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Review and updating of the Low Volume Road Pavement Design Guidelines for Kenya

Inception Report

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TRL Ltd.

AFCAP Project Reference Number. KEN 2039A

2nd February 2016

TRL

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Cover Photo:

Quality assurance and review table			
Version	Author(s)	Reviewer(s)	Date
1	A Otto, J Rolt, R Workman		14/12/2015
2	R Workman		02/02/2016

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REPUBLIC OF KENYA

MINISTRY OF TRANSPORT AND INFRASTRUCTURE

STATE DEPARTMENT OF INFRASTRUCTURE

MATERIALS TESTING AND RESEARCH DIVISION

Review and Updating of the Low Volume Roads Pavement Design Guidelines

INCEPTION REPORT

2nd February 2016

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Key words

Low Volume Sealed Roads, Guideline, Pavement Design, Review, Updating, Kenya

Acknowledgements

Materials Testing and Research Division
Kenya Rural Roads Authority
Egis International consultants
NorKen consultants

Acronyms, Units and Currencies

AC	Asphaltic Concrete
AFCAP	Africa Community Access Partnership
CBR	California Bearing Ratio
DCP	Dynamic Cone Penetrometer
esa	Equivalent Standard Axles
ETB	Emulsion Treated Base
KeRRA	Kenya Rural Roads Authority
LVR	Low Volume Roads
LVSR	Low Volume Sealed Roads
MDD	Maximum Dry Density
MTRD	Materials and Testing Research Division
OMC	Optimum Moisture Content
PI	Plasticity Index
QA	Quality Assurance
RDM	Road Design Manual
RSA	Republic of South Africa
ToR	Terms of Reference
TRL	Transport Research Laboratory
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)

Contents

1 Executive summary

AFCAP promotes safe and sustainable rural access in Africa through research and knowledge sharing between participating countries. Kenya was a beneficiary of the first phase completed in July 2014 and is also involved in the second phase which commenced in August 2014. As a part of this, the development of a cost effective road design guideline for Low Volume Sealed Roads (LVSR) is to be undertaken, which is the subject of this report.

The original LVSR document was published in 2014, in response to the fact that the Road Design Manuals (RDM) cater mainly for high volume roads. The guideline has been developed with the principle of being a simple, easy to use guide to supplement the RDM and make it easy for consultants and government engineers at all levels to effectively design low volume pavements. Significant research has been carried out on low volume roads in Africa, much of which was carried out by TRL and will be relevant to Kenya. Initial meetings with MTRD and other users of the guideline indicated that there may be some shortcomings, both in the accuracy of its outputs and in the completeness of its content.

The objectives of this project are to update current LVSR guideline, involve MTRD in its development in order to build national capacity and to scope out a sensitisation and training programme for Government, Counties and other Guideline users.

The TRL team were provided with a number of relevant documents and reports that were necessary to undertake the review. The team propose to gain feedback from users of the guideline in order to identify shortcomings and review them in more detail. The documents to be reviewed include the RDM series and the Kenyan specifications. The review process will include feedback and opinions from practitioners, which includes MTRD staff, consultants and others. This feedback will identify how the guideline is used to design pavements for LVSRs and any issues or problems encountered with using the guideline, as well as the positive aspects of the guideline and how effective it is in determining appropriate pavements for LVSRs. The team will use their experience in the region and elsewhere to ensure that international best practice central to the guideline principles.

As part of the review process, and to provide capacity building and continuity, two MTRD engineers have been identified as counterparts to the team and will assist in drafting the guideline, including two visits to TRL in UK.

A programme has been proposed and can be seen in section 6. This includes all of the main milestones, as well as the peer review and the visits of the counterpart engineers to TRL. It is expected that the deadlines for deliverables will be met.

From initial meetings and an outline review, then main issues have been identified as:

- The structure, layout and explanatory notes need to be revised to make the manual more user friendly
- The traffic section does not include sufficient information to allow the designer to make the necessary decisions in estimating diverted and generated traffic
- A number of issues have been identified so far with the sub-grade design, these will be investigated further and proposals made for improvement
- An initial check of the design charts has shown some inconsistencies in outputs, so a check of existing designs will be undertaken to identify and correct anomalies.
- The range of materials has been reviewed and initial impressions are that it is not fully comprehensive, with some potentially key materials not covered. A full list of

materials will be developed for the interim report, which will include local materials that may not have full specifications developed but which can be used cost effectively on roads in Kenya.

- The surfacing options are generally appropriate. The guideline does however omit some types of surface that are appropriate for use on LVRs, so a full list will be developed.
- Other miscellaneous issues include drainage and moisture contents, which will be fully discussed and reviewed in the interim report.

Upon review and approval of the Inception Report tasks will be assigned to team members, including the two counterpart staff from the MTRD who will also be co-authors. The first stakeholder workshop will be arranged to review the interim report, after which the revised guideline is expected to be substantially complete. A further peer review and revision process will be finalised with another stakeholder workshop to finalise the contents, after which the final document will be printed and a final report produced.

2 Background

2.1 AFCAP and Kenya

AFCAP is promoting safe and sustainable rural access in Africa through research and knowledge sharing between participating countries and the wider community. Kenya was a beneficiary of the first phase of AFCAP implemented from June 2008 to July 2014 and this has been continued within the second phase of the programme which commenced in August 2014 and will cover a period of 6 years. As a part of this, the development of a cost effective road design guideline for low volume roads is to be undertaken.

Low Volume Roads (LVR) typically carry less than 300 vehicles per day and less than 1 million equivalent standard axles (esa) loading during their design life. They provide important links from homes, villages and farms to markets and offer the public access to health, education and other essential services. They also provide important links between village centres and the State and National road network. The Kenyan Road Design Manual was developed in the late 70's and early 80's based on research in Kenya. It is considered to be very successful but it did not provide pavement designs for cumulative standard axle loadings below 250,000. Most of the roads with traffic below 250,000 cumulative standard axles have to be improved to all weather standards.

However, gravel is becoming less abundant, and therefore more expensive. Gravel roads require continuous and expensive maintenance, the dust nuisance is a health hazard and in wet weather gravel roads can become impassable if maintenance is inadequate. Thus the design of more durable roads with lower life cycle costs has become a high priority. There is therefore a need for an appropriate national road design guideline for such roads.

2.2 Low Volume Sealed Roads Guideline

This document was published in 2014, following a period of development. It was developed in response to the need for guidance in how to design the pavements for low volume sealed roads, due to the fact that the Road Design Manuals cater mainly for high volume roads. The guideline has been developed with the principle of being a simple, easy to use guide to supplement the RDM and make it easy for consultants and government engineers at all levels to effectively design low volume pavements. This is particularly relevant with the recent programme to upgrade 10,000 km of gravel roads in Kenya to a sealed surface.

This project has been designed to review and revise the LVSR guideline to make it a relevant and accurate document for the design of LVR pavements, which incorporates local conditions and international best practice. In updating the LVSR guideline it will also be necessary to review and comment on the relevant parts of the RDM Manuals, specifications and other related documents.

3 Introduction

A large amount of research has been carried out on low volume roads, both in Africa as well as in Kenya, which has led to the development of manuals, specifications, guidelines and other documents. Much of this research was carried out by TRL and much of it will be relevant to Kenya. MTRD have noted that there may be some shortcomings in the LVSR guideline, both in the accuracy of its outputs and in the completeness of its content. However, whilst the guideline will need some revision and addition, it should retain the principle of being a concise and simple to use document.

4 Project objectives

The objectives of this project are to:

- Update current Low Volume Sealed Road Design Guidelines issued in June 2014 in order to deliver best value for the Ministry's planned upgrading of 10,000km to sealed standard in 5 years.
- Involve MTRD in its development in order to build national capacity.
- Scope out a sensitisation and training programme, for Government, Counties and other Guideline users.

5 Methodology

5.1 Information gathering

MTRD provided the TRL team with a number of relevant documents and reports in both hard copy and soft copy, where available. These included:

- Geometric Design Manual RDM1.
- Pavement Design Manual RDM3 and any relevant reports or comments regarding the revision of this manual.
- Any relevant specifications that would relate to low volume roads, such as the Standard Specification for Road and Bridge Construction; Ministry of Roads and Public Works, 1986, Series 1200, 1300, 1400 and 1500.
- Any recent research reports for materials relevant to the project.
- Any reports or documents that would provide information on the development of the current 2014 guideline.
- Any documents showing the different classes of traffic used for road design in Kenya (we understand from our initial meetings that this varies).
- A copy of the Road Traffic Act.
- Any information you are able to provide on the recent DCP design trials.

The team propose to gain feedback from users of the guideline to identify relevant parts of the documents above that have an effect on the LVSR guideline. These relevant parts will then be reviewed in more detail, as shown below.

5.2 Review of key documents

A number of key documents will need to be reviewed for this project because they are either the sources of information used in the original development of the guideline or provide more detailed information that explains various features of the current Kenyan design method. The main documents to be reviewed are:

- Pavement Design Guidelines for Low Volume Sealed Roads
- RDM 3: Pavement Design.
  It is understood that this manual is under review and is due to be completed by the end of 2016. This manual was not designed to cover low volume roads but there are various aspects that are common to both high and low volume roads and these need to be identified, reviewed and incorporated. Furthermore, it is likely that the LVSR guidelines will also be incorporated, in manual form, in the final RDM. TRL hope to access any comments or reports that have been made on the

review process so far, in order to consider the aspects that affect the LVSR guidelines.

- Report 345: Survey of Subgrade Conditions in Kenya and their Influence on Road Performance
- Standard Specification for Road and Bridge Construction; Ministry of Roads and Public Works, 1986, Specification Series 1200, 1300, 1400 and 1500.
  These specifications are relevant to low volume roads and will be reviewed with the other documents.
- RDM 1: Geometric Design

5.3 Review of existing guideline

The review process will include gathering feedback and opinions from practitioners of the guideline. This will include MTRD staff, consultants and others. MTRD helped to arrange the initial meetings for the team with known users of the guideline. Further meetings will follow and the subsequent feedback will identify:

- How the guideline is used to design pavements for LVSRs
- Any issues or problems encountered with using the guideline
- The positive aspects of the guideline and how effective it is in determining appropriate pavements for LVSRs.

The team met with the following practitioners who are involved in low volume roads:
MTRD:

- Eng. Stephen Kogi – Chief Engineer Materials
- Eng. Maurice Ndeda – SPSE (RSPM)
- Eng. Joachim Mbarua – PSE
- Eng. Daniel Wanyiri - Engineer
- Eng. Hillary Cherop – Materials Engineer
- Veronica Akinyi – Technologist
- Tom O. Rae – Technologist
- Peter Makau - Technologist

Ministry of Transport and Infrastructure:

- Eng. P.C. Kilimo – Infrastructure Secretary

KeRRA:

- General Manager
- Eng. Hillary Akwiri

Private sector:

- Egis International
- NorKen
- Jon Hongve – Private Consultant

5.4 Counterpart Staff

The terms of Reference have allowed for two staff members from MTRD to assist in the review and updating of the LVSR guidelines. This is an important capacity building aspect of the project as these staff will be joint authors and will spend two blocks of two weeks in the UK at TRL, assisting in the drafting and finalisation of the guidelines. The nominated counterpart staff are:

- Joachim Mbarua Mimaria

- Albert Owuor Ndege

It is presumed that these staff will be seconded to the project on a part-time basis until the completion in June 2016. However, it is expected that the counterpart staff will be available full-time during the periods when the TRL team are in-country. The Principal Secretary, State Department if Infrastructure, shall invite participants to the stakeholder's workshops and the Chief Engineer (Materials) shall assist with the organisation of the workshops.

The programme shows the periods when the counterpart staff are expected to visit the UK. It should be noted that it takes approximately three weeks for Kenyans to obtain a visa to the UK. TRL will assist in this process, but the counterpart staff should initiate the process in good time so that the visits are not delayed and the programme can remain on track.

5.5 Checking contents against existing standards and best practice

The TRL team will use their experience in Kenya and other countries in the Region to assess the contents of the existing LVR guideline.

6 Programme

The proposed programme for the project is shown in Figure 1. The proposed milestones for deliverables are as shown in the ToR. The inception period will complete by 15/12/2015, after which feedback will be sought and the work of drafting the revised guideline will commence. It is expected that the counterpart engineers will be involved in the feedback and revision process, as detailed below. In general at least two weeks has been allowed for feedback following the submission of the various deliverables for the guideline. However, following comments from MTRD, the workshop dates and interim draft submission date have been slightly moved back to allow more time for feedback of initial drafts, but the overall completion date remains the same. It is important that feedback is provided promptly as there is very little flexibility within the programme.

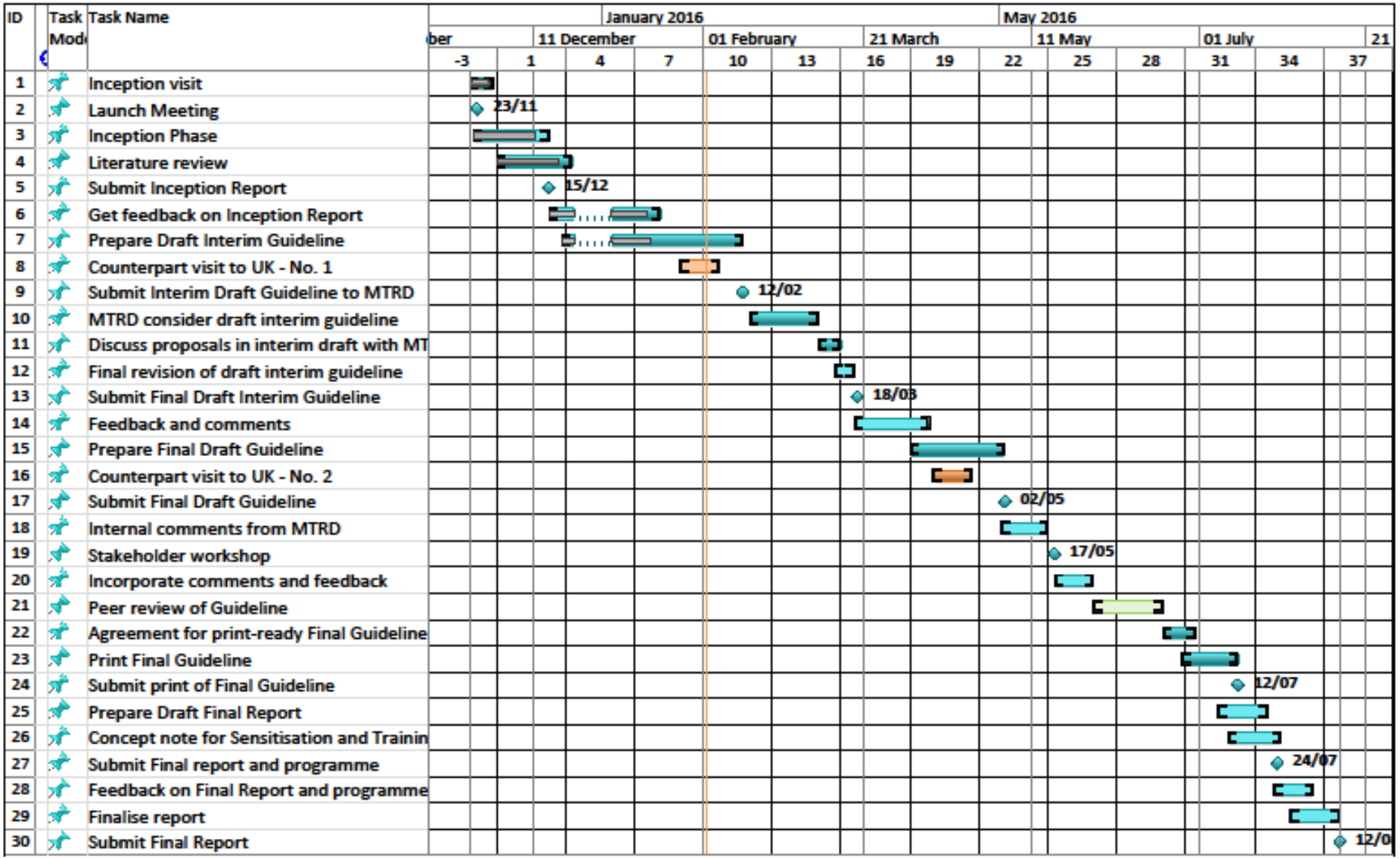
The proposed start date for the Peer review is Monday 14th March 2016. AFCAP is resourcing and arranging the peer review. A period of approximately two weeks has been allowed for this, in order to maintain the expected deadlines.

The proposed dates for the two counterpart engineers to visit UK to assist in the review of the guideline are shown on the programme as:

- 23/01/2016 to 7/02/2016 – to assist with the preparation of the first draft of the guideline, in time for the first stakeholder workshop on 9/02/2016 and submission of the interim draft on 15/02/2016.
- 05/03/2016 to 20/03/2016 – to assist with the preparation of the final draft version of the guideline in time for the second workshop on 5/04/2016 and submission on 12/04/2016.

TRL are will be required to assist with visas and logistics, so it would be beneficial if these dates could be confirmed as soon as possible. It should be noted that MTRD have the responsibility to confirm the workshop dates, invite the participants and organise the venue and logistics. This will need to be completed in good time to avoid delays.

Figure 1 - Programme for Implementation



7 Summary of Technical Review

This section includes a summary of the technical findings on the LVSR guidelines so far. The full text can be found in Annex A.

7.1 General

As stated earlier, MTRD wish to maintain the simple nature of the guidelines and make it an easy to use document. The British system for amendments is recommended, so that the guideline remains easy to update. The style and layout of Overseas Road Note 31 has been quoted as a good example. Some additional notes and text will also be necessary, which will include:

- A flow diagram to show process
- Explanatory notes to guide practitioners in how to use the guideline
- Cross-referencing to the RDM3 and other manuals/specifications
- Needs to be appropriate to a range of users

From the initial consultations and feedback the team have received, the following issues have been identified as requiring further investigation in order to revise the guidelines. Where possible some analysis has been offered, but a full review and technical analysis will be included following the literature review, in the interim draft document:

7.2 Structure, layout and instructions

The guideline is of appropriate size, but does not currently have an easily discernible structure and transition from one section to the other. In addition, all the guideline sections are referred to as annexes. We propose to change these to distinct chapters and to include a flow-chart showing the pavement design process at the beginning of the guideline. The sections and the structure tables in the guideline are not preceded by explanations, so we propose to include concise explanations on how to use the guideline at appropriate places. Lastly, we propose to colour code/shade the pavement structures to make it faster, easier and more accurate to differentiate between the pavement materials.

7.3 Traffic

The traffic chapter of the guideline does not offer the user sufficient information in estimating the design traffic, in particular how to estimate generated and diverted traffic which often occur whenever low volume roads are upgraded. The RDM3 does not offer sufficient guidance on how to deal with this. We intend to include a short and simple method to estimate normal, diverted and generated traffic in the guideline. In addition to this, we propose to include a table showing common vehicle equivalence factors of common heavy vehicles in Kenya. A review of vehicle classification is also necessary.

7.4 Subgrade

The subgrade strength influences the pavement structure and hence the cost of the design. The following is feedback from our consultations, with our proposals:

- The design charts contain overlapping subgrade classes. In consultation with some users of the guideline on which subgrade class they used for design once they have determined the subgrade CBR, the response was that they used the higher subgrade class so as to obtain a less expensive pavement. We are still reviewing documents to find out the reason for the overlap, but certainly guidance must be

offered to the user on how to select the design subgrade class, especially when the design CBR falls in two subgrade classes.

- There are a number of overlapping questions concerning foundation design and capping layers, so foundation design needs to be reviewed. It is not clear where the originals came from but, for each design chart, there are numerous options for the capping layers. A 'structural number' comparison has already been carried out for a few examples and it appears that there are serious anomalies. The SN approach and an approach based on elastic moduli will both be used to resolve the anomalies.
- Existing standards specify processing 300mm of material below foundation, with S2 minimum material. This is still subject to debate and MTRD want to reduce the number of layers and hence the cost of processing.
- There are various subgrade failure criteria developed by road authorities around the world. In the current RDM for High Volume roads the Shell subgrade criterion has been used. A review of subgrade criteria and calculation of stress strain levels under various current designs will be carried out and comparisons made. Solutions and subgrade criteria will be recommended.
- It is important to determine how is the DCP is used for evaluating subgrades and to explore the potential for its wider use if appropriate.
- There is a question about how to achieve S6. For example, what thickness of capping is required to maintain upper subgrade class, S3 to S6. Are 6 classes necessary, as S5 and S6 are very similar. The required strength with depth can be investigated based on subgrade stress/strain criteria. The feasibility of collapsing down to 4 classes will be examined.

7.5 Design Charts

The principles of pavement design are straightforward. The first task is to cover the subgrade with layers of stronger material to reduce the stresses or strains on the subgrade to a level that does not cause subgrade deformation and failure of any kind. The second is to choose material for the layers above the subgrade which will not themselves fail. If the pavement layers are of unbound material the maximum stresses will be at the surface close to the wheels of the heavy traffic hence the specifications for the top layer are critical.

In order to check pavement designs there are two basic methods, namely to compare with designs that are known to have worked – the empirical method – and to compute stresses and/or strains in the pavement and compare with recognised critical levels based on past research. In this project both methods will be used. It is not expected that these two approaches will yield the same answers hence expert engineering judgement may be required to select the most reliable designs.

A single coherent relationship between design thickness/strength and traffic from the lowest class to the highest class should be a smooth line anchored to the results of trials (which obviously cannot include all subgrade strengths and traffic levels). This facilitates the necessary interpolations. A check of the existing designs will be carried out to identify and to correct any anomalies.

7.6 Materials

The range of materials included in the LVSR guideline has been reviewed in outline. Initial impressions are that the range of materials is not fully comprehensive, with some potentially key materials not covered. A full list of potential road construction materials will be developed for the interim guideline, which will include marginal materials that

perhaps do not have specifications in Kenya, but that have been researched in other African countries and which can be used effectively for low volume roads.

Kenya has a combination of a varied geology, geomorphology, climate and residual weathering which has resulted in the occurrence of a wide range of natural materials. An emphasis therefore needs to be put on looking for solutions based on available material types, rather than the conventional approach of trying to find materials to suit standard specifications. This will result in more cost-effective road designs that incorporate appropriate materials and allows more kilometres to be built, rehabilitated and maintained for the funds available.

The guideline currently places a lot of emphasis on the CBR parameter as the sole guiding factor and leaves out important guiding factors such as Plasticity Index, Plasticity Modulus and the Grading Modulus. We propose to include these and other materials specifications in the revised guideline.

For all the levels of traffic under low volume, the existing guideline has proposed natural materials for sub base to be having CBR in the range of 25% - 50% and materials for base having CBR in the range of 30% - 80%. The strengths can be achieved through naturally occurring materials or through mechanical stabilisation for CBR up to 80%. Some naturally occurring gravels found in abundant in Kenya are, namely, lateritic gravels, calcrete, quartzites, coral gravels, weathered rock and gneiss. These gravels have been used for sub base and base for low volume roads and found to perform well, but with much less specification compared to the current guidelines. Guidance notes of how to achieve the required material specifications through blending will be provided.

7.7 Surfacing options.

The LVSR guideline covers the normal range of surfacing materials that would be expected for this type of road. The options for using the various surfacings in association with the various types of base and prime are generally appropriate. The guideline does however omit or not fully cover some types of surface that are appropriate for use on LVRs, such as concrete blocks and in-situ concrete, whilst some issues remain with the use of thin asphaltic concrete and cold asphalt.

Some guiding notes and explanations will be added in this section to assist the engineer in his/her choice for selection of an appropriate surfacing type.

7.8 Miscellaneous

Some other miscellaneous items are also discussed, such as drainage, which is an essential component of low volume roads, and design moisture contents for the various pavement layers.

8 Next Steps

Upon review and approval of the Inception Report tasks shall be assigned to team members, including the two counterpart staff from the MTRD who will also be co-authors of the guidelines. These tasks shall be:

- Review of various documents to find information relevant to the revision of the guideline (ongoing whilst Inception report is being reviewed).
- Wider literature review on the subject (ongoing whilst Inception report is being reviewed).
- Producing summaries of the document review and literature review.
- Defining revisions for key aspects of the guideline, for example the subgrade criterion to be adopted.
- Reviewing and writing the various sections of the guidelines.
- Preparation for the first stakeholder workshop, organisation and implementation.
- Gathering feedback from the workshop and revision as necessary.
- Adjust document based on feedback from peer review.
- Finalise document and print.
- Produce final report.

Throughout this process the TRL team will work very closely with the MTRD and in particular with the two counterpart engineers, in order to ensure that the commitment to capacity building is upheld.

Annex A: LVSR Technical Review

A.1 General

As stated earlier, MTRD wish to maintain the simple nature of the guidelines and make it an easy to use document. They also recognise that it will need to be regularly updated, due to the number of other manuals and specifications/standards that it relies on. Therefore the British system for amendments was recommended. The style and layout of Overseas Road Note 31 has been quoted as a good example for the LVSR guidelines. Some additional explanatory notes will be necessary. The expected revisions are:

- A flow diagram to show process
- Explanatory notes – some parts are not clear how they should be used,
- Cross-referencing will be necessary to the RDM3 and other manuals/specifications
- Needs to be appropriate to a range of users, form experienced engineers to new graduates and County staff.

From the initial consultations and feedback the team have received, the following issues have been identified as requiring further investigation in order to revise the guidelines. Where possible some analysis has been offered, but a full review and technical analysis will be included following the literature review, in the interim draft document:

A.2 Structure, layout and instructions

The guideline is of appropriate size, not too bulky to carry around for use in the field and site office. It currently does not however have an easily discernible structure and transition from one section to the other. For example the transition from the traffic section to the pavement structures is barely noticeable. In addition, all the guideline sections are referred to as annexes. We propose to change these into distinct chapters and to include a flow-chart showing the pavement design process at the beginning of the guideline.

The sections and the structure tables in the guideline are not preceded by explanations. The feedback from users of the guideline is that this is easy to use. This does not necessarily mean that they are using it in the correct way. In the absence of explanations, each user develops in their minds a method of use that they believe is correct and when asked, their answer would be that this it is easy to use. In view of the fact that the guideline will be used countrywide and by counties that are often detached from the MTRD, we propose to include concise explanations on how to use the guideline. Lastly, we propose to colour code/shade the pavement structures to make it quicker, easier and more accurate to differentiate between the pavement materials.

A.3 Traffic

The traffic chapter of the guideline does not offer the user sufficient information in estimating the design traffic. In particular how to estimate generated and diverted traffic which often occur whenever low volume roads are upgraded. The RDM3 that is to be used in conjunction with the guideline does not offer sufficient guidance on how to deal with this. We intend to include a short and simple method to estimate normal, diverted and generated traffic in the guideline. In addition to this, we propose to include a table showing common vehicle equivalence factors of common heavy vehicles in Kenya.

The following points were discussed during the feedback process:

- Traffic – link to RDM3. The LVSR guideline does not take into account traffic growth, which can be significant when a road is, for example, upgraded to a sealed surface from a gravel surface. Initial discussions with users of the guidelines have suggested that the life of the road could be reduced, with the expectation that it will need to be rehabilitated or upgraded after perhaps 5-8 years, as opposed to a design life of say 15 years. This essentially suggests a staged construction approach that could be used in some circumstances. This would also mean that the geometry of the road would need to be taken into account for the potential upgrade. Such decisions should be based on what could be described as the 'function or future function' of the road or the 'task' it is expected to provide. A road that only links a village to a higher class road, for example, will attract no diverted traffic and traffic growth will be moderate compared with a through route linking many villages.
- It has been suggested that there are too few heavy traffic classes. A review of vehicle classification is necessary. In Kenya there are many different standards. T5 is split into sub-classes. Is this too subjective? Some agencies define commercial vehicles as >1500kg, others as >3500kg, others as >7000kg. Sometimes an equivalent factor of 1 is given to vehicles as small as 1500kg. A review of axle loadings from any axle load surveys carried out in Kenya may shed light on which vehicles need to be taken into account to determine cumulative esa's for design purposes. However, vehicle classification is used for other purposes so a consensus will be required.

A.4 Subgrade

The subgrade strength influences the pavement structure and hence the cost of the design. The following are the feedback from our consultations and our proposals:

- There are a number of overlapping questions concerning foundation design and capping layers. Foundation design needs to be reviewed. What capping is necessary on weak subgrades? Capping layer thicknesses for weak subgrades in the guidelines were taken from the RDM 3. It is not clear where the originals came from but, for each design chart, there are numerous options for the capping layers. A 'structural number' comparison has already been carried out for a few examples and it appears that there are serious anomalies. The SN approach and an approach based on elastic moduli will both be used to sort out the anomalies.
- Existing standards specify processing 300mm of material below foundation, with S2 minimum material. This has been negotiated down to 200mm, but is still subject to debate. MTRD want to reduce the number of layers and hence the cost of processing.
- To complicate the issue there are various subgrade failure criteria developed by road authorities around the world. The recent US army results are valid because the research identified real subgrade failures in a number of different strength subgrades in a controlled pavement accelerated test facility under well controlled conditions and because the criteria depended on subgrade strength (surprisingly, most do not). In the current RDM for High Volume roads the Shell subgrade criterion has been used. A review of subgrade criteria and calculation of stress strain levels under various current designs will be carried out and comparisons made. Solutions and subgrade criteria will be recommended.
- It is important to determine how is the DCP used for evaluating subgrades and to explore the potential for its wider use if appropriate.
- There is a question about how to achieve S6. For example, what thickness of capping are required to maintain upper subgrade class, S3 to S6. [The latest British note is based on Stiffness Modulus for high volume roads with a large safety factor. It is unlikely to be appropriate for LVSR in Kenya but will be reviewed]. S5 and S6 are very

similar. The required strength with depth can be investigated based on subgrade stress/strain criteria. The feasibility of reducing from 6 classes to 4 will be explored.

A.5 Design Charts

The principles of pavement design are straightforward. The first task is to cover the subgrade with layers of stronger material to reduce the stresses or strains on the subgrade to a level that does not cause subgrade deformation and failure of any kind. The second is to choose material for the layers above the subgrade which will not themselves fail. If the pavement layers are of unbound material the maximum stresses will be at the surface close to the wheels of the heavy traffic hence the specifications for the top layer are critical. In order to check pavement designs there are two basic methods, namely to compare with designs that are known to have worked – the empirical method – and to compute stresses and/or strains in the pavement and compare with recognised critical levels based on past research. In this project both methods will be used.

The empirical method based on the 'structural number' approach is the simplest and requires less assumptions in its use. It is also the most widely used method. A theoretical or mechanistic analysis of the stresses and strains at the top of the subgrade will also be used based on recent research into the critical strains in the subgrade. These critical strains depend on the strength of the subgrade hence will be different for strong, medium and weak subgrades. The critical stresses and strains in the other pavement layers are much more difficult to evaluate and therefore, for these an empirical approach is used based on the specifications that have been shown to work in practice. Such specifications depend on traffic level and environmental conditions but there is sufficient evidence from experiments in the region to evaluate the LVSR designs. These two approaches are not expected to yield the same answers, so expert engineering judgement will be required to select the most reliable designs.

Figure 2: Foundation/Capping

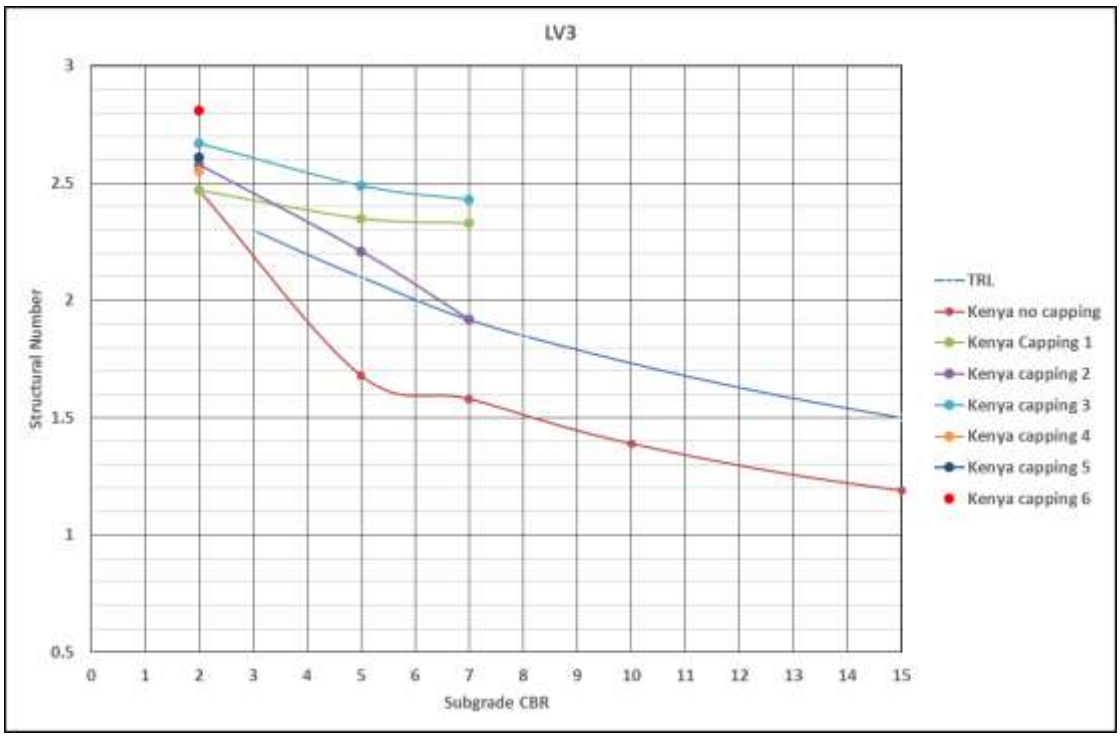


Figure 2 shows the structural number of an LV3 design for different versions of the capping options obtained from the current design charts for different subgrade strengths. It would be expected that the overall strength for each capping option would be very similar but the range is very wide. For example for a subgrade strength of 7% CBR the range is from 1.9 up to 2.4. With the capping layers labelled 'Kenya 3' for example, the 'strength' on the same subgrade is an extra 150mm of material compared with the option labelled 'Kenya 5'. Calculations need to be carried out for other traffic levels.

In addition, mechanistic calculations need to be carried out to determine the strain and stress at subgrade level. Ideally the capping options for *each subgrade strength* should all result in a similar stress/strain level and these will be different for each subgrade strength. The critical level for each subgrade needs to be determined based on the agreed subgrade criteria and the capping thicknesses re-calculated to provide a logical sequence as subgrade strength changes. The agreed subgrade criteria depends on our review of the wide range of criteria that have been published but it is expected that the criteria will also depend on subgrade strength as shown in recent controlled studies rather than in back analysis of full scale trials.

A single coherent relationship between design thickness/strength and traffic from the lowest class to the highest class should be a smooth line anchored to the results of trials (which obviously cannot include all subgrade strengths and traffic levels). This facilitates the necessary interpolations. A check of the existing designs will be carried out to identify and to correct any anomalies.

In addition, the design charts contain overlapping subgrade classes. In consultation with some users of the guideline on which subgrade class they used for design once they have determined the subgrade CBR, the response was that they used the higher subgrade class so as to obtain a less expensive pavement. We are still reviewing documents to find out the reason for the overlap, but certainly guidance must be offered to the user on how to select the design subgrade class, especially when the design CBR falls in two subgrade classes.

A.6 Materials

The range of materials included in the LVSR guideline has been reviewed in outline. Initial impressions are that the range of materials is not fully comprehensive, with some potentially key materials not covered. A full list of potential road construction materials will be developed for the interim report, which will include marginal materials that perhaps do not have specifications in Kenya, but which have been researched in other African countries and have been found to be used effectively for low volume roads.

Kenya has a combination of a varied geology, geomorphology, climate and residual weathering which has resulted in the occurrence of a wide range of natural materials. More cost-effective road designs can be achieved by using designs that incorporate appropriate materials and allow more kilometres to be built, rehabilitated and maintained for the funds available.

The benefits of utilising locally available materials in Kenya arise from:

- a reduction in haulage costs;
- less damage to existing pavements from extended haul;
- reduced carbon emissions by reducing long haul distances;
- stimulation of the local economy and local enterprise;
- road designs compatible with local maintenance capabilities;
- reduced whole life costs;

- saving scarce high quality gravels for high volume routes.

The guideline currently places a lot of emphasis on the CBR parameter as the sole guiding factor and leaves out important guiding factors such as Plasticity Index, Plasticity Modulus and the Grading Modulus. We propose to include these and other materials specifications in the revised guideline.

For all the levels of traffic included under the 'low volume' title, the existing guideline has proposed natural materials for sub base with a CBR in the range of 25% - 50% and materials for base having CBR in the range of 30% - 80%. These strengths can be achieved with naturally occurring materials or through mechanical stabilisation for CBR up to 80%. Guidance will be offered on how to achieve these characteristics through blending.

Some naturally occurring gravels found in abundance in Kenya are:

- lateritic gravels
- calcrete
- quartzites
- coral gravels
- weathered rock
- gneiss

These gravels have been used for sub base and base for low volume roads and were found to perform well, but with much less specification compared to the current guidelines.

The lateritic gravels that are abundantly found in Kenya have been found to achieve CBR strengths of up to 60%, and when mechanically stabilised with quarry dust may achieve CBR strengths of up to 80% for base when compacted at 100% of the MDD. Naturally occurring lateritic gravel may also be used as a base layer for the pavement structure for LV4, instead of the cement/lime improved gravel as proposed.

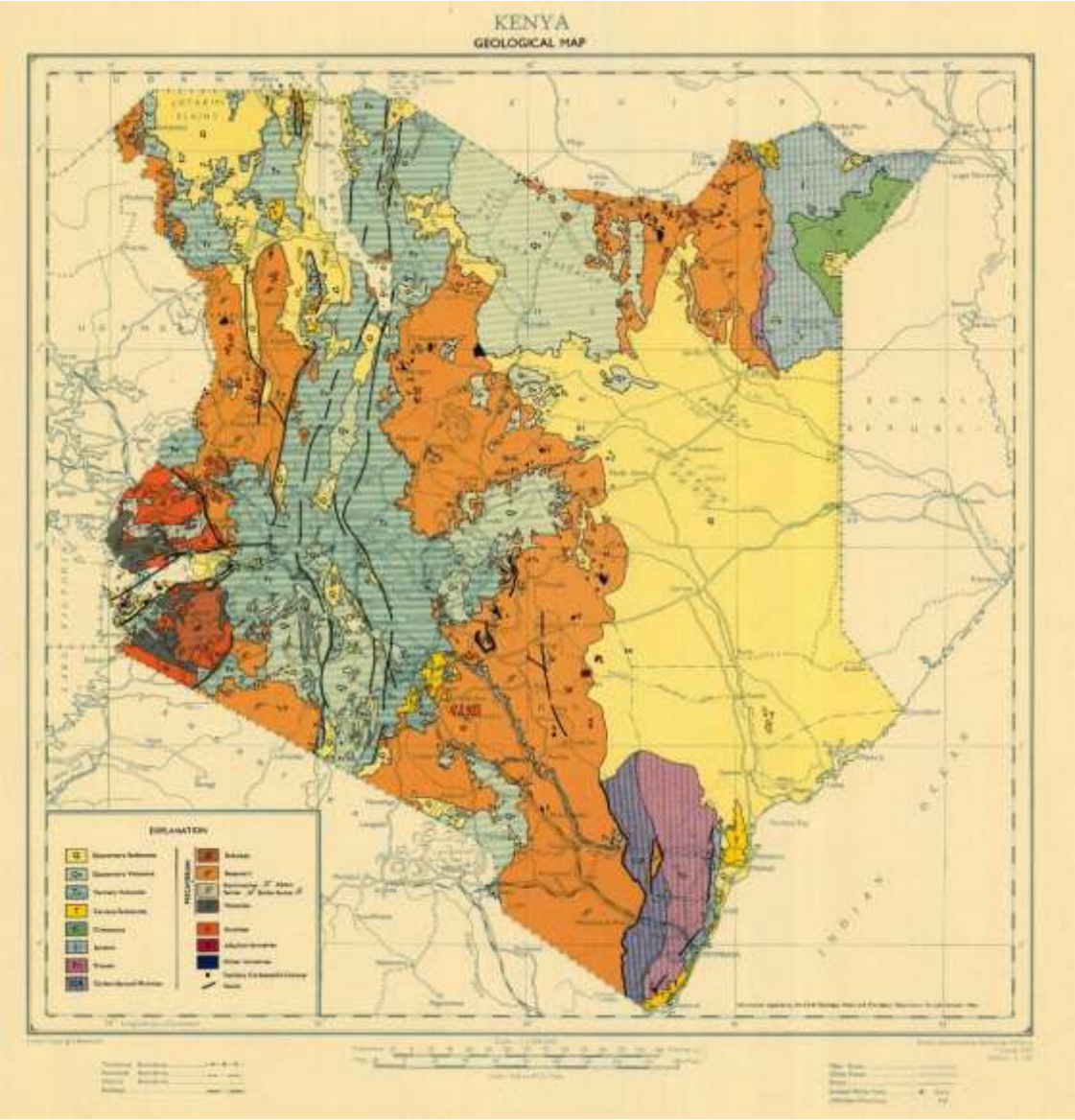
The quartz gravel will always give high CBR strengths which, based on the current guidelines, qualifies the gravel to be used naturally for sub base and base of the pavement structure for LV1 – LV6 and LV6 – LV14 without improvement. However, quartzitic materials are very weak in bonding and would disintegrate soon after compaction. In this case CBR alone cannot be used to qualify the quartzitic gravels for use without improvement. Gneiss is available in areas with shallow basement rocks, for example in Eastern, Western and parts of the North Eastern areas of Kenya. In such areas locally available crushed rocks may be used for both the base and sub base.

Design of low volume Roads: The design procedure for gravel roads will be simplified and the principal governing factors will be;

i. Quality of available material and QA regime
ii. Haul distance
iii. Subgrade characteristics
iv. Traffic, not covered in this study
v. Geometrics, not covered in this study
vi. Routine maintenance regime
vii. Likelihood of periodic re-gravelling
viii. Environmental factors

In addressing the (i), (ii), (iii), (vi) and (vii) above, we will consider the documented geological formation of Kenya, as shown in Figure 3, below;

Figure 3: Geological map of Kenya



In the review, we shall endeavour to ensure that the available materials within each region, as mapped above, are considered for use as sub-base and base as necessary.

In addition, during our consultations with the users, the following points were raised and our proposals follow:

- It was mentioned that the PI limits for unbound road bases should be tightened to reduce risk of potholes developing quickly if the surfacing is damaged, permitting water entry. The idea here is that this will be a safer design if maintenance is not as frequent as it should be but construction will be more expensive (and often by a large margin). Many roads have narrow shoulders and are thus potentially affected by

moisture ingress from the side ditches. Furthermore, many roads are low lying having 'sunk' between raised sides. For these reasons they are susceptible to wetting and it is thought that enhanced PI limits could provide a modest safety factor. The question is, will lower PI values compensate for poor maintenance. Is high PI actually a contributing factor to early failures under a poor maintenance regime. Is a higher embankment of weaker material a less expensive option in the long term. These issues need to be studied in detail and advice given depending on the individual situations. It is unlikely that one approach will be the best in all situations. Other methods should also be considered.

- Base material of CBR 50% is usually obtained by blending quarry dust with lateritic gravel. A brief guidance note will be offered on this.
- Pre-treating using lime in order to reduce PI was another subject discussed, Often cement and lime is added at the same time. MTRD want to know if possible to prep-treat and add cement later. This will be investigated.
- Emulsion Treated Base (ETB) is liked because of its early strength and quick curing properties, but it is expensive to implement because composite layers are used. However, there are differences of opinion about how to do this, i.e. lay as one or as two layers and whether to prime or tack? MTRD are using TG2 from RSA, but this does not cover composite layers. This will be investigated.
- MTRD also want TRL to recommend appropriate testing. Most PI testing is carried out by cone penetrometer, but Casagrande may be necessary for other testing of PI. TRL to recommend appropriate testing methods and whether upgrading is required and why.

A.7 Surfacing options.

The LVSR guideline covers the normal range of surfacing materials that would be expected for this type of road. The options for using the various surfacings in association with the various types of base and prime are generally appropriate. The guideline does however omit some types of surface that are appropriate for use on LVRs. The comments below highlight the main areas that will be discussed for revision:

- Cobblestones are one surfacing material that is included, but is not often used. Concrete blocks could be used instead, but there is at present no specification for this. It will be necessary to develop specifications and testing methods, for example compressive strength testing is used to test concrete blocks, but the indirect tensile strength test is an alternative that is increasingly popular and might be preferred. MTRD have indicated that they can acquire the appropriate testing equipment if necessary.
- Thin Asphaltic Concrete (AC) may be appropriate in some places, particularly where a strong base is available, but the use of AC in places that are far removed from an AC plant is not viable due to haulage costs and problems with maintaining the material in a good condition during transit.
- Cold asphalt is used in Kenya, with thin layers being applied to LVRs. Quality is inconsistent and grading and emulsion percentages vary, so residual binder varies as a result. According to specifications 6% residual binder is required, but in practice this can be as low as 4%. MTRD use Marshall stability where min. and max. values are required, but the team should review other standards. Egis have trials ongoing. The team will review BSM design using TG2 and other documents and provide clear guidelines for the use of cold asphalt are needed.
- Concrete pavements are an alternative option, particularly for steep road sections. Usually such pavements are 100mm thick with wire mesh reinforcement. This aspect is

missing from the LVSR guidelines, so it is recommended that specifications are developed for this technology.

Some guiding notes and explanations will be added in this section to assist the engineer in his/her choice for selection of an appropriate surfacing type.

A.8 Miscellaneous

Drainage is an essential component of low volume roads. Drainage is covered in the RDM3 manual but key cross referencing is required.

Design moisture contents for the various pavement layers will also need to be discussed in detailed and agreed upon. We propose that if the subgrade is designed on a soaked CBR value, then the sub-base and base course layers be designed at moisture content values close to the material OMC.

Annex B: Minutes of Launch Meeting

DRAFT Minutes of Meeting
No. 1 – Project Launch Meeting

Date: 23/11/2015
Time: 3:00pm to 4:30pm.
Location: MTRD offices

Present:
Eng. Stephen Kogi (Chairman) - MTRD
Eng. Maurice Ndeda – MTRD
Eng. Daniel Wanyiri - MTRD
Eng. Joachim Mbarua - MTRD
John Rolt - TRL
Andrew Otto - TRL
Robin Workman – TRL
Eric Abuya – TRL
Jon Hongve – AFCAP Consultant

Agenda:
1. Discuss technical content of manual
2. Discuss MTRD contact person and counterpart engineers
3. Discuss documents to be provided by MTRD
4. Discuss meeting with local consultants and introductions
5. Discuss programme for the project

Opening
Introductions were made and Eng. Kogi welcomed the TRL team to MTRD. He outlined the expectations from MTRD for the project and informed the meeting that about 3,000 km of LVR road upgrading are being designed or proposed, out of the 10,000 km that is planned under the Kenyan Government's programme for upgrading LVRs over the coming five years. This is an important document for Kenya.
Eng. Kogi also informed that MTRD are expecting an updated guideline, including a review of the existing material and infilling any missed information necessary to make the guidelines into a complete document. He also stressed the focus on capacity building and how it should be an integral part of the project. TRL agreed that this is an important aspect of the project and the involvement of the MTRD engineers in the preparation of the manual is essential, as well as the future training programme. He also said this project was the most critical of all their projects.
Action: By the end of this week it is expected that the TRL team will have discussed the guidelines internally within MTRD and will have met with KeRRA and the various consultants who are using the guidelines at present.

TRL response
RW thanked MTRD for agreeing to TRL for this project. The Key tasks from the ToR were read out to the meeting and agreed. The contract completion date is shown as 30th June 2016, with the Final Report to be submitted by 31st May 2016. RW summarised the tasks for the inception period and confirmed that the core team would be in Nairobi for the whole week.

Action: RW noted that an outline draft of the inception report will be produced by Friday 27th November, in order that a draft programme for the project can be agreed whilst the TRL team are still in country. At this time the counterpart engineers from MTRD will be proposedand if possible agreed, so that the capacity building aspects can be planned. TRL will inform MTRD of the necessary documents required to carry out the literature review and the LVR guidelines revision. MTRD will provide these documents where possible, plus any additional documents that they feel may be relevant.

Programme

The schedule of the coming week was discussed and the following meetings were tentatively agreed, pending availability of staff. MTRD will assist in arranging meetings.

Action: Meeting schedule:

Tuesday 24/11:

10.00am – MTRD technical discussions

2.30pm – Meet with PS, then KeRRA DG (if time)

Wednesday 25/11:

10.00am – Meet with Egis, Gibb, Norken, and others (TBA)

Friday 27/11:

10.00am – Eng. Kogi and MTRD, wrap up meeting to discuss draft inception report, programme and way forward.

Discussions

Main discussions focused on the technical aspects of the project, including:

- TRL to propose additions to the LVR guidelines where appropriate, such as specifications and text, so long as the guideline maintains its principles of being simple, practical and useable.
- JR suggested that if additional explanations are necessary that they either be included in an Annex or as a Preamble. This is to be recommended by TRL for MTRD consideration.
- Cross-referencing will be necessary to any relevant documents, such as manuals and specifications.
- JH also noted that it is important to consider drainage, especially the community participation aspect of roadside drainage, quoting a recent ILO document on the subject. Eng. Ndeda stated that the existing geometric design manuals include a comprehensive section on drainage, and this would not need to be included in the guidelines, but can be referenced from them.
- Eng. Ndeda advised that the revised guideline should take on the style of TRL's Overseas Road Note 31 and 29.
- Eng. Ndeda stressed that it is a pavement design guideline and other linked issues can be cross-referenced.
- Eng. Kogi noted that the guideline should be in the UK style manuals that are small and cross-references to other documents. TRL to propose the format of the guidelines for consideration.
- JH noted that the guideline should include a flowchart of the design process.
- Eng. Kogi noted that in reviewing the guidelines, TRL should include a review the pertinent parts of RDM3 and any other relevant documents as and when required.

Logistical aspects of the LVR guidelines:

- JH proposed that the newly formed counties should be involved. Eng. Kogi noted that they will have representation in the first workshop, via their own framework, which would mean that not all counties would need to attend.
- TRL has proposed a feedback period of two weeks for main deliverables including workshops, but comments will be accepted if they are later than this.
- AO asked MTRD to be prepared to recommend who should undertake the peer review, which is to be resourced by AFCAP. It may be possible to procure this through AFCAP individual frameworks, if the appropriate people are available, but as much advance notice as possible should be provided.
- Eng. Ndeda requested that the team review the pavement design manual to check that all relevant information is available. Also to produce a comprehensive list of relevant reference documents to the LVR guideline, as well as a flow diagram.

Meeting closed at 4.30pm