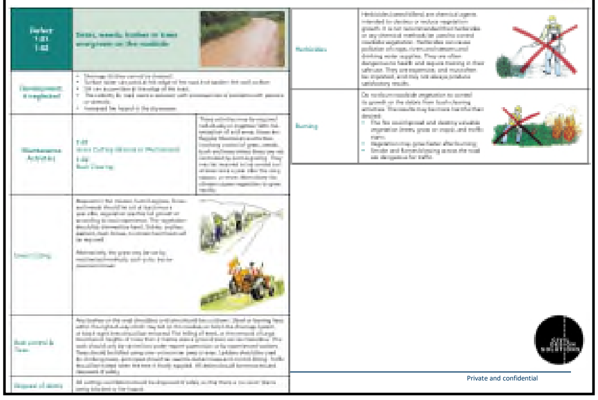
Defect	Maintenance Activity
1-01 Grass on shoulder or in drain requires cutting	1-01 Cut grass (manual or mechanised)
1-02 Trees and bushes growing on roadside	1-02 Bush clearing
2-01 Shoulder uneven or eroded, or does not drain properly	2-01 Shoulder rehabilitation (manual)
2-02 Shoulder uneven or eroded, or does not drain properly	2-02 Shoulder rehabilitation (mechanised)
2-03 Shoulder uneven or eroded, or does not drain properly (minor)	2-03 Shoulder Blading (mechanised)
3-01 Shoulder erosion	3-01 Plant grass and water it

Maintenance Activities

Table G.6.2: Drainage Activities

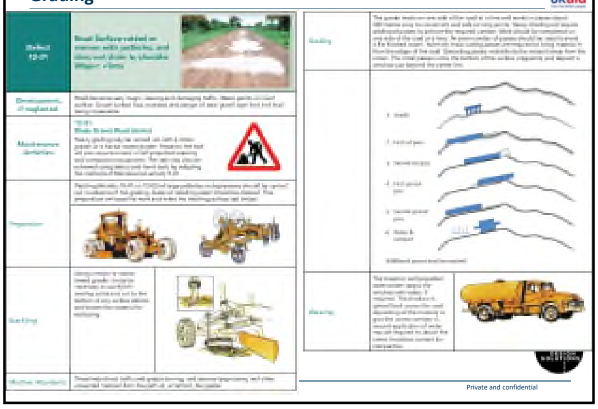
Defect	Maintenance Activity
4-01 Culvert/Drift silted/obstructed	4-01 Culvert/Drift Cleaning
4-02a Drain silted	4-02a Drain Cleaning (manual)
4-02b Drain silted	4-02b Drain Cleaning (mechanised)
5-01 Drain or slope eroded (minor)	5-01 Repair Erosion Damage (selected fill)
5-02a Drain or slope eroded (major)	5-02a Repair Erosion Damage (rock fill)
5-02b Slope eroded (major)	5-02b Terracing or Wattling
6-01 Mortared Masonry damaged	6-01 Mortared Masonry Repair
6-02 Dry Masonry damaged	6-02 Dry Masonry Repair
7-01 Gabion structure damaged	7-01 Gabion Structure Repair
8-01 Erosion in drain	8-01 Build stone/wooden scour check

Vegetation control



Drainage systems

Grading



Maintenance Specifications

DEFECT 1-02	ACTIVITY
	Bush Clearing m^2

Scope of works: Improve visibility to maintain safe sight distance, visibility of road signs, road markers, animals and pedestrians within the road reserve.

Specifications:

- Place warning signs and safety devices
- Cut, uproot and remove bushes to ensure that all bushes are cleared
- Workmen must ensure that no damage is caused to fixed objects such as road furniture when removing debris and cut or uprooted during clearing
- Backfill and compact to density of surrounding ground all excavated holes dug during removal of roots
- Collect and clear all cut roots and debris from drains, carriageway and road reserve, load and dispose to designated sites
- Measure and record the length and width of area cleared
- Remove temporary road signs and safety devices.

Description of bill item:

1-02: Clearing of bush, shrubs and roots on the side of the road to improve visibility and road safety. Unit of measurement shall be in m^2 of area of bush cleared.

Maintenance Specifications

DEFECT 12-01	ACTIVITY
	Blade gravel road carriageway (heavy) m

Scope of works: Mechanical grading gravel, scarify and move the material into a windrow and then mix and spread into required profile.

Specifications:

- Place warning signs and safety devices
- Rip and scarify the existing road surface and push into a window towards the centre of the road
- Additional material can be added if necessary
- Water and mix the material thoroughly
- Spread the material and compact forming the required profile
- Remove loose stones and windrows from the carriageway
- Remove traffic signs and safety devices.

Description of bill item:

12-01: Heavy grading of road surface to correct deep ruts, corrugations, potholes and camber. Unit of measurement shall be in carriageway-m of road graded.

Low Priority Issues

- Procurement of works (tendering);
- Planning (road prioritisation);
- Route selection;
- Design of chip seals and other bituminous surfacings;
- Technical Auditing.

Time Line

Inception Report (submitted early August 2017)

First Workshop (one day) – September 2017

Second Workshop (two days) –Early 2018

Submission of final draft MS Word version – June 2018

Launch of Manual – November 2018.

Workshop Programme

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Presentation on the Profile of Feeder Roads in Liberia

Presentation Outline

- Current status of the feeder road (FR) sector in Liberia
- Recent successes in the sector
- Challenges in the sector that need to be addressed

Current status of the feeder road sector in Liberia

The 13 years of civil crisis saw the deterioration of feeder roads through out the Country to the level where most of the roads were impassable by four wheel vehicle. That generated into hardship experienced by people in the rural areas.
Rehabilitation of feeder roads began in 2010 when the present Government allocated about US$9,000,000 to jump start the rehabilitation of Feeder Roads through out the Country. In the same year, the partnership with the Government of Sweden generated into another project named and styled the Liberian Swedish Feeder Roads Project(LSFRP) kick off in Lofa with extension into Bong and Nimba Counties.

Current status of the feeder road sector in Liberia

To date, from 2010 TO 2017 1,295.76km of feeder roads have been fully rehabilitated in the Country by GOL and the below listed partners:
GOL : 313.76km
MOA(STCRSP)/IFAD : 133km
LSFRP : 636km
USAID/ES3R & FRAMP : 213km

Current status of the feeder road sector in Liberia

Another partner Welthungerhilfe(WHH) has done and continues to do some improvement on feeder roads in the Southeast. Their intervention is mainly on road structures: construction of reinforced concrete u-culverts, box culverts and bridges in Grand Gedeh, River Gee and Sinoe Counties.

Road Structures(Reinforced concrete)
- ❑ U-culvert - 148
- ❑ Box Culvert - 26
- ❑ Bridges - 17

Partners area of concentration in feeder road sector

Sida area of intervention

Partners area of concentration in feeder road sector

FRAMP

Welthungerhelfe (WHH)

Recent successes in the sector

- Improved road surface: provided access for social services to rural people
- Feeder road Design Manual
- Routine Maintenance Manual
- Routine & Periodic Maintenance of feeder roads by CBO
- Usage of Design Manual by Stakeholders
- Capacity Building of FREs by Partners
- Road Fund

Challenges in the sector that need to be addressed

- Develop a culture of maintaining feeder road
- Strengthen local community in road maintenance activities
- Fill the gap of the Design and Specification Manual
- Capacity Building of feeder road Engineers

THANKS!!!

Geometric Design

Outline of Presentation

- Introduction
- References
- Road Classification
- How the Standards will be used
- Factors affecting Geometric Standards
- Design Speed and Geometry
- Road Cross Section
- Typical Cross Sections
- Horizontal Alignment
- Vertical Alignment
- Harmonisation of Horizontal and Vertical Alignment
- Summary of Geometric Standards for each Class of Road
- Questions

References

- Liberia Best Practice Guidelines – developed by LSFRP
- Liberia MoPW Geometric and Pavement Design Standards (2017)
- Liberia MoPW Feeder Roads Design Manual and Specifications (2016)
  - This is a comprehensive manual which will be used for the development of the new manual in terms of geometric design
- Liberia MoPW Feeder Road Design Manual (2012)
- Ghana DFR Design Standards (2009)
- Sierra Leone MoWHI National Rural Feeder Roads Policy Document (2011)
- Ethiopia RA Manual for Low Volume Roads (2016)
  - This is a comprehensive manual, parts of which will be used for the development of the new manual in terms of geometric design

Introduction

- Purpose of Roads:

  To provide traffic mobility between centres and areas, and to provide access to adjoining land and properties.

- Definition of Geometric Design:

  The process whereby the layout of the road through the terrain is designed to meet the needs of ALL road users.

- Objectives of Geometric Standards:

  To provide acceptable levels of safety and comfort for drivers through provision of adequate sight distances, coefficients of friction, road space for manoeuvres, and to minimise earthworks to reduce construction costs.

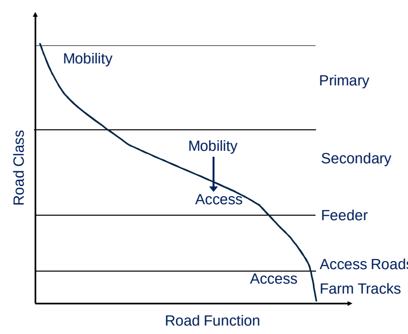
- Objectives of the Geometric Design Chapter in the new LVR Manual:

  To provide Geometric Design principles, recommendations, guidance and standards to enable the low volume road designer to meet the safety and comfort standards appropriate to the local environment for roads carrying less than 300 vehicles per day.

Road Classification

- LVR's generally carry relatively low volumes of traffic, typically less than 300 vpd and make up a significant proportion of the road network.
- LVR's provide the only form of access to rural communities and provide basic access to essential services.
- In Liberia rural roads are divided into 3 classes according to their function in the road network:
  - Primary Roads
  - Secondary Roads
  - Feeder Roads (LVR's)
- LVR's generally provide:
  - Connections within the county and districts from the Primary or Secondary roads.
  - Access to villages or settlements.

Road Classification



How The Standards Will Be Used

- Design Procedure
  - Steps will be provided for selecting the appropriate standards to be used in the geometric design process including a flow diagram.
- Scenario 1: Upgrading an Existing Road
  - Basic alignments already exist and spot improvements may be required to meet the required design standards.
- Scenario 2: Upgrading an Existing Track
  - Sub-standard alignments already exist and improvements will be required to meet the required design standards.

  Alternatively appropriate traffic calming measures can be used to reduce speed to avoid costly realignment where upgrades are required.
- Scenario 3: New Roads
  - Requires viability and route determination investigations prior to road design.

Factors Affecting Geometric Standards

The following factors that affect the geometric standards will be discussed in greater detail in the new LVR Manual:

- Cost
  - Costs associated with road construction, operation and maintenance is directly related to the geometry standard adopted.
- Level of Service (LOS)
  - LOS is directly associated with traffic volume and increases with increase in road class.
- Traffic Volume
  - Geometry standards are justified in accordance with traffic volume and increase with increase in traffic volume.
  - For LVR's the design control is Average Annual Daily Traffic (AADT) in the 'design year' incl. distribution by vehicle type.

Factors Affecting Geometric Standards (Continued)

- Traffic Composition
  - Geometry standards depend on the type of vehicles expected to use the facility i.e. lower standards can be used for smaller vehicles.
  - In Liberia LVR's are expected to accommodate small trucks with 2 axles and 3 tonnes of cargo.
- Terrain
  - Geometry standards are dependant on the terrain i.e. flat terrain can accommodate higher geometry standards, whilst hilly or mountainous terrain will only support lower standards.
  - 3 categories have been defined i.e. Flat, Rolling, Hilly or Mountainous.
- Roadside Population
  - Geometry standards are required to be modified to ensure good access and enhance safety through populated areas.

Factors Affecting Geometric Standards (Continued)

- Pavement Type
  - Surfaced (concrete, asphalt, seal or gravel) or unsurfaced (earth).
  - Surfaced roads provide higher traction or friction for vehicles as opposed to unsurfaced roads thus geometry standards are required to be higher for unsurfaced roads than for surfaced roads.
  - Supporting pavement structures generally apply to higher standard roads and consist of natural selected engineering grade crushed stone or gravel material.
- Soil type and Climate
  - Problem soils can be mitigated through geometric design such as flattening road embankments where unstable soils are encountered.
  - In Liberia the construction of LVR's generally make use of good local materials such as lateritic gravels (predominant) and sands (found in coastal areas).
  - The impact of problematic wet climates can be mitigated through geometric design such as increasing road slopes to increase precipitation runoff.

Factors Affecting Geometric Standards (Continued)

- Safety
  - One of the main objectives in geometric design and will be discussed in a separate Chapter of the presentation.
- Construction Technology
  - Labour abundant countries are required to maximise the use of labour rather than rely on equipment-based methods of road construction, thus geometric design needs to take this into consideration.
- Administrative Function
  - The administrative functional of a road may control the standards to be adopted irrespective of levels of traffic.
- Environmental
  - The location and design of the road should maximise positive effects and minimise negative effects on the environment.
  - Dust pollution, uncontrolled quarry operations, environmental degradation arising from logging activities due to increased access to remote areas are the major concerns.
  - Environmental impact assessments should be carried out for every road design

Design Speed and Geometry

The following aspects of geometric design will be discussed in greater detail in the new LVR Manual:

- Design Speed
  - Maximum safe travel speed which can be maintained over a specific section of road under free flow conditions to which Geometric Standards are related.
  - Higher design speeds require higher Level of Service (LOS) and consequently are more costly to construct.

LIBERIAN RECOMMENDED DESIGN SPEEDS

Surfaced			Unsurfaced		
Flat	Rolling	Mountainous	Flat	Rolling	Mountainous
70km/h	60km/h	40km/h	70km/h	50km/h	30km/h

- Sight Distance
  - Length of roadway ahead, clear of objects, required to visible to the driver and is the most important influence on road safety and efficient operation.
  - Sufficient sight distance is to be provided both longitudinally and laterally.

Design Speed and Geometry (Continued)

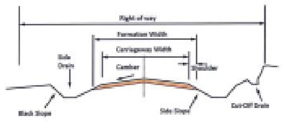
- Stopping Sight Distance
  - Distance a vehicle requires to stop safely upon viewing an object in the road and is used for the basic geometric design of the road alignments.
  - No standards currently exist – refer to Ghanaian standards below.
- Intersection Sight Distance
  - Same as for stopping however based on the object viewed being another vehicle entering the road from an intersecting side road.
  - A table reflecting these distances will be included in the manual.
- Passing Sight Distance
  - Distance a vehicle requires to overtake another safely and is used for design of passing opportunities and no-overtaking sections of roadway.
  - No standards currently exist – refer to Ghanaian standards below.

GHANAIAN RECOMMENDED SIGHT DISTANCES

Design Speed (km/h)	20	30	40	50	60	70
Min. Stopping Distance (m)	20	30	50	60	80	100
Passing Sight Distance (m)	115	170	230	290	350	420

Road Cross Section

The following elements relating to road cross section will be discussed in greater detail in the new LVR Manual:



- Road Widths:
  - Ideally roadway widths are required to be wide enough for 2 vehicles to pass safely without having to use the verge.
  - LVR's normally operate as single lane roads where vehicles drive in the centre of the road, and on the rare occasion that vehicles meet, they are able to slow down or stop in order to pass.
  - Generally the LVR road element widths are standardised based on whether these are surfaced or unsurfaced and may be influenced by the type of terrain in some cases.
  - Standard road widths for LVR's are included at the end of the Section.

Road Cross Section (Continued)

- Shoulders
  - Surfaced or unsurfaced edge supports to contain the road carriageway.
  - Protects road pavement structure from surface runoff ingress.
  - Provides safe space for non-motorised travellers, emergency vehicle breakdowns etc. where sufficiently wide enough.
- Camber
  - Facilitates the drainage of the roadway by shedding stormwater runoff to the side drains.
  - For unsurfaced roads this is generally 5 - 7% however 6% has been suggested for LVR's.
  - For surfaced sections this can be reduced to 2 to 3%.
  - Road slope changes introduced to counteract centrifugal forces of a vehicle negotiating a horizontal curve is referred to as superelevation and will be discussed later in the Chapter.

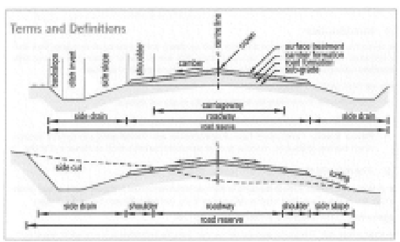
Road Cross Section (Continued)

- Roadside drains
  - Introduced to convey stormwater runoff from the road surface to suitable discharge points to avoid saturation of the pavement layers.
  - Flat bottomed drains are recommended for LVR's as V-shaped drains formed of earth develop erosion lines easily.
- Clearances
  - Minimum lateral clearance from the carriageway = 0,25m – 0,5m
  - Minimum vertical clearance above carriageway = 5m
  - Clear zones or verge areas to be kept clear of obstacles which may be hazardous to vehicles which leave the roadway.
- Side Slope
  - Slope of earthworks cut and fill embankments generally affected by stability characteristics of the natural soil.
  - In Liberia side slopes may range from 1:2 to 1:4

Road Cross Section (Continued)

- Right-Of-Way (ROW)
  - Area reserved for the roadway, drainage systems, signage, services, clear zones, non-motorised travellers, and for accommodating future upgrading requirements.
  - In Liberia ROW widths are 15m.
- Passing Opportunities
  - Where road widths are very narrow i.e. <3m, it may be necessary to install passing opportunities.
  - Generally required every 300m to 500m for road widths <3m.
  - Can be installed as widened shoulders where 2 vehicles are unable to pass or where slower moving vehicles obstruct following vehicles from safely overtaking e.g. on steep inclines.

Typical Cross Sections



LIBERIAN RECOMMENDED ROAD CROSS-SECTION STANDARDS

Road Type or Class	ADT	Surface Type	C/Way Width	Shoulder Width	Roadway Width	Crossfall or Camber	ROW Width
Feeder or LVR	>50	Surfaced	6m	0,5m	7m	3%	15m
Feeder or LVR	>50	Unsurfaced	6m	0,25m	6,5m	5 - 7%	15m

Horizontal Alignment

The following elements of horizontal alignment design will be discussed in greater detail in the new LVR Manual:

- Straights or Tangent Sections
  - Beneficial in flat terrain however less in rolling or mountainous terrain.
  - Provides good visibility and greater passing opportunities.
  - However increases danger from excessive speeding and headlight glare.
  - Generally straights should not exceed 4km in length.
- Superelevation
  - It is proposed that superelevation be excluded from unsurfaced LVR's as this increases the path length stormwater runoff has to travel over the roadway potentially leading to erosion of the earth or gravel surface.
  - Can potentially create ponding at points where the superelevation development is flat or crosses over.

Horizontal Alignment (Continued)

- Horizontal Curves
  - Must be appropriately designed for design speeds >50km/h
  - Avoid sharp curves for obvious reasons.
  - Current recommended minimum curve radii are indicated below.
  - New minimum curve radii will need to be developed as current recommendations are based on superelevation slopes.
  - For small changes of direction it is however desirable to use large radius curves to improve appearance and reduces the tendency for road users to cut corners.
  - Curve lengths should be kept to a minimum as overtaking on curves is generally difficult and often difficult to maintain adequate sight distance.

LIBERIAN MINIMUM RADII OF CURVATURE

Design Speed (km/h)	30	40	50	60	70	80
Minimum R for SE = 7% (m)	30	55	90	130	185	240

Horizontal Alignment (Continued)

- Curve Widening
  - To be applied where tight curves are unavoidable to allow for the swept paths of large vehicles and to allow drivers to manoeuvre when approaching oncoming vehicles.
  - Generally applied to the inside of the curve.
  - The following table reflecting widening recommendations based on curve radius will be included in the manual.

LIBERIAN RECOMMENDED CURVE WIDENING

Curve Radius (m)	<30	31 - 60	61 - 150	>150
Increase in Width (m)	1.5	1.0	0.6	NA

Vertical Alignment

The following elements of vertical alignment design will be discussed in greater detail in the new LVR Manual:

- Gradient
  - Grades should be kept as low as possible and consideration should be given to alternative surfacing options on high grade sections or hairpin bends in mountainous terrain.
  - Minimum gradient recommended is 0,5% (1:200) to assist with side drain conveyance of stormwater runoff.

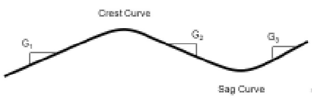
LIBERIAN RECOMMENDED MAXIMUM GRADIENTS

Design Speed (km/h)	30	40	50	60	70	80
Surfaced Roads (%)	12	10	8	8	7	6
Unsurfaced Roads (%)	12	10	8	8	7	

- Vertical Curvature
  - Parabolic curves defined by length unlike radius for horizontal curves.
  - Minimum length is defined by L = K x G where L = length of curve; G = algebraic difference in grade (%); K = relationship of design speed and safe stopping sight distance.

Vertical Alignment (Continued)

- Crest Curves
  - Based on daylight safe stopping sight distance and thus related to design speed as well as minimising driver discomforting forces.
- Sag Curves
  - Based on night-time vehicle headlight illumination distance limitations.



Recommended minimum K values = 8 for crest curves and 2.2 for sag curves.

No curve length values currently exist but will be developed – refer to Ghana's below.

GHANAIAN RECOMMENDED K VALUES & MINIMUM VERTICAL CURVE LENGTH

Design Speed (km/h)	40	50	60	70
K Values for Crest Curves	4	8	14	30
K Values for Sag Curves	5	7	10	18
Min. Vertical Curve Length	35m	40m	50m	70m

Harmonisation of Horizontal and Vertical Alignment

The following recommendations should also be considered when designing the road alignment and will be discussed in greater detail in the new LVR Manual:

- Avoid horizontal curves with changing radius that generally come as a surprise to road users.
- Avoid isolated curves connected with long tangents may come as a surprise to road users particularly if the curve is close to the minimum radius.
- Long curves are problematic to road users as they are difficult to negotiate as opposed to shorter length curves.
- Inappropriate combinations of horizontal and vertical alignments, e.g. a sharp horizontal curve located beyond a pronounced vertical crest curve, is not desirable.
- Avoid skew intersections and cross-intersections – stagger rather.
- Staggered intersections should not be located minimum 40m apart.
- Good visibility of intersections are required from both directions.
- Avoid steep grades at intersections which lead to longer vehicle acceleration and deceleration distances.

Summary of Geometric Standards for Each Class of Road

It is proposed that all the various geometric design standards be contained in a single matrix table for each class of road as shown in the example below.

Design Element	Unit	Flat	Rolling	Mountain	Escarpment	Populated areas
Design speed preferred	km/h	70	60	50[2]	25[2]	50
Road width	m	7.0[4]	7.0[4]	7.0[2]	7.0[2]	7.0[3,4]
Max. desirable gradient	%	4	6	6	6	4
Maximum gradient	%	6	9	9	9	6
Minimum gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum super-elevation	%	6	6	6	6	6
Normal cross-fall [5]	%	6	6	6	6	6
Minimum stopping sight distance	m	125	95	70	25	70
Maximum super elevation	%	6	6	6	6	6
Minimum horizontal radius Super elevation = 4%	m	245	175	110	25	110
Minimum horizontal radius Super elevation = 6%	m	215	155	100	20	100
Minimum crest vertical curve	K	34	19	11	2.5	11
Minimum sag vertical curve	K	5	3.5	2.2	1	2.2

Questions?

Road Safety

Outline of Presentation

- Introduction
- Traffic Signs
- Road Markings
- Traffic Calming
- Safety Barriers
- Safety Audits
- References
- Questions

Introduction

- Road accident statistics common with many African countries show that death rates from road accidents are 30 to 50 times higher than in Western countries.
- Economic analysis has also shown conclusively that a high level of road accidents has very significant economic consequences for a country.
- There are a number of key principles of design that can considerably improve road safety:
  - Consider ALL road users including non-motorised travellers,
  - Provide adequate warning signage where potential hazards exist,
  - Encourage appropriate speeds through design,
  - Reduce conflicts if possible,

Introduction (Continued)

- Objectives of the Road Safety Chapter in the new LVR Manual:
  To provide Road Safety design principles, recommendations, guidance and standards to enable the low volume road designer to meet the safety standards appropriate to the local environment for roads carrying less than 300 vehicles per day.
- Some general safety considerations:
  - Prevent accidents e.g. provide adequate drainage of road surface.
  - Reduce the severity of accidents e.g. through provision of flat roadside slopes.
  - Separating vulnerable road users from motorised traffic e.g. through provision of road shoulders or footways.

Traffic Signs

The following types of road signs will be discussed in greater detail in the new LVR Manual:

- Regulatory Signs
  - Indicate legal requirements of traffic movement.

- Warning Signs
  - Indicate conditions that may be hazardous to road users.

- Information Signs
  - Convey information of use to road users.

- Marker Posts
  - Guideposts intended to make road users aware of potential hazards e.g. drainage structures located on the road verge.
  - Kilometre posts generally only required on higher order roads.

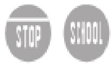
Road Markings

The following types of road markings will be briefly covered in the new LVR Manual due to it's appropriateness to surfaced roads and not unsurfaced:

- Regulation Markings and Symbols
  - Indicate legal requirements of traffic movement.

- Warning Markings and Symbols
  - Indicate conditions that may be hazardous to road users.

- Information Markings and Symbols
  - Convey information of use to road users.



- Object Markers
  - Hazardous objects in the clear zone impractical to be removed should be adequately painted by use of high-visibility material.
- Road Studs
  - Reflective devices installed to demarcate the road centreline at night.

Traffic Calming

- The following various methods of improving road safety through the implementation of traffic calming measures will be discussed in greater detail in the new LVR Manual:
- Road Alignment Controls
  - Manipulation of the road alignment or road features, such as reducing width, to cause road users to slow down e.g. chicanes.
- Warning Devices
  - Installation of artificial road texture on sealed road sections that causes considerable tyre noise and vehicle vibrations to warn road users of hazardous conditions and cause them to slow down e.g. rumble strips.
- Speed Reduction Humps and Cushions
  - Most common method used to slow traffic.
  - Generally preceded by road warning devices.
  - Unlike road warning devices these are higher and potentially hazardous if not designed correctly.
  - Humps extend the full width of the road whilst cushions have considerable gaps to allow bicycles and motorcycles to pass through.

Traffic Calming (Continued)

- The 'Village Treatment' concept of traffic calming introduced in Ethiopia has proven to be successful.
- Using a combination of the traffic calming devices, pedestrian sidewalks, and busbays, a perception is created for the driver that the approaching village is a low speed environment with the aim to encourage him to reduce speed.

- The 'Village Treatment' is made up of 3 zones:
  - The approach zone - prior to entry of village where driver is made aware that the open road speed is no longer appropriate (80 – 50km/h),
  - The transition zone - gateway to core zone and first speed humps (50km/h)
  - The core zone - centre of village and activity zone with humps (40km/h)

Safety Barriers

The following aspects of safety barriers will be briefly discussed in the new LVR Manual due to it's appropriateness to higher order roads:

- Segregating Vulnerable Road Users
  - Provision of physical separation between motorised vehicles in opposing directions and also with non-motorised travellers i.e. pedestrians and cyclists e.g. by means of crash barriers.
- Crash Barriers
  - Prevents vehicles traveling in opposite directions from colliding with each other head on.
  - Primarily used on LVR's to prevent vehicles from leaving the road where hazardous conditions exist e.g. at the top of high fills.

Safety Audits

- Road safety is complex by nature, and although many unsafe practices are glaringly obvious, there are many situations where it is difficult to identify what is likely to be unsafe, especially in the case of a new road where one is working from drawings.
- Road safety improvements mostly rely on reliable historic data much of which is never recorded or analysed using road accident characteristics.
- Professional road safety auditing is the next best practice and should be regularly undertaken on every road project particularly for road projects in populated areas.
- The new LVR manual will provide greater detail on this subject.

References

- Ethiopia RA Manual for Low Volume Roads (2016)

References

- LVR roads in Liberia

ReCAP

Research for Community Access Partnership

UKaid

Questions?

Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First Stakeholder Workshop

Materials and Pavement Design

Monrovia - Liberia

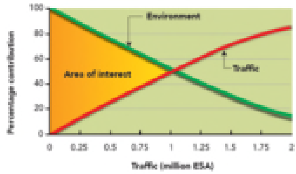
21 September 2017

Outline of Presentation

- Principles of Low Volume Road pavement design
- Site physiography
- Traffic
- Materials
- Pavement design
- Quality Assurance & Quality Control

Principles of LVR pavement design

- Low volume road :
  - ≤ 300 vpd (middle design life)
  - ≤ 1 million cumulative ESA's
- Performance more dependent on environment than traffic



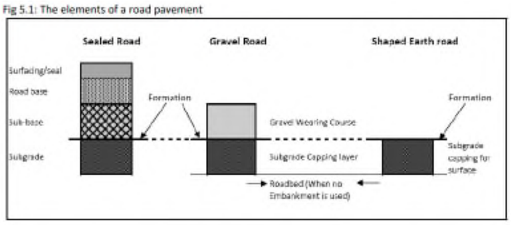
- Conventional planning, design, construction and maintenance philosophies for higher volume roads do not apply

Principles of LVR pavement design

- Multiple structural layers seldom warranted for unpaved roads
- Budgets for construction and maintenance are constrained
- Considerations for design:
  - Raise formation and gravel wearing course above NGL
  - Allowance and provision for cross drainage
  - Treatment of unsuitable subgrade material
  - Maintenance capacity and frequency
  - Phased construction, possible future upgrade to surfaced standards
- Low Volume Paved Roads vs Unpaved Roads
  - Surface dressing / surfacing seal (possibly alternative surfacing)
  - Gravel roads
  - Earth roads (un-engineered, semi-engineered)

Principles of LVR pavement design

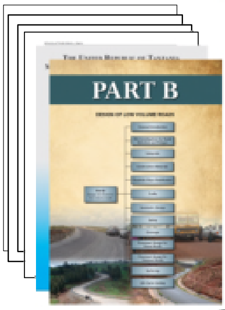
Fig 5.1: The elements of a road pavement



Principles of LVR pavement design

Principles of LVR pavement design

- Reference documents:
  - TRL: Overseas Road Note 31
  - MPW: Geometric and Pavement Design Standards
  - MPW: Feeder Roads Design Manual and Specifications
  - MPW: Technical Specifications for Contracted Rural Roads Projects
  - LVR Manuals various other AfCAP countries:
    - Tanzania
    - Ethiopia



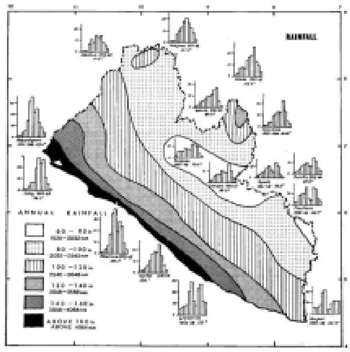
Principles of LVR pavement design

1. Design Principles
   - Road category
   - Design Period
   - Site Physiography
2. Traffic Design
   - Traffic volumes
   - Traffic loading
   - Traffic class
3. Design Investigations
   - Subgrade Characterisation
   - Material Selection
4. Structural Design
5. Economic Analysis

Site physiography

- Topography:
  - Flat
  - Rolling / hilly
  - Mountainous
- Geology
- Soils and vegetation
- Climate:
  - Temperature
  - Rainfall

Site physiography

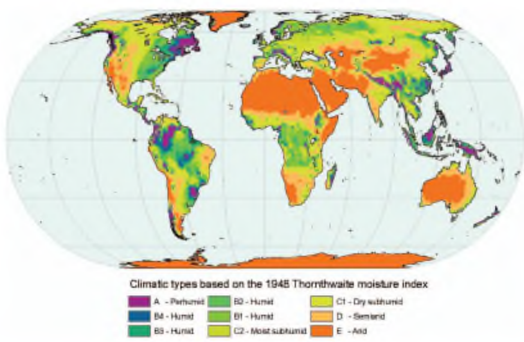


Site physiography

- Climatic indicator, e.g.:
  - Thornthwaite Moisture Index
  - Weinert N-value

Thornthwaite	Climatic region	Weinert	Climatic Region
< -40	Arid	> 5	Dry
-40 to – 20	Semi-arid		
-20 to 0	Dry sub-humid	3 To 5	Moderate
0 to 20	Moist sub-humid		
20 to 100	Humid	< 3	Wet
> 100	Perhumid		

Site physiography

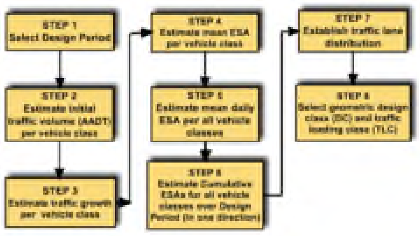


Traffic

- Traffic surveys:
  - Classified traffic counts
    - Motorised vs. NMT
    - Stationary vs Moving Observer Count (WB method)
  - O-D surveys
  - Axle load surveys
- Potential variations:
  - Seasonal (wet vs. dry)
  - Daily (market vs. non-market day)

Traffic

- Method of determining cumulative traffic loading is well documented
- Typical process:



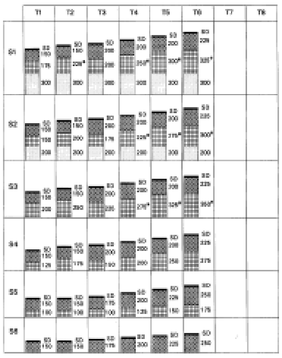
Traffic

- 3 No. Traffic Load Classes proposed for pavement design:

Traffic Load Class	Cumulative traffic load during design life (million ESAs)
TLC 1.0	0.3 – 1.0
TLC 0.3	0.01 – 0.3
TLC 0.01	< 0.01

Principles of LVR pavement design

- Typical catalogue design



Design Investigations

- Materials investigation:
  - New road; focus on:
    - Subgrade
    - Available materials for road construction
  - Existing road:
    - Also determine strength existing road structure
- Subgrade characterisation:
  - Material sampling and testing (grading, indicators, CBR)
  - DCP testing (DN, CBR)
  - LWD testing (Emod)

Design Investigations

- 4 No. proposed subgrade classes for pavement design:

Subgrade Class	CBR Range [%]	Treatment and typical usage
S1	< 3	Special treatment required
S2	3 – 7	Suitable as fill
S3	7 – 15	Suitable as fill
S4	> 15	Suitable as improved subgrade / subbase

Materials

- Build on material classifications as design manual and standard specifications
- Wearing course materials (TRH20):
- Type of surfacing:
  - Traditional surfacings
  - Non-traditional surfacings (FRAM ALVRS)
  - Non-traditional stabilisers

Wearing Course Material

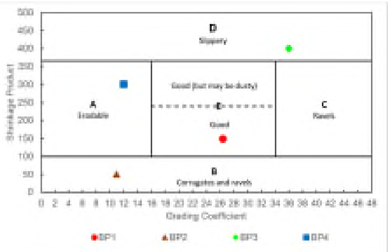
- Feeder Road Design Manual:

Table 5.2 Specifications for Gravel Wearing Course

Grading	Grading Envelope	Per cent (%) by Mass Passing	
		Class 1	Class 2
	37.5 mm (1½ in)	100	100
	20 mm (¾ in)	95 - 100	85 - 100
	14 mm	80 - 100	60 - 100
	10 mm (⅜ in)	65 - 100	55 - 100
	5 mm (No 4)	45 - 85	35 - 92
	2 mm (No 10)	30 - 65	23 - 77
	0.425 mm (No 40)	18 - 43	14 - 60
	0.075 mm (No 200)	12 - 32	10 - 40
Maximum particle size		25 mm (1 in)	25 mm (1 in)
Reject Index		< 20	< 10
Grading Modulus		1.0 - 1.7	1.0 - 1.8
Grading Coefficient		16 - 34	16 - 34
Plasticity			
Plasticity Index (PI)	Wet Regions	10 - 15	
	Semi arid /dry Regions	12 - 20	
Plasticity Product (PP)	Wet Regions	200 - 400	
	Semi arid /dry Regions	280 - 1000	
Shrinkage			
Shrinkage Product		100 - 365	
Strength			
CBR	Wet Regions	20	
	Semi arid /dry Regions	15	
Minimum Compaction	Subgrade	[illegible] Mod AASHTO	
	Gravel wearing course	95% Mod AASHTO	

Wearing Course Material

- Selection of wearing course material:
  - Shrinkage Product SP = LS x $P_{0.425}$ 100 – 365 (240)
  - Grading Coefficient = ($P_{26.5}$ – $P_{2.0}$) x $P_{4.75}$ / 100 16 - 34



Zone A: Fine grained material prone to erosion

Zone B: Non-cohesive materials that lead to corrugations and ravelling / material loss

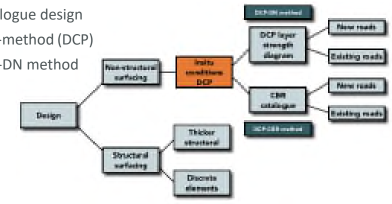
Zone C: Poorly graded materials that are prone to ravelling

Zone D: Fine plastic material prone to slipperiness and excessive dust

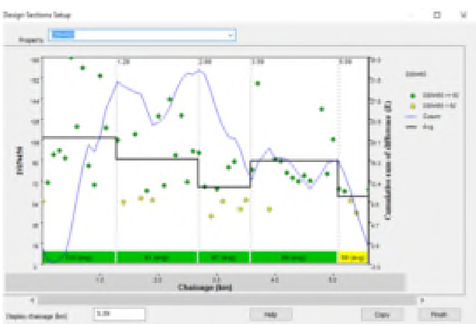
Zone E: Optimum materials for best performance

Pavement Design

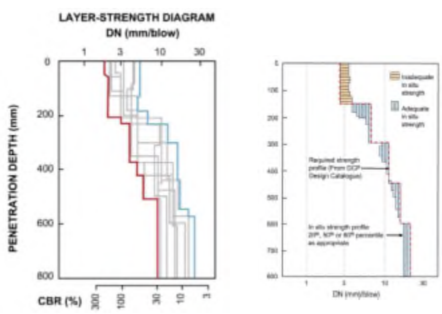
- Current design method:
  - No structural design methods for paved roads (Prim & Sec: ORN 31)
  - Gravel roads:
    - < 50 vpd : standard wearing course thickness
    - > 50 vpd : formula for thickness on improved subgrade
- Proposed:
  - Method 1: Catalogue design
  - Method 2: CBR-method (DCP)
  - Method 3: DCP-DN method



Pavement Design



Pavement Design



Pavement Design

- Gravel wearing course thickness (gravel loss):
  - Thickness = f (min. thickness, traffic, maintenance, design period)
    - Feeder Roads Manual
    - HDM-4
    - TRH20 (RSA)
    - Tabulated values:

Material Quality Zone [1]	Material Quality	Typical gravel loss (mm/yr/100vpd)
Zone A	Satisfactory	20
Zone B	Poor	45
Zone C	Poor	45
Zone D	Marginal	30
Zone E	Good	10

Private and confidential 25

Quality Management System

- Quality Plan
  - Provide guidance on the contractual specification for quality management and a quality plan
- Quality Assurance
  - Method statements
  - Work instructions
  - Control forms
  - Check lists
  - Measurement & Monitoring
- Quality Control
  - Production Control
  - Acceptance Control

Private and confidential 26

Quality Management System

- Example of materials sampling and testing plan:

Material	Frequency of the sampling and testing requirements
[illegible]	[illegible]
Grading tests	[illegible]
Atterberg limits	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Tests for concrete	
[illegible]	[illegible]
Cube strength tests	[illegible]
[illegible]	[illegible]
Grading	[illegible]
ACV	[illegible]
10% FACT	[illegible]
Water absorption	[illegible]

Private and confidential 27

ReCAP

UKaid

Questions?

Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First Stakeholder Workshop

Dr Gareth Hearn

Monrovia

21st September 2017

Investigations & Roadside Stabilisation

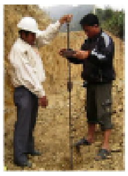
Contents

Roads in hilly and mountainous terrain

Investigations & Roadside Stabilisation

Background Literature

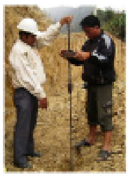
- Feeder Roads Design Manual (LSFRP-MPW 2011/16)
- Technical Specifications for Feeder Road Works and Minor Bridges (LSFRP-MPW)
- Best Practice Guidelines (LSFRP-MPW undated)
- Engineering Services for Rural Roads Rehabilitation Project – Technical Specifications (USAID – MPW 2015)
- Geometric & Pavement Design Specification (GIZ-MPW 2017)
- Other documents and manuals from the African region, e.g Ethiopia LVR, SI, Geotech Design Manuals and Tanzania LVR Manual



Investigations & Roadside Stabilisation

Feeder Roads Design Manual

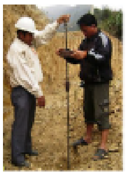
- Emphasises maximum use of local materials
- States that field surveys need to be carried out and material properties determined
- Provides outline of standard material tests for subgrade
  - PIs; PSDs; CBRs; field density
- Provides pavement design in relation to the range of material types/strengths
- No discussion on techniques of investigation and field testing
- No discussion on earthwork design in relation to geology, materials or slope protection



Investigations & Roadside Stabilisation

Technical Specifications for Feeder Roads and Minor Bridges

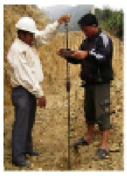
- Specifies testing requirements for subgrade and fill
- General specifications and outline description of ground improvement, cut and fill geometry and earthworks management
- Construction materials specification
- Roadside planting and erosion protection
- Not particularly Liberia-specific in terms of geology and materials setting



Investigations & Roadside Stabilisation

Best Practice Guidelines

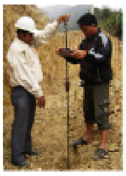
- Outline principles of:
- Environmentally-optimised design
- Road alignment
- Cross-sections, including side slopes
- Earthworks management and material selection.



Investigations & Roadside Stabilisation

Engineering Services for Rural Roads Rehabilitation

- Defines standard tests for subgrade and materials (CBR; PIs; PSDs
- Specifications for subgrade and fill
- Earthworks specifications
- Not Liberia-specific in terms of geological and materials setting

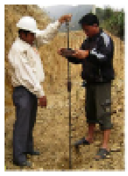


Investigations & Roadside Stabilisation

Geometric & Pavement Design Specification

- Useful background to topography & soils
- Subgrade strength and CBR values
- Choice of cross-section cut and fill slide slopes recommendations
- Outline consideration of slope stability

- Limited discussion on techniques of investigation



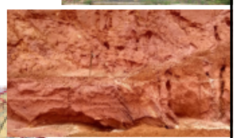
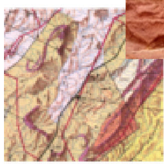
Route Selection

- Principal factors
  - Engineering
  - Cost
  - Environmental
- Methods of route investigation
  - Desk study
  - Field work
- Methods of route comparison and selection
  - Illustration - the route selection for the Gangra haul road, Nimba Mountains will be used as an illustration


Private and confidential 9

Investigations for new roads and road improvement schemes

- Geological investigations
  - Role of geology in LVR engineering
    - Common rock types of Liberia
    - Weathering profiles and soil types
      - In situ weathered soils
      - Colluvial soils
      - Alluvial soils
  - Desk study data sources in Liberia
    - Published maps
    - Remote sensing

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Investigations for new roads and road improvement schemes

- Problematic soils
  - Weathered lateritic soils
  - Soft compressible soils
  - Expansive soils?
  - Collapsible soils?
  - Dispersive soils?
  - Soils prone to erosion

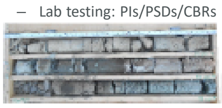
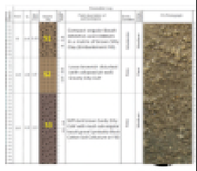


Private and confidential 11

Investigations for new roads and road improvement schemes

- Sub-grade investigations
  - Importance of sub-grade condition
    - For embankments and pavements
    - For foundations to bridge abutments and other structures
  - Techniques of investigation
    - Field mapping
    - Trial pitting
    - In situ testing - DCP
    - Drilling investigations
    - Lab testing: PIs/PSDs/CBRs



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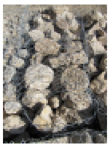
Investigations - materials

- Construction materials: prospecting for borrow pits and rock quarries
  - Capping layer
  - Fill material
  - Subbase-base material
  - Sand, aggregate, rock fill etc


Investigations - materials

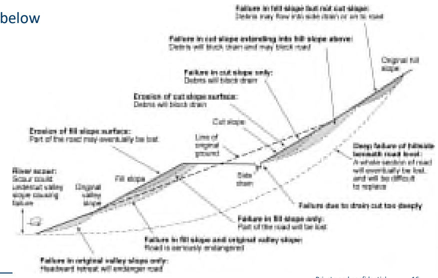
- Construction materials continued –
- Prospecting techniques
  - Desk study
    - -Topographic maps
    - -Geological maps
    - -Remote sensing
  - Field investigations – borrow pits
    - -Surface mapping
    - -Trial pitting
    - -Sampling & laboratory testing
    - -Survey of designated source areas
  - Field investigations – rock quarries
    - - Geological mapping
    - - Drilling investigations
    - - RQD


Investigations - materials

- Construction materials continued –
- Borrow pit operation and restoration
  - Control of runoff
  - Stockpiling and control of erosion
  - Restoration
    - Landscaping
    - Re-topsoiling
    - Replanting


Roadside slope stabilisation

- Mechanisms of slope instability and erosion
- Instability in natural slopes
- Instability in cuts and fills
- Instability above the road
- Instability below



Roadside slope stabilisation

- Design, stabilisation, mitigation
- Cut slope geometry (rock/soil vs height vs angle)
- Slope stabilisation measures (earthworks, drainage, retaining walls)
- Slope protection measures (erosion control, netting, retention walls)




Roads in hilly and mountainous terrain

- Route selection and alignment design
- Choice of cross-section
- Earthworks design and spoil disposal
- Slope stabilisation and erosion control
- Cross-drainage

Thank you
Any questions?

Hydrology/Drainage

Festus Odametey

Outline

1. *Introduction*

i. General

Water is often the cause, whether directly or indirectly of roadway destruction or pavement failure. Poor drainage is a major contributing factor to failure of road pavement structure.

ii. Purpose

To equip the Design Engineer with the need knowledge, tools and techniques for effective design of drainage structures on Low Volume Roads.

iii. Scope

- cover extensively the steps required to design storm drainage structures to minimize or eliminate flooding of Low Volume Rural Roads (LVRR).
- ensure that Low Volume Rural Roads are motorable all year round by providing adequate drainage structures across and along the road corridor to keep surface free of surface runoff after heavy downpours.

- Three main stages involved in the design of drainage structures namely:
  - Data collection
  - Hydrological studies (estimation of peak flows)
  - Hydraulic analysis (estimation of capacities of drainage structures)

iv. Summary of Standards

- Design Return Periods

Type of Drainage Structure	Designed Return Period, years	Maximum Return Period, years
Unlined side drains	2	5
Lined Side drains	5	10
Drifts	2	5
Vented Drifts	5	10
U and Pipe Culverts	10	25
Minor Box Culverts	10	25
Major Box Culverts	25	50
Small Bridges, Span < 10m	25	50
Major Bridges, Span >= 10m	50	100

- Minimum Culvert Size
  - A minimum size of 900 x 1200 diameter U-Culvert or 900 mm diameter pipe culvert is recommended for watercourse culvert.
  - A minimum culvert size of 700 x 900 diameter U-Culvert or 600mm diameter pipe culvert is recommended for access culvert
- Minimum and Maximum Velocities
  - Velocities in the range of 1.0m/s (min.) to 3.0m/s (max.) tend to have fewer operational problems than culverts that produce velocities outside of this range.
- Multiple Cell/Barrel Culvert
- Culvert Material Selection
- End Treatment (Inlet & Outlet)
- Outlet Protection

- Culvert Alignment and Grade
  - It is recommended that culverts be placed on the same alignment and grade as the natural streambed, especially on year-round streams.
- Sections of Drains
  - *Open – Trapezoidal*

    Minimum bottom width: 30cm

    Side Slope Unlined: 1:2 to 1:4

    Side Slope Lined: 1:1, 1:1.5, 1:2
  - *Circular/Pipe Culverts*

    Minimum Diameter: 900mm for cross culverts and 600mm for accesses/junctions

    Maximum Diameter: 1500mm/2000mm

    Minimum Cover: 0.6m

- *Rectangular Culvert*
  Minimum Height 1.0m
  Minimum Width 1.0m

- *U-Culverts*
  Minimum Height 0.7m
  Minimum Width 0.9m

- *Carrying capacity of drains:*
  Manning's roughness coefficient, n.

Material in the drain	Roughness coefficient
Concrete lined channel.	0.013 – 0.015
Sandcrete block	0.015 – 0.020
Masonry	0.017 – 0.030
Earth (new)	0.018 – 0.030
Earth (existing)	0.022 – 0.060

- *Flow Velocities in Drains*
  Minimum Velocities in all drains 0.60 m/s
  Maximum Velocities;
  i. Open Earth Drains (no lining) 1.7 m/s
  ii. Block / Masonry lined 2.5 m/s
  iii. Reinforced Concrete 2.5 – 3.0 m/s
- *Freeboard*
  Open Drains 0.30m
  Culverts 0.67m

v. General Considerations
- Environmental Considerations
- Safety Considerations

vi. Terminologies

2. *Hydrological and Drainage Studies*

i. Administrative Processes
- Collection of Existing Documents and Desk Studies
- Field Data Collection

ii. Classification of LVR Drainage
- Surface Drainage
- Subsurface Drainage
- Slope Drainage
- Drainage of Structures

iii. Catchment Characteristics
- Land Use
- Soil Type
- Slope
- Stream Length
- Catchment Area

iv. Estimation of Peak flow

a. Field Observation Methods
- Direct Observation of the size of the Stream Channel or Watercourse
- Direct Observation of Erosion and Debris
- History and Local Knowledge
- Replicating Successful Practice

b. Rational Method
- Gives satisfactory discharge results only on small catchments areas i.e. < 2.0 square kilometers.
- It is assumed that the intensity of the rainfall is the same over the entire catchment area.

– Required Data:
- ✓ Runoff Coefficient
- ✓ Rainfall Intensity
- ✓ Catchment Area

c. Modified Rational Method
- Use for larger catchment i.e. > 2.0 square kilometers.
- Areal Reduction Factor (ARF)

d. WinTR 20
- Subarea Parameters
- Stream Parameters
- Structure Data
- Design Return Period

3. *Choice of Drainage Structure*

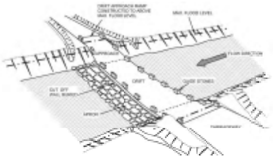
i. Side Drains
- Rectangular (U-Shaped) concrete lined –Recommended at settlement areas along the road corridor
- Trapezoidal Earth Channel
- Trapezoidal Stone Pitched
- Trapezoidal Concrete Lined
- Triangular (V-Shaped) Earth Channel

ii. Culverts
- Watercourse Culverts: Usually Pipe and Box culverts will be used.
- Relief Culverts: Pipe and U-Culverts will be recommended
- Access Culverts: U-Culverts will be recommended at accesses

iii. Small Bridges
- Will be recommended where stream depth is greater than 4.0m

iv. Drifts and Vented Drifts or Causeways

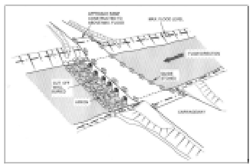
- Drifts are suitable for shallow water courses with a gentle gradient and at sites where raising the road over a culvert would require the transport of large quantities of earth. **Depth of flow ≤ 0.3m**



Typical features of a drift

A Hand Packed drift

- Vented drift is a combination of a culvert and a drift. They are suitable for carrying roads across water courses which have a base water flow for most of the year and which have large flows for less than three days after heavy rains.



Typical features of a vented drift

A typical vented drift / causeway

4. *Hydraulic Analysis*

i. Introduction

Hydraulic design is aimed at minmizing or eliminating their occurrence of Overtopping and washing out of embankment; scouring; erosion; etc.

ii. Side Drains

- Longitudinal ditches
- Mitre drains (Turn-outs)
- Catch water drains (Cut-off ditches/drains)

Design Methods:

- The flow capacities of side drains can be determined from the simple expression:

$$Q = VA \text{ i.e. Manning's formula}$$
$$V = 1/n\ R^{2/3}\ S^{1/2}$$

where,

Q = Peak flow, m^3/s
V = Velocity of Flow, m/s
A = Catchment Area, m^2
R = Hydraulic Radius = A/P, P = wetted Perimeter, m
S = Slope, m/m
n = Roughness Coefficient

- The flow capacities of side drains can again be determined using the computer based software, HY-22 for open channel analysis.
  - ➢ Select channel type: rectangular, circular, trapezoidal
  - ➢ Input data :
    1. Channel slope, m/m
    2. Bottom Width, m
    3. Side Slopes
    4. Manning's Coefficient
    5. Designed Discharge, m^3/s
    6. Depth, m
  - ➢ Analyze

Mitre Drain (Turn-outs):

- Generally rule, provided every 25 metres
- At least one at every 100 metres.
- Maximum distance normally be 200 metres.

Mitre Drain (Turn out Spacing)

Longitudinal/ Side drain Gradient, S (%)	Spacing (m)
1 in 100 or less	50
1 in 100 to 1 in 50	40
1 in 50 to 1 in 20	25
1 in 20 to 1 in 10	15
more than 1 in 10	10

Source: Liberia Feeder Road Design Manual, March 2012

iii. Culverts

- Cross Drainage Structures (Stream Culverts, Relief Culverts)

  Relief culverts may be required at intermediate points where a side drain carries water for more than about 200m without a mitre drain or other outlet.
- Access Culverts

Recommended Spacing between Relief Culverts

Longitudinal Gradient of Road/ drain, %	Recommended Interval of cross drainage, m
2	200
3-4	150
5	135
6	120
7-8	100
9-10	80
11-12	60

Source: Liberia Feeder Road Design Manual, March 2012

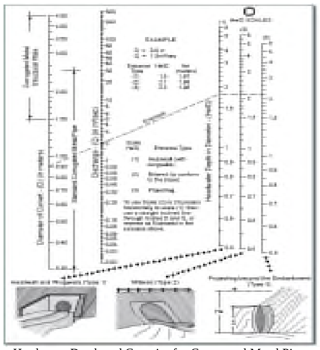
Design Methods:

a. Culvert opening is estimated using the nomograms for:
   - corrugated metal pipes
   - concrete pipes
   - concrete box culverts.

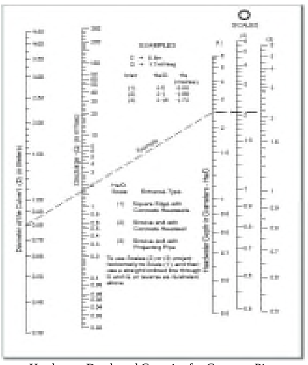
b. Using HY-8 Culvert Analysis software

Input Data:

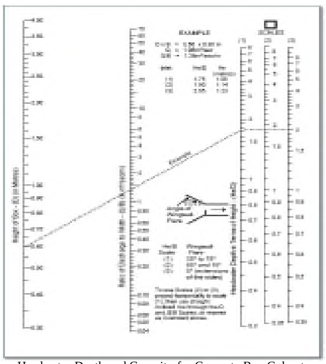
- ➢ Crossing Properties (Discharge Data, Tailwater Data, Roadway Data)
- ➢ Culvert Properties
  - Culvert Data (Slope, Material, Manning's n)
  - Site Data (Culvert Invert Data or Embankment Data)
- ➢ Overtopping Analysis



Headwater Depth and Capacity for Corrugated Metal Pipe Culverts with Inlet Control (Adapted from FHWA, 1998)



Headwater Depth and Capacity for Concrete Pipe Culverts with Inlet Control (Adapted from FHWA, 1998)

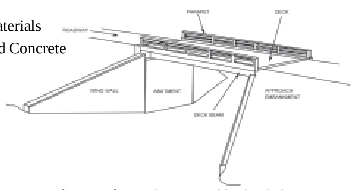


Headwater Depth and Capacity for Concrete Box Culverts with Inlet Control (Adapted from FHWA, 1998)

iv. Small Bridges

- Bridges are generally the most expensive type of road structure, requiring specialist engineering advice and technically approved designs.

- Bridge Materials
- ✓ Reinforced Concrete
- ✓ Steel
- ✓ Timber



Key features of a simply supported bridge deck

- If the crossing is to be used by pedestrians, proper protected footways should be designed on both sides of the carriageway.
- Reinforced concrete parapets are preferred rather than steel guard rails.

5. *Sedimentation and Erosion Control*

- Sedimentation Control
  - ✓ A factor of safety of 2 (in terms of water flow capacity) in flat terrain.
  - ✓ Slope/fall should be 3-5%. to minimize silting and deposition of debris in the culvert.

Siltation in cross culvert

- Erosion Protection
- Scour Checks for Erosion Control

Scour check Spacing

Drain Gradient , S (%)	Scour Check Spacing, m
5	20
6	15
7	10
8	7.5
9	6
10	5
11-12	4

Source: Liberia Feeder Road Design Manual, March 2012

6. *Design of Drainage Structures*

- Scour
- Foundations
- Concrete slab
- Aprons
- Headwall & Wingwalls
- Rip-rap
- Gabions

7. *Construction Materials*

- Stone Masonry
- Brick and Block Masonry
- Timber
- Plain and Reinforced Concrete

8. *Construction Methods*

- Preparatory Work
- Site Work
- Site Administration

9. *References*

i. Liberian Feeder Roads Design Manual and Specifications (2016)
ii. Liberian-Swedish Feeder Roads Project- best Practice Guidelines
iii. Ethiopian Manual for Low Volume Roads (2016)
iv. Tanzania Ministry of Works, Transport and Communication, Low Volume Roads Manual (2016)
v. Ghana DFR Guidance Notes for the Design of Rural Feeder Roads (2004)
vi. Ghana DFR Site Supervision Pocketbook (2004)
vii. Hydrological & Drainage Design: Design Guidelines, Criteria and Standards by Bureau of Design
viii. Ghana Highway Authority Road Design Guide (1991)
ix. Ghanaian Practitioners Guide to Rural Roads Improvement and Maintenance (2014)
x. Ghana MoT Standard Specification for Road and Bridge Works (2007)
xi. Sierra Leone National Rural Feeder Roads Policy Document (2011)

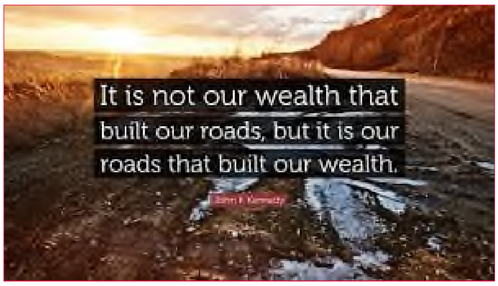
Annex F. Presentations made – Sierra Leone

ReCAP

Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First project workshop for Sierra Leone

26st September 2017



Outline of Presentation

- Workshop Programme
- Objectives of the Project, the Manual and the Workshop
- Approach and Methodology for Implementation of the Project
- Findings of Initial Visit
- Recommendations from the Initial Visit.

Workshop Programme

Time	Activity	Person Responsible
09:00 - 09:15	Registration	All Participants
09:15 - 09:30	Welcome Remarks	Chairman of SLRA Board
09:30 - 10:00	Self-Introduction	All Participants
10:00 - 10:45	Workshop Objective and Overview and Summary of Findings of Initial Visit	Robert Geddes
10:45 - 11:00	Status of Feeder Road Sector in Sierra Leone	SLRA Deputy Director General
11:00 – 11:30	Tea/Coffee Break	All Participants
11:30 - 12:15	Session 1: Site Investigation and Roadside Stabilization	Gareth Hearn
12:15 - 13:00	Session 2: Geometric Design and Road Safety	Ronald Isaac
13:00 - 14:00	Lunch Break	All Participants
14:00 – 14:45	Session 3: Material and Pavement Design	Lucas - Jan Ebels/ Robert Geddes
14:45 - 15:30	Session 4: Hydrology and Drainage Design	Festus Odametey
15:30 - 16:00	Tea/Coffee Break	All Participants
16:00 – 16:20	Summary of key Issues Arising and Way Forward	Robert Geddes

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Objectives

Objective of the project:

To prepare manuals for ***low volume roads*** *in Ghana, Sierra Leone and Liberia based on a review, adaption and expansion of previous AfCAP LVR manuals and local manuals that are available in these countries.*

Objective of the manuals:

In each country, to provide a relevant resource, based on recognised good practice, that will help build capacity and result in improved sector performance.

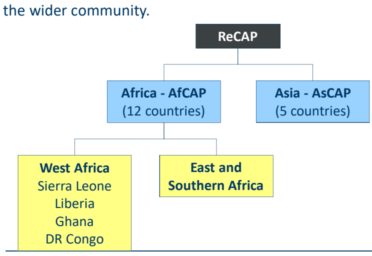
Objective of the 1st Stakeholder workshop:

To reach agreement on the scope of the LVR manual, and receive feedback on issues relevant to the national context.

Research for Community Access - ReCAP

- Programme of applied research and knowledge dissemination for the rural transport sector in Africa and Asia (2014 to 2020)
- Funded by UK Aid.

Overall aim: to promote safe and sustainable rural access in Africa and Asia through research and knowledge sharing between participating countries and the wider community.



ReCAP Activities in Sierra Leone

- Project Scoping Study for Sierra Leone and Liberia (July 2016)
- GEM project – Economic Growth through Effective Road Asset Management
- Training of trainers for DCP/DN pavement design method
- Participation in regional AfCAP events
- **LVR Manual project**
- Materials mapping
- Research on seals/surfacings for LVRs
- Transport services
- Accident data
- Training programes for transport services.

Manual Project - Approach and Methodology

Approach

Provide opportunities for local stakeholder input to ensure that the manual is relevant to the local context.

Methodology

- Initial visit with ***stakeholder consultation***;
- ***First workshop***;
- Preparation of drafts of each chapter
- ***Second workshop***;
- Preparation of revised drafts;
- ***Formal Peer Review***;
- Preparation of final versions.

Approach and Methodology

Build on existing material, especially existing local and regional standards:

- National Rural Feeder Roads Policy (2011)
- Project specifications (World Bank, EU)
- ILO documents for labour-based works
- Existing documents in Ghana and Liberia.

Approach and Methodology

AFCAP-supported manuals for Ethiopia, Tanzania, Malawi, Mozambique, South Sudan.

Initial Visit

Stakeholder meetings and field visit in Sierra Leone

10th to 14th July 2017

- Sierra Leone Roads Authority
- Sierra Leone Road Safety Authority
- DFID
- EU
- SCADeP Project Management Unit
- Local consultants

Initial Visit

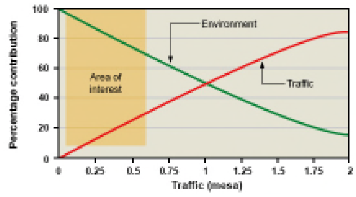
Field Visit to Makeni (EU-funded roads)



Findings from the initial visit to Sierra Leone

- Relatively undeveloped road network and low traffic levels;
- Dependence on international donors;
- No existing design manual or standard specification for rural roads;
- No Standard Specification for Roads and Bridges (all roads);
- Maintenance management systems still being developed;
- Low capacity for materials testing (only SLRA labs in Freetown and Kenema);
- Lack of standardisation of test methods – BS, AASHTO/ASTM, SANS, TMH;
- No road or pavement design currently taught in the universities;
- Road standards are dictated by extreme rainfall conditions.

Traffic versus Environment



Low volume roads carry:

- Less than about 300 VPD.
- Less than about 1 million esas over the design life.

Basic Access

Environmentally Optimised Design

Recommendations arising from the initial visit

- Each country will have unique manual – existing standards will be used wherever possible;
- Draw on relevant aspects of other AfCAP manuals particularly Ethiopia Manual for Low Volume Roads (2016) and Tanzania LVR Manual (2016);
- Provide a relatively high level of detail in the manual;
- Technical working group in each country (WhatsApp).

Structure of the Manual

Five Parts:

Part A : Geometric Design and Road Safety

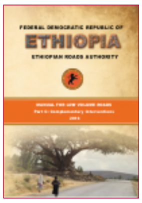
Part B : Materials, Pavement Design and Construction

Part C : Hydrology, Drainage and Roadside Stabilisation

Part D: Complementary Interventions (?)

Part E: Road Maintenance (?)

Complementary Interventions



- Community participation in roads projects
- Small community infrastructure
- Planning and identification of complementary interventions
- Contract provisions to support complementary interventions
- Supervision, monitoring and enforcement.



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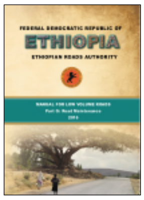
Road Maintenance



- The Purpose of Maintenance
- Maintenance Activities
  - Regular (Routine) Maintenance
  - Occasional (Periodic) Maintenance
- Prioritisation
- Planning and Productivity
- Maintenance of Bridges & Structures
- Specifications for Maintenance of Low Volume Roads

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Maintenance Activities

Table G.6.1: Roadside Activities

Defect	Maintenance Activity
1-01 Grass on shoulder or in drain requires cutting	1-01 Cut grass (manual or mechanised)
1-02 Trees and bushes growing on roadside	1-02 Bush clearing
2-01 Shoulder uneven or eroded, or does not drain properly	2-01 Shoulder rehabilitation (manual)
2-02 Shoulder uneven or eroded, or does not drain properly	2-02 Shoulder rehabilitation (mechanised)
2-03 Shoulder uneven or eroded, or does not drain properly (minor)	2-03 Shoulder Blading (mechanised)
3-01 Shoulder erosion	3-01 Plant grass and water it

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Maintenance Activities

Table G.6.2: Drainage Activities

Defect	Maintenance Activity
4-01 Culvert/Drift silted/obstructed	4-01 Culvert/Drift Cleaning
4-02a Drain silted	4-02a Drain Cleaning (manual)
4-02b Drain silted	4-02b Drain Cleaning (mechanised)
5-01 Drain or slope eroded (minor)	5-01 Repair Erosion Damage (selected fill)
5-02a Drain or slope eroded (major)	5-02a Repair Erosion Damage (rock fill)
5-02b Slope eroded (major)	5-02b Terracing or Wattling
6-01 Mortared Masonry damaged	6-01 Mortared Masonry Repair
6-02 Dry Masonry damaged	6-02 Dry Masonry Repair
7-01 Gabion structure damaged	7-01 Gabion Structure Repair
8-01 Erosion in drain	8-01 Build stone/wooden scour check

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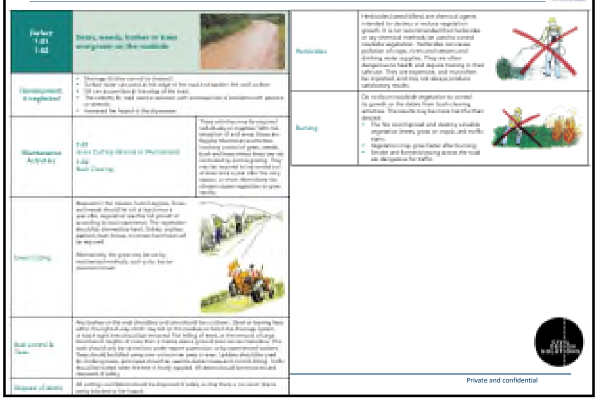
Vegetation control



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Drainage systems

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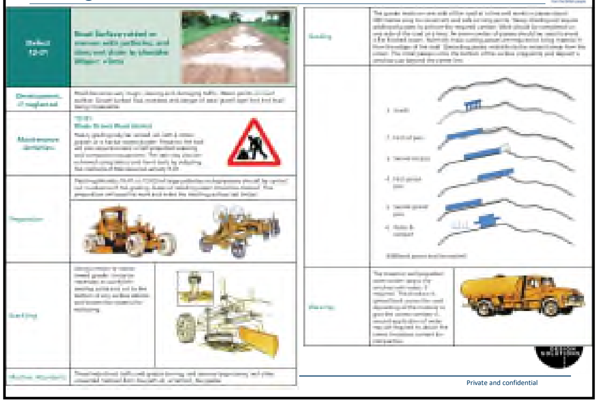
Grading



Maintenance Specifications

DEFECT 1-02	ACTIVITY
	Bush Clearing m²

Scope of works: Improve visibility to maintain safe sight distance, visibility of road signs, road markers, animals and pedestrians within the road reserve.

Specifications:

- Place warning signs and safety devices
- Cut, uproot and remove bushes to ensure that all bushes are cleared
- Workmen must ensure that no damage is caused to fixed objects such as road furniture when removing debris and cut or uprooted during clearing
- Backfill and compact to density of surrounding ground all excavated holes dug during removal of roots
- Collect and clear all cut roots and debris from drains, carriageway and road reserve, load and dispose to designated sites
- Measure and record the length and width of area cleared
- Remove temporary road signs and safety devices.

Description of bill item:

1-02: Clearing of bush, shrubs and roots on the side of the road to improve visibility and road safety. Unit of measurement shall be in m² of area of bush cleared.

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Maintenance Specifications

DEFECT 12-01	ACTIVITY
	Blade gravel road carriageway (heavy) m

Scope of works: Mechanical grading gravel, scarify and move the material into a windrow and then mix and spread into required profile.

Specifications:

- Place warning signs and safety devices
- Rip and scarify the existing road surface and push into a windrow towards the centre of the road
- Additional material can be added if necessary
- Water and mix the material thoroughly
- Spread the material and compact forming the required profile
- Remove loose stones and windrows from the carriageway
- Remove traffic signs and safety devices.

Description of bill item:

12-01: Heavy grading of road surface to correct deep ruts, corrugations, potholes and camber. Unit of measurement shall be in carriageway-m of road graded.

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Low Priority Issues

- Procurement of works (tendering);
- Planning (road prioritisation);
- Route selection;
- Design of chip seals and other bituminous surfacings;
- Technical Auditing.

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Time Line

Inception Report (submitted early August 2017)

First Workshop (one day) – September 2017

Second Workshop (two days) –Early 2018

Submission of final draft MS Word version – June 2018

Launch of Manual – November 2018.

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Workshop Programme

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13:00 - 14:00	Lunch Break	All Participants
14:00 - 14:45	Session 3: Material and Pavement Design	Lucas - Jan Ebels/ Robert Geddes
14:45 - 15:30	Session 4: Hydrology and Drainage Design	Festus Odametey
15:30 - 16:00	Tea/Coffee Break	All Participants
16:00 – 16:20	Summary of key Issues Arising and Way Forward	Robert Geddes
16:20 - 16:30	Closing Remarks	SLRA

Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First Stakeholder Workshop

Dr Gareth Hearn

Freetown

26th September 2017

Investigations & Roadside Stabilisation

Contents

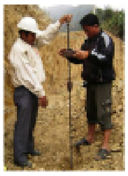
Background literature
Route selection
Geological and subgrade investigations
Investigations for construction materials
Roadside slope stabilisation

Roads in hilly and mountainous terrain

Investigations & Roadside Stabilisation

Background Literature

- There are no formal guidelines that exist in Sierra Leone that address methods of:
- Subgrade investigation
- Materials investigation
- Slope investigation

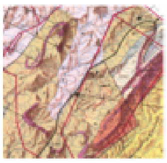


Route Selection

- Principal factors
  - Engineering
  - Cost
  - Environmental
- Methods of route investigation
  - Desk study
  - Field work
- Methods of route comparison and selection

Investigations for new roads and road improvement schemes

- Geological investigations
  - Role of geology in LVR engineering
    - Common rock types of Sierra Leone
    - Weathering profiles and soil types
      - In situ weathered soils
      - Colluvial soils
      - Alluvial soils
  - Desk study data sources in Liberia
    - Published maps
    - Remote sensing

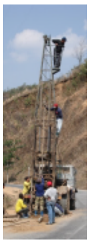
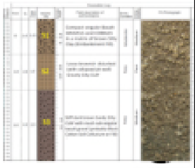
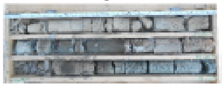


Investigations for new roads and road improvement schemes

- Problematic soils
  - Weathered lateritic soils
  - Soft compressible soils
  - Expansive soils?
  - Collapsible soils?
  - Dispersive soils?
  - Soils prone to erosion

Investigations for new roads and road improvement schemes

- Sub-grade investigations
  - Importance of sub-grade condition
    - For embankments and pavements
    - For foundations to bridge abutments and other structures
  - Techniques of investigation
    - Field mapping
    - Trial pitting
    - In situ testing - DCP
    - Drilling investigations
    - Lab testing: PIs/PSDs/CBRs

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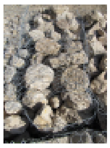
Investigations - materials

- Construction materials: prospecting for borrow pits and rock quarries
  - Capping layer
  - Fill material
  - Subbase-base material
  - Sand, aggregate, rock fill etc





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Investigations - materials

- Construction materials continued –
  - Prospecting techniques
    - Desk study
      -Topographic maps
      -Geological maps
      -Remote sensing
    - Field investigations – borrow pits
      -Surface mapping
      -Trial pitting
      -Sampling & laboratory testing
      -Survey of source areas
    - Field investigations – rock quarries
      - Geological mapping
      - Drilling investigations
      - RQD

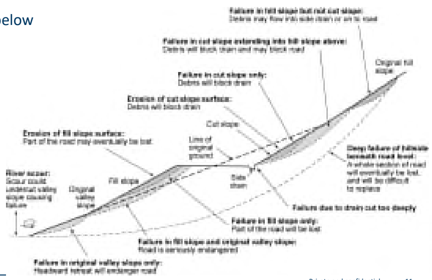

Investigations - materials

- Construction materials continued –
  - Borrow pit operation and restoration
    - Control of runoff
    - Stockpiling and control of erosion
    - Restoration
      - Landscaping
      - Re-topsoiling
      - Replanting

Private and confidential 10

Roadside slope stabilisation

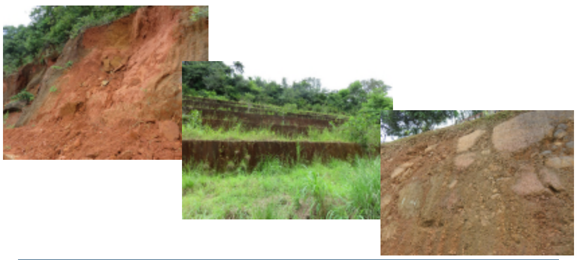
- Mechanisms of slope instability and erosion
  - Instability in natural slopes
  - Instability in cuts and fills
  - Instability above the road
  - Instability below



Private and confidential 11

Roadside slope stabilisation

- Design, stabilisation, mitigation
  - Cut slope geometry (rock/soil vs height vs angle)
  - Slope stabilisation measures (earthworks, drainage, retaining walls)
  - Slope protection measures (erosion control, netting, retention walls)



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Roads in hilly and mountainous terrain

- Route selection and alignment design
- Choice of cross-section
- Earthworks design and spoil disposal
- Slope stabilisation and erosion control
- Cross-drainage


Thank you
Any questions?

Geometric Design

Outline of Presentation

- Introduction
- References
- Road Classification
- How the Standards will be used
- Factors affecting Geometric Standards
- Design Speed and Geometry
- Road Cross Section
- Typical Cross Sections
- Horizontal Alignment
- Vertical Alignment
- Harmonisation of Horizontal and Vertical Alignment
- Summary of Geometric Standards for each Class of Road
- Questions

References

- Sierra Leone MoWHI National Rural Feeder Roads Policy Document (2011)
  - Although not a design manual the policies contained in this document will be incorporated into the new manual
- Liberia MoPW Feeder Roads Design Manual and Specifications (2016)
  - This is a comprehensive manual which will be used for the development of the new manual for Sierra Leone in terms of geometric design
- Ghana DFR Design Standards (2009)
- Ethiopia RA Manual for Low Volume Roads (2016)
  - This is a comprehensive manual, parts of which will be used for the development of the new manual in terms of geometric design

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Introduction

- Purpose of Roads:

  To provide traffic mobility between centres and areas, and to provide access to adjoining land and properties.

- Definition of Geometric Design:

  The process whereby the layout of the road through the terrain is designed to meet the needs of ALL road users.

- Objectives of Geometric Standards:

  To provide acceptable levels of safety and comfort for drivers through provision of adequate sight distances, coefficients of friction, road space for manoeuvres, and to minimise earthworks to reduce construction costs.

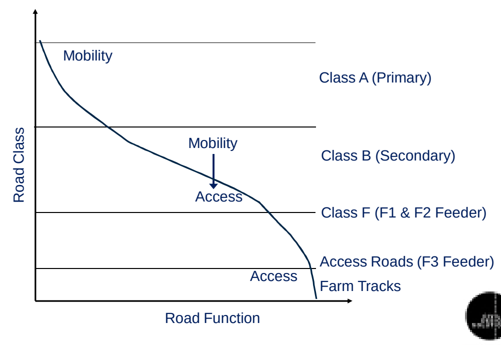
- Objectives of the Geometric Design Chapter in the new LVR Manual:

  To provide Geometric Design principles, recommendations, guidance and standards to enable the low volume road designer to meet the safety and comfort standards appropriate to the local environment for roads carrying less than 300 vehicles per day.

Road Classification

- LVR's generally carry relatively low volumes of traffic, typically less than 300 vpd and make up a significant proportion of the road network.
- LVR's provide the only form of access to rural communities and provide basic access to essential services.
- In Sierra Leone rural roads are divided into 3 main classes according to their function in the road network:
  - Primary Roads
  - Secondary Roads (Some of these roads will be LVR's, <300vpd)
  - Feeder Roads (All LVR's)
- Feeder Roads are further divided into 3 main categories:
  - F1 Link Roads (<100vpd) (mostly unsurfaced and in fairly good condition)
  - F2 Tertiary Gravel Roads (<50 vpd) (mostly unsurfaced and most in poor condition)
  - F3 Community / Farm Rds (unsurfaced mostly in poor condition)

Road Classification



How The Standards Will Be Used

- Design Procedure
  - Steps will be provided for selecting the appropriate standards to be used in the geometric design process including a flow diagram.
- Scenario 1: Upgrading an Existing Road
  - Basic alignments already exist and spot improvements may be required to meet the required design standards.
- Scenario 2: Upgrading an Existing Track
  - Sub-standard alignments already exist and improvements will be required to meet the required design standards.

  Alternatively appropriate traffic calming measures can be used to reduce speed to avoid costly realignment where upgrades are required.
- Scenario 3: New Roads
  - Requires viability and route determination investigations prior to road design.

Factors Affecting Geometric Standards

The following factors that affect the geometric standards will be discussed in greater detail in the new LVR Manual:

- Cost
  - Costs associated with road construction, operation and maintenance is directly related to the geometry standard adopted.
- Level of Service (LOS)
  - LOS is directly associated with traffic volume and increases with increase in road class.
- Traffic Volume
  - Geometry standards are justified in accordance with traffic volume and increase with increase in traffic volume.
  - For LVR's the design control is Average Annual Daily Traffic (AADT) in the 'design year' incl. distribution by vehicle type.

Factors Affecting Geometric Standards (Continued)

- Traffic Composition
  - Geometry standards depend on the type of vehicles expected to use the facility i.e. lower standards can be used for smaller vehicles.
- Terrain
  - Geometry standards are dependant on the terrain i.e. flat terrain can accommodate higher geometry standards, whilst hilly or mountainous terrain will only support lower standards.
  - 3 categories have been defined i.e. Flat, Rolling, Hilly or Mountainous.
- Roadside Population
  - Geometry standards are required to be modified to ensure good access and enhance safety through populated areas.

Factors Affecting Geometric Standards (Continued)

- Pavement Type
  - Surfaced (concrete, asphalt, seal or gravel) or unsurfaced (earth).
  - Surfaced roads provide higher traction or friction for vehicles as opposed to unsurfaced roads thus geometry standards are required to be higher for unsurfaced roads than for surfaced roads.
  - In Sierra Leone only Category F1 and F2 roads receive gravel surfacing whilst Category 3 roads are generally earth roads.
- Soil type and Climate
  - Problem soils can be mitigated through geometric design such as flattening road embankments where unstable soils are encountered.
  - In Sierra Leone the construction of LVR's generally make use of good local materials such as lateritic gravels (predominant) and sands (found in coastal areas).
  - The impact of problematic wet climates can be mitigated through geometric design such as increasing road slopes to increase precipitation runoff.

Factors Affecting Geometric Standards (Continued)

- Safety
  - One of the main objectives in geometric design and will be discussed in a separate Chapter of the presentation.
- Construction Technology
  - Labour abundant countries are required to maximise the use of labour rather than rely on equipment-based methods of road construction, thus geometric design needs to take this into consideration.
- Administrative Function
  - The administrative functional of a road may control the standards to be adopted irrespective of levels of traffic.
- Environmental
  - The location and design of the road should maximise positive effects and minimise negative effects on the environment.
  - Dust pollution, uncontrolled quarry operations, environmental degradation arising from logging activities due to increased access to remote areas are the major concerns.
  - Environmental impact assessments should be carried out for every road design

Design Speed and Geometry

The following aspects of geometric design will be discussed in greater detail in the new LVR Manual:

- Design Speed
  - Maximum safe travel speed which can be maintained over a specific section of road under free flow conditions to which Geometric Standards are related.
  - Higher design speeds require higher Level of Service (LOS) and consequently are more costly to construct.

SIERRA LEONE RECOMMENDED DESIGN SPEEDS (Feeder Rds)

Category F1	Category F2	Category F3
60 - 80km/h	40 - 60km/h	20 - 40km/h

- Sight Distance
  - Length of roadway ahead, clear of objects, required to visible to the driver and is the most important influence on road safety and efficient operation.
  - Sufficient sight distance is to be provided both longitudinally and laterally.

Design Speed and Geometry (Continued)

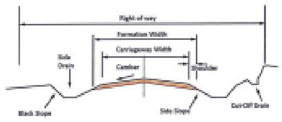
- Stopping Sight Distance
  - Distance a vehicle requires to stop safely upon viewing an object in the road and is used for the basic geometric design of the road alignments.
  - No standards currently exist – refer to Ghanaian standards below.
- Intersection Sight Distance
  - Same as for stopping however based on the object viewed being another vehicle entering the road from an intersecting side road.
  - A table reflecting these distances will be included in the manual.
- Passing Sight Distance
  - Distance a vehicle requires to overtake another safely and is used for design of passing opportunities and no-overtaking sections of roadway.
  - No standards currently exist – refer to Ghanaian standards below.

GHANAIAN RECOMMENDED SIGHT DISTANCES

Design Speed (km/h)	20	30	40	50	60	70
Min. Stopping Distance (m)	20	30	50	60	80	100
Passing Sight Distance (m)	115	170	230	290	350	420

Road Cross Section

The following elements relating to road cross section will be discussed in greater detail in the new LVR Manual:



- Road Widths:
  - Ideally roadway widths are required to be wide enough for 2 vehicles to pass safely without having to use the verge.
  - LVR's normally operate as single lane roads where vehicles drive in the centre of the road, and on the rare occasion that vehicles meet, they are able to slow down or stop in order to pass.
  - Generally the LVR road element widths are standardised based on whether these are surfaced or unsurfaced and may be influenced by the type of terrain in some cases.
  - Standard road widths for LVR's are included at the end of the Section.

Road Cross Section (Continued)

- Shoulders
  - Surfaced or unsurfaced edge supports to contain the road carriageway.
  - Protects road pavement structure from surface runoff ingress.
  - Provides safe space for non-motorised travellers, emergency vehicle breakdowns etc. where sufficiently wide enough.
- Camber
  - Facilitates the drainage of the roadway by shedding stormwater runoff to the side drains.
  - For unsurfaced roads this is generally 5 - 7% however 6% has been suggested for LVR's.
  - For surfaced sections this can be reduced to 2 to 3%.
  - Road slope changes introduced to counteract centrifugal forces of a vehicle negotiating a horizontal curve is referred to as superelevation and will be discussed later in the Chapter.

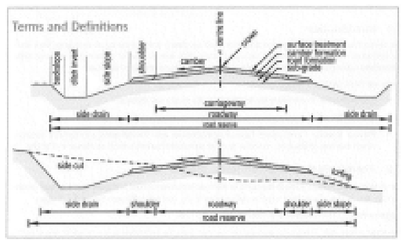
Road Cross Section (Continued)

- Roadside drains
  - Introduced to convey stormwater runoff from the road surface to suitable discharge points to avoid saturation of the pavement layers.
  - Flat bottomed drains are recommended for LVR's as V-shaped drains formed of earth develop erosion lines easily.
- Clearances
  - Minimum lateral clearance from the carriageway = 0,25m – 0,5m
  - Minimum vertical clearance above carriageway = 5m
  - Clear zones or verge areas to be kept clear of obstacles which may be hazardous to vehicles which leave the roadway.
- Side Slope
  - Slope of earthworks cut and fill embankments generally affected by stability characteristics of the natural soil.

Road Cross Section (Continued)

- Right-Of-Way (ROW)
  - Area reserved for the roadway, drainage systems, signage, services, clear zones, non-motorised travellers, and for accommodating future upgrading requirements.
  - In Sierra Leone ROW widths vary between road category as indicated below.
- Passing Opportunities
  - Where road widths are very narrow i.e. <3m, it may be necessary to install passing opportunities.
  - Generally required every 300m to 500m for road widths <3m.
  - Can be installed as widened shoulders where 2 vehicles are unable to pass or where slower moving vehicles obstruct following vehicles from safely overtaking e.g. on steep inclines.

Typical Cross Sections



SIERRA LEONE RECOMMENDED FEEDER ROAD CROSS-SECTION STANDARDS

Road Category	ADT	Surface Type	C/Way Width	Shoulder Width	Roadway Width	Crossfall or Camber	ROW Width
F1	50 - 100	Unsurfaced	6m	1m	7m	5 - 7%	7,3m
F2	20 - 50	Unsurfaced	6m	None	6,5m	5 - 7%	4,6m
F3	≤20	Unsurfaced	4,5m	None	6,5m	3 - 5%	3,5m

Horizontal Alignment

The following elements of horizontal alignment design will be discussed in greater detail in the new LVR Manual:

- Straights or Tangent Sections
  - Beneficial in flat terrain however less in rolling or mountainous terrain.
  - Provides good visibility and greater passing opportunities.
  - However increases danger from excessive speeding and headlight glare.
  - Generally straights should not exceed 4km in length.
- Superelevation
  - It is proposed that superelevation be excluded from unsurfaced LVR's as this increases the path length that stormwater runoff has to travel over the roadway potentially leading to erosion of the earth or gravel surface.
  - At positions where the superelevation development is flat or crosses over this can potentially create ponding.
  - Superelevation will be considered for Low Volume Secondary Roads

Horizontal Alignment (Continued)

- Horizontal Curves
  - No standards are currently available in Sierra Leone so new minimum curve radii values will need to be developed – refer to Ghana's below.
  - Must be appropriately designed for design speeds >50km/h
  - Avoid sharp curves for obvious reasons.
  - For small changes of direction it is however desirable to use large radius curves to improve appearance and reduces the tendency for road users to cut corners.
  - Curve lengths should be kept to a minimum as overtaking on curves is generally difficult and often difficult to maintain adequate sight distance.

GHANAIAN MINIMUM RADII OF CURVATURE

Terrain		Access/Spur			Connector			Inter-District		
		Speed	Absolute	Desirable	Speed	Absolute	Desirable	Speed	Absolute	Desirable
Flat	GS	50km/h	85m	150m	60km/h	130m	220m	60km/h	130m	220m
	BS	60km/h	130m	220m	80km/h	230m	420m	80km/h	230m	420m
Rolling	GS	40km/h	50m	100m	50km/h	85m	150m	50km/h	85m	150m
	BS	50km/h	85m	150m	60km/h	130m	220m	60km/h	130m	220m

Note: GS = Gravel Surface BS = Bituminous Surface

Horizontal Alignment (Continued)

- Curve Widening
  - To be applied where tight curves are unavoidable to allow for the swept paths of large vehicles and to allow drivers to manoeuvre when approaching oncoming vehicles.
  - Generally applied to the inside of the curve.
  - The following table reflecting widening recommendations based on curve radius will be included in the manual.
  - No standards are currently available in Sierra Leone so new recommended widths for widening on curves will need to be developed – refer to Ghana's below.

GHANAIAN RECOMMENDED CURVE WIDENING

Curve Radius (m)	16 - 19	19 - 21	21 - 26	26 - 32	32 - 45	45 - 60	60 - 90	90 - 160
Increase in Width (m)	2.00	1.75	1.50	1.25	1.00	0.75	0.50	0.25

Vertical Alignment

The following elements of vertical alignment design will be discussed in greater detail in the new LVR Manual:

- Gradient
  - Grades should be kept as low as possible and consideration should be given to alternative surfacing options on high grade sections or hairpin bends in mountainous terrain.
  - Minimum gradient recommended is 0,5% (1:200) to assist with side drain conveyance of stormwater runoff.
  - No standards currently exist – refer to Ghanaian standards below.

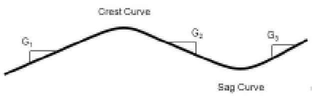
GHANAIAN RECOMMENDED MAXIMUM GRADIENTS

Design Speed (km/h)	20	30	40	50	60	70
Max. Vertical Grade (%)	12	10	7	6	5	4

- Vertical Curvature
  - Parabolic curves defined by length unlike radius for horizontal curves.
  - Minimum length is defined by L = K x G where L = length of curve; G = algebraic difference in grade (%); K = relationship of design speed and safe stopping sight distance.

Vertical Alignment (Continued)

- Crest Curves
  - Based on daylight safe stopping sight distance and thus related to design speed as well as minimising driver discomforting forces.
- Sag Curves
  - Based on night-time vehicle headlight illumination distance limitations.



No vertical curve values currently exist but will be developed – refer to Ghana's below.

GHANAIAN RECOMMENDED K VALUES & MINIMUM VERTICAL CURVE LENGTH

Design Speed (km/h)	40	50	60	70
K Values for Crest Curves	4	8	14	30
K Values for Sag Curves	5	7	10	18
Min. Vertical Curve Length	35m	40m	50m	70m

Harmonisation of Horizontal and Vertical Alignment

The following recommendations should also be considered when designing the road alignment and will be discussed in greater detail in the new LVR Manual:

- Avoid horizontal curves with changing radius that generally come as a surprise to road users.
- Avoid isolated curves connected with long tangents may come as a surprise to road users particularly if the curve is close to the minimum radius.
- Long curves are problematic to road users as they are difficult to negotiate as opposed to shorter length curves.
- Inappropriate combinations of horizontal and vertical alignments, e.g. a sharp horizontal curve located beyond a pronounced vertical crest curve, is not desirable.
- Avoid skew intersections and cross-intersections – stagger rather.
- Staggered intersections should not be located minimum 40m apart.
- Good visibility of intersections are required from both directions.
- Avoid steep grades at intersections which lead to longer vehicle acceleration and deceleration distances.

Summary of Geometric Standards for Each Class of Road

It is proposed that all the various geometric design standards be contained in a single matrix table for each class of road as shown in the example below.

Design Element	Unit	Flat	Rolling	Mountain	Escarpment	Populated areas
Design speed preferred	km/h	70	60	50(2)	25(2)	50
Road width	m	7.0(4)	7.0(4)	7.0(2)	7.0(2)	7.0(3,4)
Max. desirable gradient	%	4	6	6	6	4
Maximum gradient	%	6	9	9	9	6
Minimum gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum super-elevation	%	6	6	6	6	6
Normal cross-fall (5)	%	6	6	6	6	6
Minimum stopping sight distance	m	125	95	70	25	70
Maximum super elevation	%	6	6	6	6	6
Minimum horizontal radius Super elevation = 4%	m	245	175	110	25	110
Minimum horizontal radius Super elevation = 6%	m	215	155	100	20	100
Minimum crest vertical curve	K	34	19	11	2.5	11
Minimum sag vertical curve	K	5	3.5	2.2	1	2.2

Questions?

Road Safety

Outline of Presentation

- Introduction
- Traffic Signs
- Road Markings
- Traffic Calming
- Safety Barriers
- Safety Audits
- References
- Questions

Introduction

- Road accident statistics common with many African countries show that death rates from road accidents are 30 to 50 times higher than in Western countries however Sierra Leone has low accident rate.
- Low vehicle ownership, an extensive network of roads, and roads generally in poor condition which minimises speed contribute to the low accident rate.
- Economic analysis has also shown conclusively that a high level of road accidents has very significant economic consequences for a country.
- There are a number of key principles of design that can considerably improve road safety:
  - Consider ALL road users including non-motorised travellers,
  - Provide adequate warning signage where potential hazards exist,
  - Encourage appropriate speeds through design,
  - Reduce conflicts if possible,

Introduction (Continued)

- Objectives of the Road Safety Chapter in the new LVR Manual:
  To provide Road Safety design principles, recommendations, guidance and standards to enable the low volume road designer to meet the safety standards appropriate to the local environment for roads carrying less than 300 vehicles per day.
- Some general safety considerations:
  - Prevent accidents e.g. provide adequate drainage of road surface.
  - Reduce the severity of accidents e.g. through provision of flat roadside slopes.
  - Separating vulnerable road users from motorised traffic e.g. through provision of road shoulders or footways.

Traffic Signs

The following types of road signs will be discussed in greater detail in the new LVR Manual:

- Regulatory Signs
  - Indicate legal requirements of traffic movement.

- Warning Signs
  - Indicate conditions that may be hazardous to road users.

- Information Signs
  - Convey information of use to road users.

- Marker Posts
  - Guideposts intended to make road users aware of potential hazards e.g. drainage structures located on the road verge.
  - Kilometre posts generally only required on higher order roads.

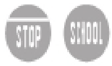
Road Markings

The following types of road markings will be briefly covered in the new LVR Manual due to it's appropriateness to surfaced roads and not unsurfaced:

- Regulation Markings and Symbols
  - Indicate legal requirements of traffic movement.

- Warning Markings and Symbols
  - Indicate conditions that may be hazardous to road users.

- Information Markings and Symbols
  - Convey information of use to road users.



- Object Markers
  - Hazardous objects in the clear zone impractical to be removed should be adequately painted by use of high-visibility material.
- Road Studs
  - Reflective devices installed to demarcate the road centreline at night.

Traffic Calming

- The following various methods of improving road safety through the implementation of traffic calming measures will be discussed in greater detail in the new LVR Manual:
- Road Alignment Controls
  - Manipulation of the road alignment or road features, such as reducing width, to cause road users to slow down e.g. chicanes.
- Warning Devices
  - Installation of artificial road texture on sealed road sections that causes considerable tyre noise and vehicle vibrations to warn road users of hazardous conditions and cause them to slow down e.g. rumble strips.
- Speed Reduction Humps and Cushions
  - Most common method used to slow traffic.
  - Generally preceded by road warning devices.
  - Unlike road warning devices these are higher and potentially hazardous if not designed correctly.
  - Humps extend the full width of the road whilst cushions have considerable gaps to allow bicycles and motorcycles to pass through.

Traffic Calming (Continued)

- The 'Village Treatment' concept of traffic calming introduced in Ethiopia has proven to be successful.
- Using a combination of the traffic calming devices, pedestrian sidewalks, and busbays, a perception is created for the driver that the approaching village is a low speed environment with the aim to encourage him to reduce speed.

- The 'Village Treatment' is made up of 3 zones:
  - The approach zone - prior to entry of village where driver is made aware that the open road speed is no longer appropriate (80 – 50km/h),
  - The transition zone - gateway to core zone and first speed humps (50km/h)
  - The core zone - centre of village and activity zone with humps (40km/h)

Safety Barriers

The following aspects of safety barriers will be briefly discussed in the new LVR Manual due to it's appropriateness to higher order roads:

- Segregating Vulnerable Road Users
  - Provision of physical separation between motorised vehicles in opposing directions and also with non-motorised travellers i.e. pedestrians and cyclists e.g. by means of crash barriers.
- Crash Barriers
  - Prevents vehicles traveling in opposite directions from colliding with each other head on.
  - Primarily used on LVR's to prevent vehicles from leaving the road where hazardous conditions exist e.g. at the top of high fills.

Safety Audits

- Road safety is complex by nature, and although many unsafe practices are glaringly obvious, there are many situations where it is difficult to identify what is likely to be unsafe, especially in the case of a new road where one is working from drawings.
- Road safety improvements mostly rely on reliable historic data much of which is never recorded or analysed using road accident characteristics.
- Professional road safety auditing is the next best practice and should be regularly undertaken on every road project particularly for road projects in populated areas.
- The new LVR manual will provide greater detail on this subject.

References

- Review of Road Safety Management Capacity in Sierra Leone (2011)
- Ethiopia RA Manual for Low Volume Roads (2016)

Low Volume Roads in Sierra Leone

Questions?

ReCAP

Development of Low Volume Road Design Manuals and update of standard specifications and detailed drawings for three AfCAP member countries in West Africa

First Stakeholder Workshop

Materials and Pavement Design

Freetown – Sierra Leone

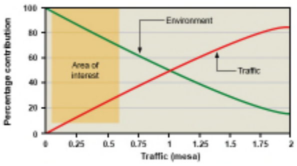
26 September 2017

Outline of Presentation

- Principles of Low Volume Road pavement design
- Site physiography
- Traffic
- Materials
- Pavement design
- Quality Assurance & Quality Control

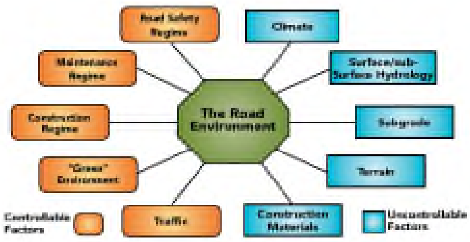
Principles of LVR pavement design

- Low volume road :
  - ≤ 300 vpd (middle design life)
  - ≤ 1 million cumulative ESA's



- Performance more dependent on environment than traffic
- Conventional planning, design, construction and maintenance philosophies for higher volume roads do not apply.

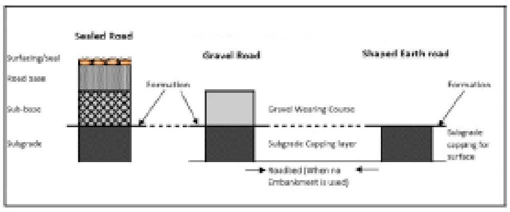
Principles of LVR pavement design



Principles of LVR pavement design

- Multiple structural layers seldom warranted for unpaved roads
- Budgets for construction and maintenance are constrained
- Considerations for design:
  - Raise formation and gravel wearing course above NGL
  - Allowance and provision for cross drainage
  - Treatment of unsuitable subgrade material
  - Maintenance capacity and frequency
  - Phased construction, possible future upgrade to surfaced standards
- Low Volume Paved Roads vs Unpaved Roads
  - Surface dressing / surfacing seal (possibly alternative surfacing)
  - Gravel roads
  - Earth roads (un-engineered, semi-engineered)

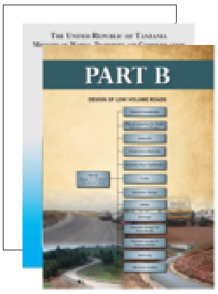
Principles of LVR pavement design



Lucas-Jan Ebels and Robert Geddes (presenter)

Principles of LVR pavement design

- Reference documents:
  - National Rural Feeder Roads Policy
  - "Standard" specifications (materials) various feeder road projects in SL (IDA & EU)
  - TRL: Overseas Road Note 31
  - LVR Manuals various other AfCAP countries:
    - Tanzania
    - Ethiopia

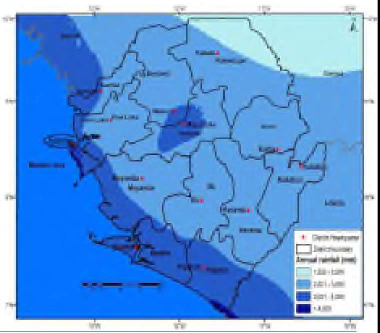


Principles of LVR pavement design

1. Design Principles
   - Road category
   - Design Period
   - Site Physiography
2. Traffic Design
   - Traffic volumes
   - Traffic loading
   - Traffic class
3. Design Investigations
   - Subgrade Characterisation
   - Material Selection
4. Structural Design
5. Economic Analysis

Site physiography

- Topography:
  - Flat
  - Rolling / hilly
  - Mountainous
- Geology
- Soils and vegetation
- Climate:
  - Temperature
  - Rainfall

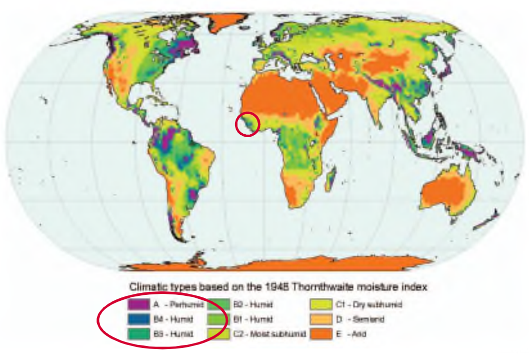


Site physiography

- Climatic indicator, e.g.:
  - Thornthwaite Moisture Index
  - Weinert N-value

Thornthwaite	Climatic region	Weinert	Climatic Region
< -40	Arid	> 5	Dry
-40 to – 20	Semi-arid		
-20 to 0	Dry sub-humid	3 to 5	Moderate
0 to 20	Moist sub-humid		
20 to 100	Humid	< 3	Wet
> 100	Perhumid		

Site physiography

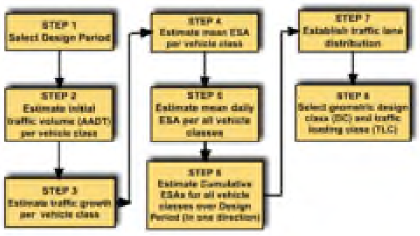


Traffic

- Traffic surveys:
  - Classified traffic counts
    - Motorised vs. NMT
    - Stationary vs Moving Observer Count (WB method)
  - O-D surveys
  - Axle load surveys
- Potential variations:
  - Seasonal (wet vs. dry)
  - Daily (market vs. non-market day)

Traffic

- Method of determining cumulative traffic loading is well documented
- Typical process:



Traffic

- 3 No. Traffic Load Classes proposed for pavement design:

Traffic Load Class	Cumulative traffic load during design life (million ESAs)
TLC 1.0	0.3 – 1.0
TLC 0.3	0.01 – 0.3
TLC 0.01	< 0.01

ORN 31	Cumulative traffic load during design life (million ESAs)
T3	0.7 – 1.5
T2	0.3 – 0.7
T1	< 0.3

Design Investigations

- Materials investigation:
  - New road; focus on:
    - Subgrade
    - Available materials for road construction
  - Existing road:
    - Also determine strength existing road structure
- Subgrade characterisation:
  - Material sampling and testing (grading, indicators, CBR)
  - DCP testing (DN, CBR)
  - LWD testing (Emod)

Design Investigations

- 4 No. proposed subgrade classes for pavement design:

Subgrade Class	LVR Manual CBR Range [%]	Treatment and typical usage	ORN 31
S1	< 3	Special treatment required	< 2
S2	3 – 7	Suitable as fill	3-4
S3	7 – 15	Suitable as fill	5-7
S4	> 15	Suitable as improved subgrade / subbase	8-14
S5			15 – 29
S6			30 +

Materials

- Build on material classifications as design manual and standard specifications
- Wearing course materials (TRH20):
- Type of surfacing:
  - Traditional surfacings (surface dressing / surfacing seal)
  - Non-traditional surfacings (e.g. concrete strips, cobblestone, block paving)
  - Non-traditional stabilisers (polymers, emulsions, etc.)

Wearing Course Material

- Some historic specifications of Feeder Road Projects in SL:
  - European Union (EDF):

Natural Material or Gravel

(a)	Grading	(see Table 3.1)
(b)	Plasticity Index	5 – 20%
(c)	Plasticity Modulus	500 max
(d)	CBR at 95% MDD (AASHTO T180) and 4 days soaking	30% (min)

TABLE 3.1
Grading Limits for Surface Course Materials

Sieve Size (mm)	Percentage Passing by Mass – Maximum Size of Particle (mm)			
	37.5	26.5	19.0	13.2
37.5	100	100	100	100
26.5	85-100	100	100	100
19.0	70-100	80-100	100	100
13.2	60-85	60-85	75-100	100
4.75	40-60	45-65	50-75	60-100
2.00	25-45	30-50	35-55	45-70
0.425	15-40	15-40	18-45	25-50
0.075	7-30	7-30	7-30	7-20

Lucas-Jan Ebels and Robert Geddes (presenter)

Wearing Course Material

- Some historic specifications of Feeder Road Projects in SL:
  - International Development Association:

Table 6-1 Gradation Requirements for Gravel Surfacing

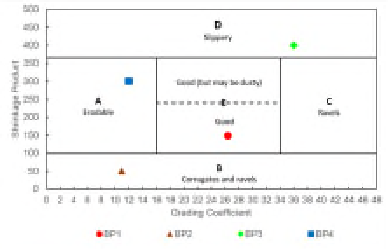
Sieve Size (mm)	Percentage Passing (by mass)
37.5	100
25.0	90 - 100
9.5	50 - 85
4.75	35 - 75
2.0	25 – 60
0.425	15 – 40
0.075	5 – 30

The gravel material shall further comply with the following characteristics when compacted on the road except for CBR for which material shall be obtained from uncompacted layers:

- Liquid limit: maximum 40 %;
- Plasticity Index: 5 – 15 %;
- CBR 4 days soaked 95% modified : minimum 20%

Wearing Course Material

- International / AfCAP specifications for wearing course material:
  - Shrinkage Product SP = LS x $P_{0.425}$ 100 – 365 (240)
  - Grading Coefficient = $(P_{26.5} – P_{2.0}) \times P_{4.75} / 100$ 16 - 34



Zone A: Fine grained material prone to erosion

Zone B: Non-cohesive materials that lead to corrugations and ravelling / material loss

Zone C: Poorly graded materials that are prone to ravelling

Zone D: Fine plastic material prone to slipperiness and excessive dust

Zone E: Optimum materials for best performance

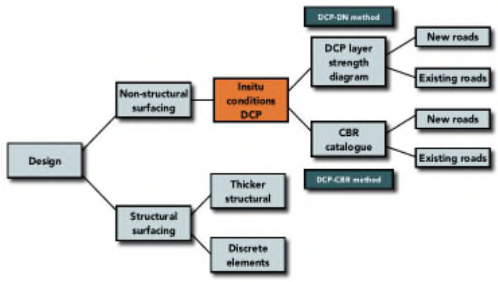
Pavement Design

- Gravel wearing course thickness (gravel loss):
  - National Rural Feeder Road Policy:
    - F1: 150 mm; F2: 100 mm; F3: spot regravelleing
  - Thickness = f (min. thickness, traffic, maintenance, design period)
    - HDM-4
    - Reference manuals (e.g. TRH20, AfCAP manuals)

Material Quality Zone [1]	Material Quality	Typical gravel loss (mm/yr/100vpd)
Zone A	Satisfactory	20
Zone B	Poor	45
Zone C	Poor	45
Zone D	Marginal	30
Zone E	Good	10

Pavement Design

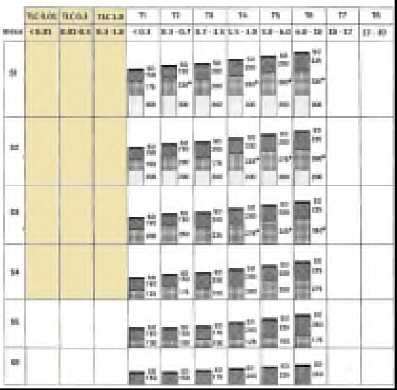
- Current design method:
  - No structural design methods for low volume sealed roads in Sierra Leone
- Proposed methods:



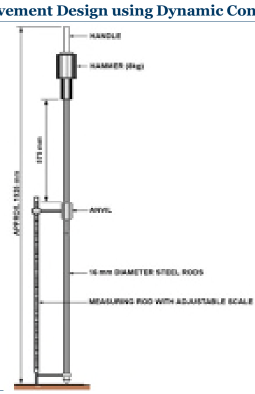
Principles of LVR pavement design

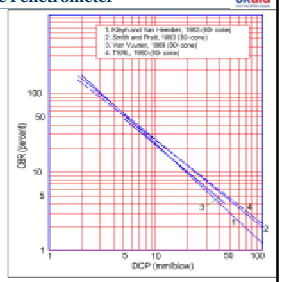
Typical catalogue design:

- From ORN31 (Chart 1 - Granular Road Base)
- Traffic Load Classes
- Subgrade Classes



Pavement Design using Dynamic Cone Penetrometer



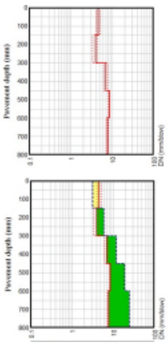


Pavement Design – DCP/DN Method

DCP/DN design method for upgrading existing gravel roads

- Estimate the traffic loading
- Assess the existing pavement and subgrade - DN profile with depth (uniform sections)
- Compare the actual strength profile with required profile from the catalogue
- Determine how to make up deficiency
- Look for materials with required DN values for new layers

DN = mm/blow



Pavement Design – DCP/DN Method

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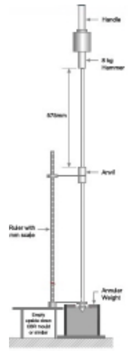

Quality Management System

- Quality Plan
  - Provide guidance on the contractual specification for quality management and a quality plan
- Quality Assurance
  - Method statements
  - Work instructions
  - Control forms
  - Check lists
  - Measurement & Monitoring
- Quality Control
  - Production Control
  - Acceptance Control

 27

ReCAP

UKaid

Questions?

ReCAP
Research for Community Access Partnership

UKaid

Hydrology/Drainage

Festus Odametey

Outline

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1. *Introduction*

i. General

Water is often the cause, whether directly or indirectly of roadway destruction or pavement failure. Poor drainage is a major contributing factor to failure of road pavement structure.

ii. Purpose

To equip the Design Engineer with the needed knowledge, tools and techniques for effective design of drainage structures on Low Volume Roads.

iii. Scope

- cover extensively the steps required to design storm drainage structures to minimize or eliminate flooding of Low Volume Rural Roads (LVRR).
- ensure that Low Volume Rural Roads are motorable all year round by providing adequate drainage structures across and along the road corridor to keep surface free of surface runoff after heavy downpours.

- Three main stages involved in the design of drainage structures namely:
  - Data collection
  - Hydrological studies (estimation of peak flows)
  - Hydraulic analysis (estimation of capacities of drainage structures)

iv. Summary of Standards and Departures from Standard

- Design Return Periods

Type of Drainage Structure	Designed Return Period, years	Maximum Return Period, years
Unlined side drains	2	5
Lined Side drains	5	10
Drifts	2	5
Vented Drifts	5	10
U and Pipe Culverts	10	25
Minor Box Culverts	10	25
Major Box Culverts	25	50
Small Bridges, Span < 10m	25	50
Major Bridges, Span >= 10m	50	100

Minimum Culvert Size

Watercourse Culvert	Minimum	Access/Relief Culverts	Minimum
Pipe	900 mm Dia.	Pipe	600 mm Dia.
U-Culvert	900 x 1200	U-Culvert	700 x 900
Rectangular	1000 x 1000	Rectangular	1000 x 1000

Flow Velocities in Drainage Structures

Drainage Structure	Minimum, m/s	Maximum, m/s
Culverts	1.0	3.0
Open Earth Drains (no lining)	0.6	1.7
Stone or Block Masonry	0.6	1.8
Plain/Reinforced concrete	0.6	3.0
Dry Compacted gravel or Clay	0.6	1.0

- Freeboard
  - Open Drains 0.30m
  - Minor Culverts: Spans ≤2.0m 0.30m
  - Major Culverts: Spans > 2.0m 0.67m
- Culvert Alignment and Grade
  - It is recommended that culverts be placed on the same alignment and grade as the natural streambed, especially on year-round streams.
- Multiple Cell/Barrel Culvert
- Culvert Material Selection
- End Treatment (Inlet & Outlet)
- Outlet Protection

- Sections of Drains
  - *Open – Trapezoidal*

    Minimum bottom width: 30cm

    Side Slope Unlined: 1:2 to 1:4

    Side Slope Lined: 1:1, 1:1.5, 1:2

  - *Circular/Pipe Culverts*

    Minimum Diameter: 900mm for watercourse culverts and 600mm for accesses/junctions

    Maximum Diameter: 2000mm

    Minimum Cover: 0.6m

  - *Rectangular/Box Culvert*

    Minimum Height: 1.0m

    Minimum Width: 1.0m

  - *U-Culvert*

    Minimum Height: 0.7m

    Minimum Width: 0.9m

- *Carrying capacity of drains:*

Manning's Formula is used to size drainage structures with the following values of Manning's roughness coefficient, n.

Material in the drain	Roughness coefficient
Concrete lined channel.	0.013 – 0.015
Sandcrete block	0.015 – 0.020
Masonry	0.017 – 0.030
Earth (new)	0.018 – 0.030
Earth (existing)	0.022 – 0.060

v. General Considerations
- Environmental Considerations
- Safety Considerations

vi. Terminologies

vii. Classification of LVR Drainage
- Surface Drainage
- Subsurface Drainage
- Slope Drainage
- Drainage of Structures

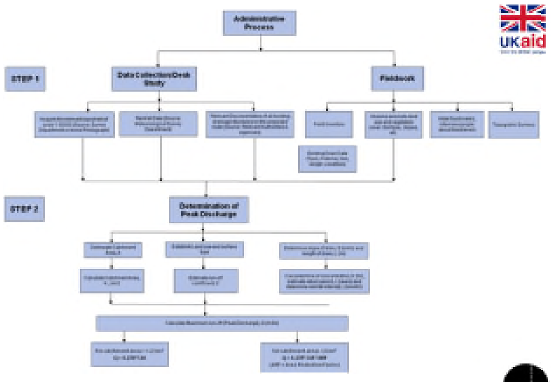
2. *Hydrological and Drainage Studies*

i. Administrative Processes
- Collection of Existing Documents and Desk Studies
- Field Data Collection

ii. Estimation of Peak flow

a. Field Observation Methods
- Direct Observation of the size of the Stream Channel or Watercourse
- Direct Observation of Erosion and Debris
- History and Local Knowledge
- Replicating Successful Practice

b. Rational Method
- Gives satisfactory discharge results only on small catchments areas i.e. < 2.0 square kilometers.
- It is assumed that the intensity of the rainfall is the same over the entire catchment area.



Flow Chart for Estimation of Peak flow

c. Modified Rational Method -
- Use for larger catchment i.e. > 2.0 square kilometers.
- Areal Reduction Factor (ARF)

d. WinTR 20
- Subarea Parameters
- Stream Parameters
- Structure Data
- Design Return Period

3. Choice of Drainage Structure

i. Side Drains

- Rectangular (U-Shaped) concrete lined –Recommended at settlement areas along the road corridor
- Trapezoidal Earth Channel
- Trapezoidal Stone Pitched
- Trapezoidal Concrete Lined
- Triangular (V-Shaped) Earth Channel

ii. Culverts

- *Watercourse Culverts:* Usually pipe and box culverts will be used.
- *Relief Culverts:* Pipe and U-Culverts.
- *Access Culverts:* U-Culverts recommended.

iii. Small Bridges

- Will be recommended where stream depth is greater than 4.0m

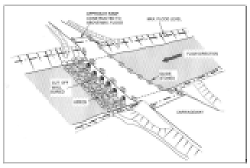
iv. Drifts and Vented Drifts or Causeways

- Drifts are suitable for shallow water courses with a gentle gradient and at sites where raising the road over a culvert would require the transport of large quantities of earth

Typical features of a drift

A Hand Packed drift

- Vented drift is a combination of a culvert and a drift. They are suitable for carrying roads across water courses which have a little water flow for most of the year and which have large flows for less than three days after heavy rains.



Typical features of a vented drift

A typical vented drift / causeway

4. Hydraulic Analysis

i. Side Drains

- Longitudinal ditches
- Mitre drains (Turn-outs)
- Catch water drains (Cut-off ditches/drains)

Design Methods:

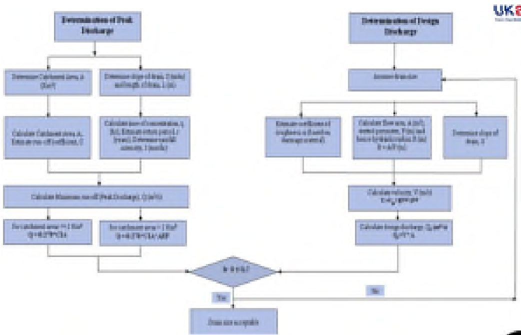
- The flow capacities of side drains can be determined from the simple expression:

$Q = VA$ i.e. Manning's formula

$V = 1/n\, R^{2/3} S^{1/2}$

where,

Q = Peak flow, m^3/s
V = Velocity of Flow, m/s
A = Catchment Area, m^2
R = Hydraulic Radius = A/P, P = wetted Perimeter, m
S = Slope, m/m
n = Roughness Coefficient



Flow Chart for Estimation of flow capacities of Side Drains

- The flow capacities of side drains can again be determined using the computer based software, HY-22 for open channel analysis.
  - ➢ Select channel type: rectangular, circular, trapezoidal
  - ➢ Input data :
    1. Channel slope, m/m
    2. Bottom Width, m
    3. Side Slopes
    4. Manning's Coefficient
    5. Designed Discharge, m^3/s
    6. Depth, m
  - ➢ Analyze

Mitre Drain (Turn-outs):

- Generally rule, provided every 25 metres
- At least one at every 100 metres.
- Maximum distance normally be 200 metres.

Mitre Drain (Turn out Spacing)

Longitudinal/ Side drain Gradient, S (%)	Spacing (m)
1 or less	50
1 - 2	40
2 -5	25
5 - 10	15
more than 10	10

iii. Culverts

- Cross Drainage Structures (Stream Culverts, Relief Culverts)
  Relief culverts may be required at intermediate points where a side drain carries water for more than about 200m without a mitre drain or other outlet.
- Access Culverts

Recommended Spacing between Relief Culverts

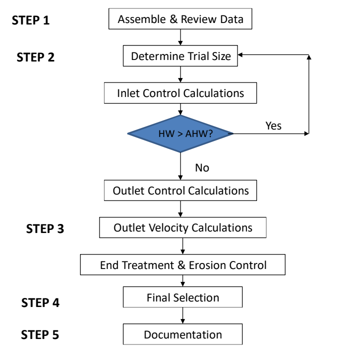
Longitudinal Gradient of Road/ drain, %	Recommended Interval of cross drainage, m
2	200
3-4	150
5	135
6	120
7-8	100
9-10	80
11-12	60

Design Methods:

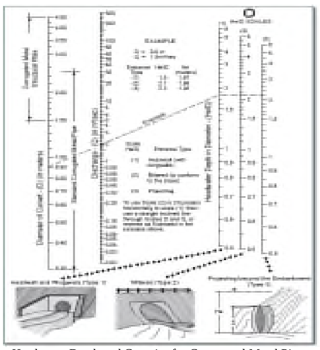
a. Culvert opening is estimated using the nomographs for:
   - corrugated metal pipes
   - concrete pipes
   - concrete box culverts.

b. Using HY-8 Culvert Analysis software

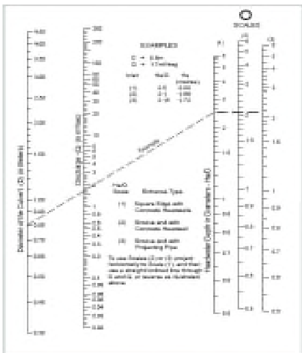
   Input Data:
   - ➢ Crossing Properties (Discharge Data, Tailwater Data, Roadway Data)
   - ➢ Culvert Properties
     - Culvert Data (Slope, Material, Manning's n)
     - Site Data (Culvert Invert Data or Embankment Data)
   - ➢ Overtopping Analysis



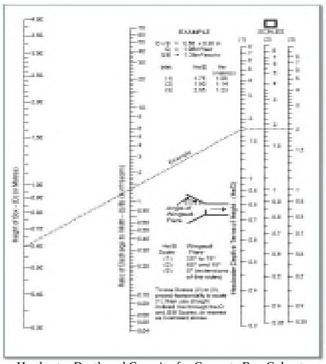
Flow Chart for Estimation of flow capacities of Culverts



Headwater Depth and Capacity for Corrugated Metal Pipe Culverts with Inlet Control (Adapted from FHWA, 1998)



Headwater Depth and Capacity for Concrete Pipe Culverts with Inlet Control (Adapted from FHWA, 1998)

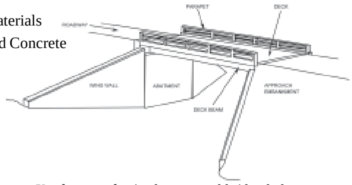


Headwater Depth and Capacity for Concrete Box Culverts with Inlet Control (Adapted from FHWA, 1998)

iv. Small Bridges

- Bridges are generally the most expensive type of road structure, requiring specialist engineering advice and technically approved designs.

- Bridge Materials
  - ✓ Reinforced Concrete
  - ✓ Steel
  - ✓ Timber



Key features of a simply supported bridge deck

- If the crossing is to be used by pedestrians, proper protected footways should be designed on both sides of the carriageway.
- Reinforced concrete parapets are preferred rather than steel guard rails.

5. *Sedimentation and Erosion Control*

- Sedimentation Control
  - ✓ A factor of safety of 2 (in terms of water flow capacity) in flat terrain.
  - ✓ Slope/fall should be 3-5%. to minimize silting and deposition of debris in the culvert.

Siltation in cross culvert

- Erosion Protection
- Scour Checks for Erosion Control

Scour check Spacing

Drain Gradient , S (%)	Scour Check Spacing, m
5	20
6	15
7	10
8	7.5
9	6
10	5
11-12	4

6. *Design of Drainage Structures*

- Scour
- Foundations
- Concrete slab
- Aprons
- Headwall & Wingwalls
- Cut-off Wall/Curtain Wall
- Rip-rap
- Gabions

7. *Construction Materials*

- Stone Masonry
- Brick and Block Masonry
- Timber
- Plain and Reinforced Concrete

8. *Construction Methods*

- Preparatory Work
- Site Work
- Site Administration

9. *References*

i. Sierra Leone National Rural Feeder Roads Policy Document (2011)
ii. Ethiopian Manual for Low Volume Roads (2016)
iii. Tanzania Ministry of Works, Transport and Communication, Low Volume Roads Manual (2016)
iv. Liberian Feeder Roads Design Manual and Specifications (2016)
v. Liberian-Swedish Feeder Roads Project- best Practice Guidelines
vi. Ghana DFR Guidance Notes for the Design of Rural Feeder Roads (2004)
vii. Ghana DFR Site Supervision Pocketbook (2004)
viii. Hydrological & Drainage Design: Design Guidelines, Criteria and Standards by Bureau of Design
ix. Ghana Highway Authority Road Design Guide (1991)
x. Ghanaian Practitioners Guide to Rural Roads Improvement and Maintenance (2014)
xi. Ghana MoT Standard Specification for Road and Bridge Works (2007)