Training and Application of the DCP-DN Pavement Design Method in Ghana

Training Report

J. Hongve & E. Mukandila

AFCAP Project Reference Number GHA2054A

February 2016
The views in this document are those of the authors and they do not necessarily reflect the views of the Research for Community Access Partnership (ReCAP), [optional insert name of author’s organisation] or Cardno Emerging Markets (UK) Ltd for whom the document was prepared.
AFRICA COMMUNITY ACCESS PARTNERSHIP (AfCAP)

Safe and sustainable transport for rural communities

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

See www.afcap.org
## Acronyms, Units and Currencies

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASTHO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>AfCAP</td>
<td>Africa Community Access Partnership</td>
</tr>
<tr>
<td>DCP</td>
<td>Dynamic Cone Penetrometer</td>
</tr>
<tr>
<td>DN</td>
<td>DCP Number (mm/blow)</td>
</tr>
<tr>
<td>EOD</td>
<td>Environmentally Optimised Design</td>
</tr>
<tr>
<td>GoG</td>
<td>Government of Ghana</td>
</tr>
<tr>
<td>JICA</td>
<td>Japan International Cooperation Agency</td>
</tr>
<tr>
<td>km</td>
<td>Kilometre</td>
</tr>
<tr>
<td>LVSR</td>
<td>Low Volume Sealed Road(s)</td>
</tr>
<tr>
<td>m</td>
<td>Metre</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetre</td>
</tr>
<tr>
<td>MDD</td>
<td>Maximum Dry Density</td>
</tr>
<tr>
<td>Mod</td>
<td>Modified</td>
</tr>
<tr>
<td>OMC</td>
<td>Optimum Moisture Content</td>
</tr>
<tr>
<td>ToT</td>
<td>Training of Trainers</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom (of Great Britain and Northern Ireland)</td>
</tr>
<tr>
<td>UKAid</td>
<td>United Kingdom Aid (Department for International Development, UK)</td>
</tr>
</tbody>
</table>
Contents

Acronyms, Units and Currencies .................................................................................. 4
1 Executive summary .................................................................................................... 6
2 Introduction ................................................................................................................ 8
  2.1 Background .......................................................................................................... 8
  2.2 Objectives of the Assignment .............................................................................. 9
  2.3 Purpose and Scope of the Report .......................................................................... 9
3 Training Programme .................................................................................................. 9
  3.1 Preparations .......................................................................................................... 9
    3.1.1 Procurement of DCPs .................................................................................. 9
  3.2 Training Modules and Programme ...................................................................... 10
  3.3 In-country preparations ...................................................................................... 12
  3.4 Training .............................................................................................................. 12
    3.4.1 Practical training ......................................................................................... 12
    3.4.2 Classroom training ..................................................................................... 15
4 Conclusion ............................................................................................................... 17
5 Next Steps ................................................................................................................. 17
    5.1 Training of Trainers .......................................................................................... 17
    5.2 Demonstration projects .................................................................................... 18
    5.3 Recommendations ............................................................................................ 18

Annex 1: Mission Itinerary and Programme................................................................. 19
Annex 2: Training Methodology and Modules .............................................................. 20
Annex 3: Report on in-country preparatory activities .................................................. 24
Annex 4: Presentations ................................................................................................. 27
Annex 5: Course Evaluation ......................................................................................... 37
Annex 6: List of participants ....................................................................................... 39
Annex 7: Roads 2000 – Central Province, Kenya ......................................................... 41
Annex 8: Summary of findings in AfCAP LVR-DCP v1.0 and proposals for improvements... 45

Page 5
1 Executive summary

Feeder road rehabilitation and maintenance is seen as a crucial part of Ghana's efforts in agricultural development and in its strategies for economic recovery and growth, poverty alleviation and food security. Hence a methodology to improve the cost-effectiveness of low-volume road design would have significant beneficial application in the Ghanaian feeder road environment.

The Dynamic Cone Penetromer (DCP) has been an established tool for in situ estimation of subgrade strength for more than 20 years and used as such extensively in Africa and other regions. Recently, an alternative method for DCP application has been developed for pavement structural design that avoids the use of direct correlation with the CBR test by utilising the cone penetration rate (DN value) obtained directly from DCP measurements to quantify the in situ strength of materials. This procedure is becoming popular because of its simplicity in the upgrading design of sealed roads. Under AfCAP 1, the DCP-DN pavement design procedure was trialled and undertaken in countries such as Kenya, Malawi, and Mozambique.

The Government of Ghana (GoG) through the Ministry of Roads and Highways (MRH) now wishes to adopt and adapt the application of the DCP-DN method as used in the above mentioned countries, and facilitate a wider application of this innovative design methodology for the cost-effective provision of low volume sealed roads (LVSR) in Ghana.

Two International Trainers with extensive experience in design of LVSR using the DCP-DN design method were engaged by AfCAP to undertake training in the application of the method for practicing engineers in Ghana and from selected countries in the West African Sub Region as a part of AfCAP commitment to capacity development for beneficiary countries to improve the development, maintenance and operation of low volume roads.

The Training Course was held at the Koforidua Training Centre in the period 8 – 19 February 2016 for two groups of engineers with 17 and 12 participants respectively and included the following topics:

- Background to the DCP-DN design method
- LVSR and EOD design principles
- Field training in execution of DCP tests
- Laboratory testing of pavement materials
- Introduction to and use of the AfCAP LVR-DCP Pavement Design software, including:
  - Setting of system parameters
  - Creation of new project files
  - Data entry and single/multiple point analysis
  - Export/import of projects to/from Excel
  - Report options
- Pavement design using DCP data sets from various projects using the LVR-DCP software in combination with Excel
- The Pavement Balance concept
- The Cumulative Sum method for determination of trends in the DCP data set and selection of uniform sections

The assessment of the Trainers is that objectives of the training have been achieved. The Trainees have got a good grasp of the DCP-DN design method and use of the software for producing an environmentally optimised pavement design and will be able to apply the method to a fully-fledged project design with some further coaching and guidance. This assessment is confirmed by the Trainees own evaluation of the course.
To build on the momentum from this initial training it is recommended to identify 5-6 candidates from among the Trainees to undergo a Training-of-Trainers Course. The ToT should be combined with the design and construction of Demonstration Project(s) for bringing the National Trainers up to an advanced level and enable them to sustain the training and mainstream the LVSR design approach with diminishing support from the International Trainers.

Demonstration Projects are important for promotion of new technologies to gain acceptance and support from political and local leaders as well as the engineering community at large. It would seem that synergies for the construction of the Demonstration Projects from 2017 onwards can potentially be attained through discussion and co-ordination with JICA.

It is recommended suitable projects be identified within April/May 2016 and that the design be done towards the end of the wet season in June/July 2016 for construction to commence early 2017.
2 Introduction

2.1 Background

The second phase of the Africa Community Access Partnership (AfCAP) is a programme of research and knowledge dissemination funded by the UK government through the Department for International Development (DFID). The aim of the new AfCAP initiative, under the overall Research in Community Access Partnership (ReCAP) umbrella, is to build on the programme of high quality research established under AfCAP phase 1 and take this forward to a sustainable future in which the results of the research are adopted in practice and influence future policy.

AfCAP is promoting safe and sustainable rural access in Africa through research and knowledge sharing between participating countries and the wider community in order to make a vital contribution to the sustainable socio-economic development of the more remote regions, and in particular their disadvantaged groups, in terms of access to markets, schools, health facilities and employment opportunities.

Feeder road rehabilitation and maintenance is seen as a crucial part of Ghana's efforts in agricultural development and in its strategies for economic recovery and growth, poverty alleviation and food security. Hence a methodology to improve the cost-effectiveness of low-volume road design would have significant beneficial application in the Ghanaian feeder road environment.

The soaked California Bearing Ratio (CBR) procedure is a long established empirical strength test that historically has been used extensively for materials selection and in the design of pavement and earthwork layers. Though tested and tried, with minimal risk of failure, it is generally interpreted in a very conservative manner. Besides, the test procedure is considered to be time consuming, costly, and requires large samples for laboratory testing with poor reproducibility in non-homogenous materials.

The Dynamic Cone Penetrometer (DCP) has been an established tool for in situ estimation of subgrade strength for more than 20 years and used as such extensively in Africa and other regions. Recently, an alternative method for DCP application has been developed for pavement structural design that avoids the use of direct correlation with the CBR test by utilising the cone penetration rate (DN value) obtained directly from DCP measurements to quantify the in situ strength of materials. This procedure is becoming popular because of its simplicity in the upgrading design of sealed roads. Under AfCAP 1, the DCP-DN pavement design procedure was trialled and undertaken in countries such as Kenya, Malawi, and Mozambique.

The Government of Ghana (GoG) through the Ministry of Roads and Highways (MRH) now wishes to adopt and adapt the application of the DCP-DN method as used in the above mentioned countries, and facilitate a wider application of this innovative design methodology for the cost-effective provision of low volume sealed roads (LVSR) in Ghana. To this end two International Trainers with extensive experience in design of LVSR using the DCP-DN design method were engaged by AfCAP to undertake training in the application of the method for practicing engineers in Ghana and from selected countries in the West African Sub Region as a part of AfCAP commitment to capacity...
development for beneficiary countries to improve the development, maintenance and operation of low volume roads.

2.2 Objectives of the Assignment

The objective of the assignment is to provide training to personnel at various levels in the relevant government institutions and agencies and private sector on the use of the DCP-DN Pavement Design Method to enable wider application of this innovative design methodology for cost-effective provision of LVSR in Ghana and selected countries in the West African Sub Region.

The project will provide and strengthen opportunities for uptake of national, regional and international best practice, particularly in relation to innovative and appropriate design methods for low volume roads.

2.3 Purpose and Scope of the Report

The purpose of this report is:

- to provide detailed feedback from the training courses held at the Koforidua Training Centre 8-19 February 2016,
- to highlight challenges and experiences in the use of the recently upgraded AfCAP LVR-DCP software, and
- to provide concrete proposals for the way forward for demonstration of the DCP-DN Pavement Design Method and establishment of in-country training capacity.

The Mission Itinerary and Programme is attached in Annex 1.

The report covers the following:

- **Section 3** – Training Programme: This section provides a summary of the training activities and experiences in the use of the AfCAP LVR-DCP software.

- **Section 4** – Conclusion: This section provides an assessment of the training outcome by the Trainers as well as a summary of the Course Evaluation by the Trainees.

- **Section 5** – Next Steps: This section presents proposals for the next steps for demonstrating the application of the DCP-DN Pavement Design method and establishment of in-country training capacity for uptake of the DCP-DN design method as a viable alternative to the traditional CBR based design method.

3 Training Programme

3.1 Preparations

3.1.1 Procurement of DCPs

In accordance with the ToR two DCPs devices had been ordered from Warapp Engineering (Pty) Ltd, Zimbabwe (see Figure 1). Unfortunately, problems with the shipping resulted in the DCPs only arriving in Accra Friday 5 February, i.e. three days before the start of the training. Due to cumbersome clearing procedures, the DCPs were only received at the Koforidua Training Centre the following Friday. Alternative solutions therefore had to be sought for the practical training for the
first group. Luckily a DCP could be borrowed from the Ministry of Roads and Highways ensuring that the practical training could go ahead as planned.

Figure 1: DCPs procured from Warapp Engineering (Pty) Ltd, Zimbabwe

3.2 Training Modules and Programme

With up to 30 participants the Training Programme was divided in two equal parts, each of one-week duration, with a maximum of 15 participants in each group. This was based on previous experience from similar training courses to ensure that each participant could be given satisfactory attention during the classroom training.

The Training Methodology, Modules and Programme are shown in Annex 2. The list of participants is shown in Annex 6.
Figure 2: Group 1 participants

Figure 3: Group 2 participants
3.3 In-country preparations

Due to the limited time available for the Trainers in Ghana, preparations for the training had to be done by Department of Feeder Roads (DFR) prior to the start of the training programme.

To this end a schedule of preparatory activities was prepared as part of the Training Methodology, Modules and Programme shown in Annex 2, including:

- Identification of training roads and borrow pits
- Centre line samples for determination of Field Moisture Content (FMC) of the three upper 150 mm layers and the FMC/OMC ratio
- Classification tests for borrow pit materials
- Preparation of samples for demonstration of the Laboratory DN test

All of the above had been carried out in a satisfactory manner prior to the start of the training ensuring that the training could go ahead as planned. The report on the preparatory activities is provided in Annex 3.

3.4 Training

3.4.1 Practical training

DCP Field tests

Due to the delay with the clearing of the new DCPs, the training programme for the first group had to be rescheduled slightly. This did however not affect the overall programme and the training outcome.

A DCP was borrowed from Ministry of Roads and Highways for the practical training of the first group. It turned out that the bottom rod of this DCP was shorter than with the standard model normally used with the effect that penetration depth of 800 mm could not be reached. The DCP data therefore and had to be extrapolated based on the last two readings. This provided an opportunity to demonstrate this feature of the software and revealed a flaw in the programme that needs to be rectified along with other programming “bugs” that came to light during the training.

Two roads had been identified for the practical field exercises situated about 20 minutes’ drive from the training centre. The location map is shown in Annex 3.

Figure 4: Training roads. Tinkong – Konko (left) and Tinkong – Mangoase (right)
The Eastern Region was in the midst of the dry season and the low field moisture of the gravel pavement combined with high content of oversize materials in the top 150-200 mm, made it very difficult to penetrate with the DCP. For each group therefore only 6-10 DCP tests were carried out, but this was still deemed to be sufficient for teaching the proper procedures for carrying out the DCP field tests, including:

- Checking condition of the equipment before use (hammer dropping height, condition of roads and cones)
- Set-up for DCP test (team of three with one person holding DCP in vertical position, one person lifting the hammer and one person recording the readings)
- Seating of the cone before start of DCP test and recording of zero blows reading
- Procedure for counting out loud the no of blows and reading out loud the DCP readings to avoid recording of erroneous results

It should be noted that field DCP test during the dry season may require an extracting device as the bottom rod of the DCP may get stuck in the ground, as indeed happened during the field exercise on Tinkong – Mangoase road, even when disposable cones are used.

**Figure 5: Practical exercise on Tinkong – Konko road**

**Laboratory DN test**

During the practical training for the first group, a visit was paid to the borrow pit from where samples had been taken for the Laboratory DN test. The material was a good quality laterite (see Figure 7) with the following basic properties:
- MDD 2,217 kg/m³
- PI 20.5%
- OMC 7.2%

Samples for the Laboratory DN test had been prepared in advance at the Ghana Highway Materials Laboratory in Koforidua at various compaction efforts and moisture contents in accordance with the instructions sent prior to arrival of the trainers. Unfortunately, a mistake had been made in the instructions for drying back a set of the samples resulting in these being dried back to 0.75% of OMC instead of 75% of OMC as intended. These samples were therefore discarded for the test.

Enough samples had been prepared to demonstrate the test to both groups as shown in Figure 8.

The average DN values for all tests are shown in Figure 6, clearly demonstrating the effect of the pavement moisture content and the importance of compaction for optimal use of natural, often moisture sensitive, pavement materials. Research has shown that with reasonable drainage and an impervious bituminous seal, the pavement moisture content on LVSR is normally below OMC, even in the outer wheel path. Designing at OMC instead of Soaked condition therefore facilitates cost-effective design using natural materials that may otherwise have been discarded.

Figure 6: Laboratory DN Test results
3.4.2 Classroom training

Presentations

Two presentations were given covering the following main topics:

- Introduction and background to the DCP-DN design method
- LVSR Environmentally Optimised Design (EOD) principles
- Importance of compaction for cost-effective use of naturally occurring, moisture sensitive pavement materials
- Surfacing options for LVSR
- Materials prospecting and testing procedures

The presentations are shown in Annex 4.

Introduction to the AfCAP LVR-DCP software

The DCP test results from the field exercises were used to introduce the trainees to the features of the AfCAP LVR-DCP software, including:

- Opening a new project file
- Showing the use of the various menu options
- DCP system settings
- Choosing Traffic Load Class (TLC) design curve
- Setting report options
- Entering DCP test data (from field exercises)
• Performing Single Point and Multiple Point analysis
• Explaining the use of percentiles for moisture adjustments of DN values
• Explaining the Layer Strength Diagram (LSD) and Normalised/Redefined LSD
• Explaining the Pavement Balance concept and the effect on the Power Exponent for well-balanced pavements for estimation of Design Traffic Loading

Pavement design exercises using the AfCAP LVR-DCP software

Having gone through at length the software features and concepts of the DCP-DN design, the trainees were given full data sets from various projects in Kenya, Malawi, Tanzania and DRC on which to go through the whole design process, analyse the data, determine uniform sections and determine the pavement design for the various sections.

Most of the procedures that were previously done manually in Excel have now been automated in the upgraded version of the software. Of these procedures the most important is the Cumulative Sum method for determination of the trend in the data set and selection of uniform sections. To engender a thorough understanding of the software outputs, the data sets were exported to Excel to manually perform Cumulative Sum analysis of the DCP data and produce graphs similar to the ones produced by the software for determination of uniform sections.

The Trainees worked individually and in groups to produce pavement designs for the various data sets, which were then discussed in plenary. Examples of pavement designs for the same data set are shown in Table 1:

Table 1: Example of Group Designs of same DCP data set

<table>
<thead>
<tr>
<th>Pavement Layer (mm)</th>
<th>Required DN value for TLC 0.3</th>
<th>Section no.</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>0-150</td>
<td>0.03 to 1.405 km</td>
<td>1.405 to 2.585 km</td>
<td>2.585 to 4.855 km</td>
<td>4.855 to 5.64 km</td>
<td>5.64 to 7.19 km</td>
</tr>
<tr>
<td></td>
<td>0.03 to 1.38 km</td>
<td>1.38 to 2.57 km</td>
<td>2.57 to 3.955 km</td>
<td>3.955 to 5.95 km</td>
<td>5.59 to 7.61 km</td>
</tr>
<tr>
<td>0-150</td>
<td>0.03 to 1.16 km</td>
<td>1.16 to 2.325 km</td>
<td>2.325 to 3.17 km</td>
<td>3.17 to 4.67 km</td>
<td>4.67 to 6.57 km</td>
</tr>
</tbody>
</table>

As can be seen, none of the groups came up with the exact same design although the differences in practice would not be very big. The design exercises gave rise to useful plenary discussions on:
• How to interpret the Cusum curves for determination of uniform sections, and
• Options for treatment of in-situ layers as an alternative to import of new layers

The exercises gave all trainees the opportunity to become intimately familiar with the design procedure through repeated designs with different data sets as well as report options, export and import of project file to/from Excel.

A worked example of how to determine “User Defined” design curves with different layer configurations than the standard layers in the DCP-DN catalogue, was also presented (see paragraph 10 of Annex 8).

Experiences with the use of the upgraded AfCAP LVR-DCP software

The software in its current form is user friendly and, based on the experience from the training courses, quite easy for new users to get familiar with. It is functional for producing pavement design, although the final step must be done in Excel. A list of programming bugs and deficiencies that were identified during the training is shown in Annex 8. These will be rectified in the near future.

4 Conclusion

The engineering background and experience of the trainees contributed to interesting discussions during the classroom sessions. This offered opportunities to repeat difficult issues and further clarify key concepts in the design method and use of the software. It is the impression of the Trainers that the objectives of the assignment have been achieved and that the Trainees have got a solid foundation for application of the DPC-DN Pavement Design Method with some further coaching and guidance.

This assessment is confirmed by the course evaluation by the Trainees shown in Table 2. Full details of the course evaluation are shown in Annex 5.

Table 2: Course evaluation summary

<table>
<thead>
<tr>
<th>Course evaluation summary</th>
<th>Average score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
</tr>
<tr>
<td>Training</td>
<td>1.90</td>
</tr>
<tr>
<td>Organisation</td>
<td>1.77</td>
</tr>
<tr>
<td>Venue</td>
<td>1.69</td>
</tr>
</tbody>
</table>

Score: 1 (best), 5 (worst)

5 Next Steps

5.1 Training of Trainers

It is important that this initial training is followed up with establishment of in-country training capacity to ensure uptake of the DCP-DN design method on a broad basis.

It is assumed that, say, 5 to 6 candidates to become future trainers can be identified among the group of Trainees. These should be offered the opportunity to undergo a Training of Trainers course, which would bring them up to an advanced level.
5.2 Demonstration projects

For promotion and uptake of the new approach to LVSR pavement design, it is imperative to construct demonstration projects. This will greatly contribute to the acceptance of the new technology in the engineering community and among political and local leaders.

At the end of the second week, a meeting was held at the Koforidua Training Centre with two representatives from JICA. Key project data from Roads 2000 Kenya was provided as an example of a viable approach to provision of LVSR, which could also be applicable in Ghana. As shown in Annex 7, the Kenya approach can provide high quality LVSR and at the same time offer considerable employment opportunities and wage income to the local communities.

JICA aims to construct two demonstration projects within the next three-year period. This would offer an excellent opportunity to combine the objectives of JICA with the Training of Trainers for promotion of the DCP-DN pavement design method and construction of demonstration projects.

5.3 Recommendations

To build on the momentum from the initial training in the application of the DCP-DN pavement design method, the following is recommended:

- Identify candidates for Training of Trainers (ToT) course (April-May 2016).
- Seek agreement with JICA to combine objectives for construction of demonstration projects. Failing this, GoG/DFR should make separate plans for construction of demonstration projects (April-May 2016).
- Select at least two suitable demonstration projects in different regions. For the promotional effect, at least one should be within easy reach of Accra (April-May 2016).
- Pavement Design and Construction Supervision of the demonstration projects should be an integral part of the Training of Trainers course. The ToT course will therefore span the entire project cycle for the demonstration projects, while at the same time training of more engineers can be done, initially with assistance of the international Trainers.
- ToT course to commence towards the end of the rainy season, say in June/July 2016 with DCP testing and pavement design.
- Construction of demonstration projects to commence from January 2017.
## Annex 1: Mission Itinerary and Programme

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>07.02</td>
<td>Arrival in Accra, travel to Koforidua</td>
</tr>
<tr>
<td>Mon</td>
<td>08.02</td>
<td>Training Group 1</td>
</tr>
<tr>
<td>Tue</td>
<td>09.02</td>
<td>Training Group 1</td>
</tr>
<tr>
<td>Wed</td>
<td>10.02</td>
<td>Training Group 1</td>
</tr>
<tr>
<td>Thu</td>
<td>11.02</td>
<td>Training Group 1</td>
</tr>
<tr>
<td>Fri</td>
<td>12.02</td>
<td>Training Group 1</td>
</tr>
<tr>
<td>Sat</td>
<td>13.02</td>
<td>Rest day</td>
</tr>
<tr>
<td>Sun</td>
<td>14.02</td>
<td>Rest day</td>
</tr>
<tr>
<td>Mon</td>
<td>15.02</td>
<td>Training Group 2</td>
</tr>
<tr>
<td>Tue</td>
<td>16.02</td>
<td>Training Group 2</td>
</tr>
<tr>
<td>Wed</td>
<td>17.02</td>
<td>Training Group 2</td>
</tr>
<tr>
<td>Thu</td>
<td>18.02</td>
<td>Training Group 2</td>
</tr>
<tr>
<td>Fri</td>
<td>19.02</td>
<td>Meeting with JICA</td>
</tr>
<tr>
<td>Sat</td>
<td>20.02</td>
<td>Travel to Accra</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reporting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Departure from Accra (E. Mukandila)</td>
</tr>
<tr>
<td>Sun</td>
<td>21.02</td>
<td>Rest day</td>
</tr>
<tr>
<td>Mon</td>
<td>22.02</td>
<td>J. Hongve - Debriefing Meeting at DFR with Deputy Director Planning and AfCAP Technical Manager West Africa</td>
</tr>
<tr>
<td>Tue</td>
<td>23.03</td>
<td>Departure from Accra (J. Hongve)</td>
</tr>
</tbody>
</table>
Annex 2: Training Methodology and Modules

Methodology
An application-oriented training approach will be adopted with clearly defined topics, objectives and learning outcomes that are relevant to the substantive jobs held by the staff. This approach will allow the trainees to actually undertake DCP data collection in the field and to subsequently use this data in the classroom to design a LVR pavement based on the DCP-DN method. The training will also focus on the materials investigation and assessment of the suitability of borrow pit materials for incorporation in the road pavement by undertaking or witnessing, as appropriate, laboratory DCP-DN measurements. Thus, the training methodology will be divided in such a manner that the field, classroom and laboratory training are complementary to each other in a mutually reinforcing way.

With up to 30 participants, it has been found necessary, based on prior experience with similar courses, to divide the trainees in two groups with a one week course for each group to enable two-way interaction between the trainees and the trainers and to give adequate attention to each trainee as required.

An outline of the Training Programme is shown in Table 1 below. As can be seen from Table 1, the time available in-country does not allow time for the necessary preparatory activities. These activities shown in Table 2 below, will therefore have to be carried out by DFR prior to the arrival of the trainers.

Training Programme and Modules

Training Modules

- Module 1: Field Work
  - Road inspection
  - DCP testing and data collection
- Module 2: Overview of Low Volume Roads philosophy and the DCP design principles
  - Introduction/Background
  - Design Philosophy and Principles
  - Materials
  - Drainage
  - Surfacing
  - Pavement Design
  - Geometric design
  - Road safety
  - Sustainability
- Module 3: Materials sampling and testing
- Module 4: WinDCP software (on screen guided exercise)
  - Exploring the programme features and User Manual
  - Entering DCP data
  - Lab DN test and data entry
- Module 5: Applying the WinDCP software for pavement design (on screen guided exercise)
  - Step by step procedure using the DCP data to produce a pavement design
### Table 3: Training Programme Outline

**Week 1 – Group 1 (up to 15 participants)**

<table>
<thead>
<tr>
<th>Training sessions</th>
<th>Mon 08.02.15</th>
<th>Tue 09.02.15</th>
<th>Wed 10.02.15</th>
<th>Thu 11.02.15</th>
<th>Fri 12.02.15</th>
<th>Sat 13.02.15</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. session</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08.30 – 10.00</td>
<td>Module 1 cont.</td>
<td>Module 2</td>
<td>Module 4</td>
<td>Module 4 cont.</td>
<td>Module 5 cont.</td>
<td></td>
</tr>
<tr>
<td>• Background</td>
<td>• Background</td>
<td>• Background</td>
<td>• Background</td>
<td>• Background</td>
<td>• Background</td>
<td></td>
</tr>
<tr>
<td>• LVR design</td>
<td>• WinDCP software</td>
<td>• WinDCP software</td>
<td>• WinDCP software</td>
<td>• WinDCP software</td>
<td>• WinDCP software</td>
<td></td>
</tr>
<tr>
<td>Break 10.00-10.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. session</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.30-12.00</td>
<td>Registration</td>
<td>Module 1 cont.</td>
<td>Module 2 cont.</td>
<td>Module 4 cont.</td>
<td>Module 5 cont.</td>
<td>Module 5 cont.</td>
</tr>
<tr>
<td>• Introduction</td>
<td>• Using WinDCP for pavement design</td>
<td>• Using WinDCP for pavement design</td>
<td>• Using WinDCP for pavement design</td>
<td>• Using WinDCP for pavement design</td>
<td>• Using WinDCP for pavement design</td>
<td>• Using WinDCP for pavement design</td>
</tr>
<tr>
<td>Lunch 12.00-13.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. session</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.00 – 14.30</td>
<td>Module 1: Field work</td>
<td>Module 1 cont.</td>
<td>Module 3</td>
<td>Module 4 cont.</td>
<td>Module 5 cont.</td>
<td>Wrap-up</td>
</tr>
<tr>
<td>• Road and borrow pit inspection</td>
<td>• Materials sampling and testing</td>
<td>• Materials sampling and testing</td>
<td>• Materials sampling and testing</td>
<td>• Materials sampling and testing</td>
<td>• Materials sampling and testing</td>
<td>• Materials sampling and testing</td>
</tr>
<tr>
<td>Break 14.30 – 15.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4. session</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Week 2 – Group 2 (up to 15 participants)

<table>
<thead>
<tr>
<th>Training sessions</th>
<th>Mon 15.02.15</th>
<th>Tue 16.02.15</th>
<th>Wed 17.02.15</th>
<th>Thu 18.02.15</th>
<th>Fri 19.02.15</th>
<th>Sat 20.02.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. session</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08.30 – 10.00</td>
<td>Field work</td>
<td>Module 1</td>
<td>Module 3</td>
<td>Module 3 cont.</td>
<td>Module 4 cont.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Background</td>
<td>• WinDCP software</td>
<td>• Lab DN test demo</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• LVR design</td>
<td>• DCP data entry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Break 10.00-10.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. session</td>
<td>Registration &amp; Introduction</td>
<td>Field work</td>
<td>Module 1 cont.</td>
<td>Module 3 cont.</td>
<td>Module 4</td>
<td>Module 4 cont.</td>
</tr>
<tr>
<td>10.30-12.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lunch 12.00-13.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. session</td>
<td>Module 1: Field work</td>
<td>Field work</td>
<td>Module 2</td>
<td>Module 3 cont.</td>
<td>Module 4 cont.</td>
<td>Wrap-up</td>
</tr>
<tr>
<td>13.00 – 14.30</td>
<td>• Road and borrow pit inspection</td>
<td>• Materials sampling and testing</td>
<td></td>
<td></td>
<td></td>
<td>• Q&amp;A • Course evaluation</td>
</tr>
<tr>
<td>Break 14.30 – 15.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. session</td>
<td>Field work</td>
<td>Field work</td>
<td>Module 2 cont.</td>
<td>Module 3 cont.</td>
<td>Module 4 cont.</td>
<td></td>
</tr>
<tr>
<td>15.00 – 16.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Preparatory Activities
The preparatory activities to be completed prior to the start of the training course are summarised in the Table 2 below.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Responsible</th>
<th>Completion date</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procurement and shipment of DCPs</td>
<td>AFCAP</td>
<td>30 Jan 2016</td>
<td></td>
</tr>
<tr>
<td>Preparation of Training Methodology and Modules</td>
<td>AFCAP</td>
<td>18 Dec 2015</td>
<td></td>
</tr>
<tr>
<td>Choice of testing sites (roads)</td>
<td>DFR</td>
<td>30 Jan 2016</td>
<td>One or two sites</td>
</tr>
<tr>
<td>Choice of borrow pits for gravel materials</td>
<td>DFR</td>
<td>30 Jan 2016</td>
<td>One or two borrow pits area</td>
</tr>
<tr>
<td>Choice of a geotechnical and materials Laboratory</td>
<td>DFR</td>
<td>30 Jan 2016</td>
<td>The Laboratory must be able to perform the following tests: indicators (grading, Atterberg Limits), Compaction, CBR, test on aggregate (shape and strength), using international Standards such as BS or AASHTO</td>
</tr>
</tbody>
</table>
| Test pits                                    | DFR         | 05 Feb -16      | Three test pits are required:  
  - One on high ground  
  - One in a low lying area  
  - One at an elevation between the first two.  
  The pits must be dug to a depth of 450mm and a sample taken from each 150mm layer.  
  Tests to be carried out:  
    - In situ moisture content as % of OMC   |
| Laboratory DCP test samples                  | DFR         | 05 Feb -16      | Representative samples of material taken from existing gravel borrow pit in the vicinity of the road. Prepare samples in CBR moulds following the procedures in the Malawi DCP Design Manual as follows:  
  a) 6 samples compacted at OMC and sealed: 3 samples compacted to 95% and 3 compacted to 98% Mod AASHTO compaction.  
  b) 6 samples compacted at OMC then dried back to 0.75% of OMC and sealed: 3 samples compacted to 95% and 3 compacted to 98% Mod AASHTO compaction.  
  c) 6 samples compacted at OMC then soaked for 4 days: 3 samples compacted to 95% and 3 compacted to 98% Mod AASHTO compaction.   |
| Gravel classification tests                  | DFR         | 05 Feb -16      | On the sample taken from the gravel pit:  
  - Liquid limit  
  - Plasticity Index  
  - Particle Size Distribution   |
| Traffic count                                | DFR         | 05 Feb -16      | Two 12-hour classified traffic counts (6am to 6pm) on the heaviest trafficked section of the road. One during a week day and one during a weekend. |
Annex 3: Report on in-country preparatory activities

A: INTRODUCTION
The Department of Feeder Roads (DFR) is supposed or expected to perform certain duties before the training course begins. This report outlines the status of activities performed by DFR.

B: CHOICE OF TESTING SITES (ROADS)
The selected roads are Tinkong to Mangoase (7.1km) and Tinkong to Konko (6.3km). Figure 1 shows a location map of the roads. The roads are about 20 minutes’ drive from the Koforidua Training Centre (KTC).

C: CHOICE OF BORROW PITS FOR GRAVEL
One borrow pit was located at Kokofa about 1 km from the left side of the end of the Tinkong – Konko road.

D: CHOICE OF GEOTECHNICAL AND MATERIAL LABORATORY
The Ghana Highway Materials Laboratory at Koforidua was selected. It is located about 1 km from KTC.

E: TEST PITS
Three test pits were identified on each of the identified roads. The test pits were located on low, intermediate and high elevation along each of the roads. Compaction test and natural moisture content were performed for each of layer per specification.

Tinkong-Konko
<table>
<thead>
<tr>
<th>Depth (mm)</th>
<th>Moisture Content</th>
<th>OMC</th>
<th>Ratio (MC/OMC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>1.0</td>
<td>7</td>
<td>0.14</td>
</tr>
<tr>
<td>300</td>
<td>5.6</td>
<td>7.4</td>
<td>0.76</td>
</tr>
<tr>
<td>450</td>
<td>6.9</td>
<td>10.9</td>
<td>0.63</td>
</tr>
</tbody>
</table>

**Low Elevation (Ch. 2+300)**

<table>
<thead>
<tr>
<th>Depth (mm)</th>
<th>Moisture Content</th>
<th>OMC</th>
<th>Ratio (MC/OMC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>7.1</td>
<td>11.2</td>
<td>0.63</td>
</tr>
<tr>
<td>300</td>
<td>12.1</td>
<td>18.5</td>
<td>0.65</td>
</tr>
<tr>
<td>450</td>
<td>13.0</td>
<td>9.4</td>
<td>1.38</td>
</tr>
</tbody>
</table>

**Intermediate Elevation (Ch. 2+100)**

<table>
<thead>
<tr>
<th>Depth (mm)</th>
<th>Moisture Content</th>
<th>OMC</th>
<th>Ratio (MC/OMC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>9.5</td>
<td>10.7</td>
<td>0.89</td>
</tr>
<tr>
<td>300</td>
<td>14.5</td>
<td>15.6</td>
<td>0.93</td>
</tr>
<tr>
<td>450</td>
<td>15.7</td>
<td>18</td>
<td>0.87</td>
</tr>
</tbody>
</table>

**High Elevation (Ch. 1+500)**

**F: LABORATORY DCP TEST SAMPLES**

**F1: 6 Samples compacted at OMC and Sealed**

All Samples prepared and sealed

**F2: 6 Samples compacted at OMC then dried back to 0.75% OMC and Sealed**

All Samples prepared and sealed

**F3: 6 Samples compacted at OMC then soaked for 4 days**

All Samples prepared and sealed
**G: GRAVEL CLASSIFICATION TESTS**

Below are the properties of the gravel material sampled from the borrow pit.

**Gradation**

<table>
<thead>
<tr>
<th>BS Sieve</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.40</td>
<td>100</td>
</tr>
<tr>
<td>19.05</td>
<td>97</td>
</tr>
<tr>
<td>12.70</td>
<td>87.7</td>
</tr>
<tr>
<td>9.50</td>
<td>73.5</td>
</tr>
<tr>
<td>6.35</td>
<td>54.3</td>
</tr>
<tr>
<td>4.76</td>
<td>44.1</td>
</tr>
<tr>
<td>2.40</td>
<td>28.6</td>
</tr>
<tr>
<td>1.20</td>
<td>26.5</td>
</tr>
<tr>
<td>600µm</td>
<td>25.3</td>
</tr>
<tr>
<td>400µm</td>
<td>24.8</td>
</tr>
<tr>
<td>300µm</td>
<td>24.3</td>
</tr>
<tr>
<td>150µm</td>
<td>22.5</td>
</tr>
<tr>
<td>75µm</td>
<td>20.3</td>
</tr>
</tbody>
</table>

**Atterberg Limits**

LL=46  
PL=25.5  
PI=20.5

**Compaction Test**

MDD=2.217Mg/m3  
OMC=7.2%

**H: TRAFFIC COUNT**

Traffic Count has been conducted on the heaviest trafficked section of each of the selected roads. Details of traffic count attached.
Annex 4: Presentations

Overview of Presentation
- Introduction/Background
- Design Philosophy
- Materials
- Drainage
- Surfacing
- Pavement Design
- Geometric Design
- Road safety
- Sustainability

Traditional Approaches to LVR Provision
- Have stemmed from technology and research carried out over 40 years ago in very different environments
- Generally inappropriate for application to the African region where locally prevailing circumstances are very different in terms of climate, traffic, materials and road usage.
- Technology, research and knowledge about LVRs have advanced significantly in the region during recent years
- Question the validity of the accepted paradigm on LVR provision and show quite clearly the need to revise conventional approaches.
- New, more appropriate, approaches to the provision of low-volume roads are now required if Africa is to improve road transport efficiency and attain its broader goals of socio-economic growth, development and poverty alleviation.

The Stark Facts
- Majority of rural roads are unhardened and carry relatively light traffic.
- They impact significantly on the livelihoods of the majority of the population of many countries in the region, who live and work in rural areas where poverty levels are generally very high.
- They are central to sustained socio-economic growth and development of the region and are a key component of development programmes targeted by donors and governments in which poverty reduction strategies feature.
- Generally poor condition of these roads has denied real accessibility to transport services which has acted as a brake on economic development and hindered poverty alleviation efforts.

Rural Accessibility Index (2007)

Poverty and Accessibility (Vietnam, 2002)

Our Challenge
- Poverty is linked to lack of basic access – a constitutional/human right?
- Need to close accessibility gap by doing more with less
- Traditional approaches have generally not worked
- Need for new approaches that are research based
- New approaches may challenge conventional paradigms, but...
- We cannot make progress without making change!

Characteristics of Low Volume Roads
- Traffic up to about 300 vpd and less than about 1.0 MESA
- Constructed mostly from naturally-occurring, often “non-standard”, moisture-sensitive materials.
- Adoption of “environmentally optimized design” (EOD).
- Pavement deterioration driven primarily by environmental factors.
- Alignment may not necessarily always be fully “engineered”.
- A need to cater for a significant amount of non-motorized traffic.
- Variable travelling speeds seldom exceeding 80 km/h.

Typical Types of Low Volume Roads

Design Philosophy
- Full understanding by the design engineer of the local environment (natural and social).
- Ability to work within the demands of the local environment and to turn these to a design advantage.
- Recognition and management of risk.
- Innovative and flexible thinking through application of appropriate engineering solutions rather than following traditional thinking related to road design.
- A client who is open and responsive to innovation.
- Assured routine and periodic maintenance.

Road Environment Factors

Page 28
Implementation within an EOD Context

Framework for sustainable provision of LVRs

Use of Local Materials

- The art of the engineer consists for a good part in utilizing technologies that will make possible the use of materials that he finds in the vicinity of the works.
- Unfortunately, force of habit, inadequate specifications and lack of interest have suppressed the more widespread use of innovative technology.
- In order to capitalize on the use of these local materials, a better understanding of their properties and behaviour is necessary.

Drainage Design

Example of Non- Bituminous Surfacing
Geometric Design

Option A:
- Alignment engineered for fulfilling an access function
- Existing alignment will fix the travel speed
- Accepts alignment generally as is, except at potentially problematic sections where traffic safety may be an issue for which specifically engineered measures provided
- Adoption will result in variable travel speeds but will not incur significant earthworks costs.

Option B:
- Alignment engineered for fulfilling a mobility function which is based on a pre-determined design speed
- Design speed will fix the travel alignment
- Existing alignment improved to satisfy various prescribed (GO) requirements
- Adoption will incur potentially significant earthworks costs for which the benefit, in relation to relatively low levels of traffic, likely to be outweighed by costs.

Dominant Mode of Deterioration

Deterioration of a LVR is driven primarily by environmental factors, with traffic being a lesser factor in deterioration.
**Pavement Design – Based on DCP**

**CBR – Very Poor Reproducibility**

The CBR test is relatively inaccurate with low reproducibility.

Standard deviation ($\sigma$) = 10 x where $x = (1.477 \times 3852)^{1/2}$

<table>
<thead>
<tr>
<th>CBR</th>
<th>n</th>
<th>95% confidence</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>4</td>
<td>± 6</td>
<td>2 – 18</td>
</tr>
<tr>
<td>30</td>
<td>7</td>
<td>± 14</td>
<td>16 – 44</td>
</tr>
<tr>
<td>60</td>
<td>12</td>
<td>± 24</td>
<td>36 – 94</td>
</tr>
<tr>
<td>897</td>
<td>16</td>
<td>± 32</td>
<td>58 – 122</td>
</tr>
</tbody>
</table>

**CBR – Poor Correlation With Performance**

South African Low Volume Road Investigation (CBR)

**Site Investigations: DCP Vs CBR**

**Determination of Uniform Sections**

DCP provides a good “picture” of in situ ground conditions

**Determination of Uniform Sections**
Training and Application of the DCP-DN Pavement Design Method in Ghana

Training Report

Integration of In Situ and Required Strength Profiles

Strength Measurement - Lab DN value
- DN measures density relationship required for suitable pavement material
- DCP used to penetrate the CBR mould
- Takes into account pore pressure release during testing

4-day soaked sample - soaked for 4 days in plastic bag
Sample at OMC, soaked for 4 to 7 days in plastic bag

DN/Density/Moisture Relationship

Benefits of Increased Compaction

Appreciation of Risk Factors
Five main risks:
- Drained
- Material quality
- Construction control
- Maintenance
- Traffic (overloading)

- Relax ONE and keep control of others. Risk increases BUT probably acceptable
- Relax TWO and risk possible failure

Framework for Sustainable Provision of LVRs

- Monitor and improve (early warnings)
- Review and report (early warnings)
- Investigate and improve
- Enhance LVR service
Examples of DCP Designed Roads

Benefits of Adopting New Approaches

Pavement Structure Comparisons

Resistance to Change

Adoption of New Technology

The new idea either finds a champion or dies. No ordinary involvement with a new idea provides the energy required to cope with the intelligence and tenacity that major technological change provokes... Champions of new innovations must display persistence and courage of heroic quality.

Edward de Bono, MIT.
Materials investigation and choice of suitable road Materials

CENTRE LINE TEST PITTING

- Materials testing requirements
  - Number of test pits: every 500m to 1000m
  - Number of DCP tests: every 50m to 100m
  - Sieve analysis testing: at least 2 per test pit
  - Atterberg limit testing: at least 2 per test pit
  - MDD, CMC, FMC testing: at least 1 per test pit

BORROWPIT TEST PITTING

- Materials testing requirements
  - Number of test pits: 6 per borrowpit
  - Sieve analysis testing: 1 per test pit
  - Atterberg limit testing: 1 per test pit
  - MDD and CMC testing: 1 per test pit

TEST PIT

- Example of test pits

BORROWPIT TEST PITTING

- Investigation is done for existing Borrowpits.
  - A search for new borrowpits in the area can also be done.
TEST PIT

- Test pit size
  - Centre line: area: 1.25 x 0.75m; depth: 300 mm
  - Borrow pit: ± 5m or refusal, but not less than 2m

FIELD MOISTURE CONTENT (FMC) COLLECTION

- Collection of FMC using Auger

SPECIFICATIONS FOR PROFILING

- Based on: Jennings, Bink and Williams 1973
- Principles: MCGSSD
  - Moisture slightly moist, moist, very moist, wet
  - Colour: dark grey chart
  - Crude type: refusal, toughness, strength
  - Very few clods: impervious, dense, weak (pore cohesive)
  - Fine grained soil: silt, very stiff cohesive
  - Electrical conductivity: absence of joints for cohesive soil
  - Soil type: based on refusal
  - Stakes: 50 x 50 x 150 cm
  - (230-240), sand (240-250), silt (210-230), clay (230-240)
  - Origin: excavation, transported soil

SPECIFICATIONS FOR PROFILING

- Special notes on the top sheet
  - Depth at which the water table is encountered
  - Fractured depth and the material in the refusal excavation
  - Crude type: geological formations and considerations, etc.
  - Type of samples taken and their corresponding depths
  - Testing that will be required
  - Other required information
  - Grooves, ditches, agricultural activities, obstacles and obstructions, etc.
  - Environmental sensitive areas
  - Rock outcrops and refusal, possible refusal hardness
  - Expected borrow pit excavation hardness and material over size
  - Material quantity in general

TYPICAL PROFILING
TYPICAL PROFILING

- Profiling description and details

TESTING & RESULTS PRESENTATION

- Handling of Test operations:
  - Tests executed per layer per test pit
  - Mix materials only when required and in case of similarity
  - Proper sampling
    - Separate test pit layers
    - Sample bagging and labelling
    - Provision of Photograph

- Presentation of Results
  - Centre line material results

<table>
<thead>
<tr>
<th>Test</th>
<th>Mix Design</th>
<th>PS</th>
<th>ESA</th>
<th>MS</th>
<th>Density</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2.98</td>
<td>0.06</td>
<td>1.11</td>
<td>98.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3.29</td>
<td>0.08</td>
<td>1.15</td>
<td>97.3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>2.97</td>
<td>0.06</td>
<td>1.10</td>
<td>98.7</td>
<td></td>
</tr>
</tbody>
</table>

Note: contamination percentage by mass of material tested on the 1.8 mm sieve (AP) minus RUPP in square, divided by 100.
## Annex 5: Course Evaluation

### Course Evaluation - Group 1 (17 Participants)

<table>
<thead>
<tr>
<th></th>
<th>Number of forms filled in</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Blank</th>
<th>W.A.</th>
<th>Average score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Training</td>
<td></td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.90</td>
</tr>
<tr>
<td>The objectives of the course were generally achieved</td>
<td>7</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The classroom presentations were well presented and understood</td>
<td>4</td>
<td>11</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have now got a good understanding of the characteristics of Low Volume Roads</td>
<td>4</td>
<td>11</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have now got a good understanding of the design principles for Low Volume Roads</td>
<td>6</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method</td>
<td>3</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software</td>
<td>7</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1,94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>There was enough time for practical exercises using the software and discussions / clarifications</td>
<td>3</td>
<td>11</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have got a good understanding of the pavement balance concept and how to use this for defining User Defined Design curves</td>
<td>2</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2,38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The practical instructions were well delivered and understood</td>
<td>6</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1,81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Organisation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,77</td>
</tr>
<tr>
<td>I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training</td>
<td>8</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1,71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrangements for accommodation during the course was satisfactory</td>
<td>13</td>
<td>3</td>
<td></td>
<td></td>
<td>1</td>
<td>0</td>
<td>1,19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I was given satisfactory support from my employer/organization for participation in the course</td>
<td>4</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2,31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The course was well organized</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td></td>
<td></td>
<td>0</td>
<td>1,88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Venue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,69</td>
</tr>
<tr>
<td>The classroom facilities were satisfactory</td>
<td>10</td>
<td>6</td>
<td>1</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1,47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The practical training site was well organized</td>
<td>5</td>
<td>9</td>
<td>3</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1,88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The meals and refreshments were satisfactory</td>
<td>7</td>
<td>9</td>
<td>1</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1,71</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Key to Scores:** 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average
### Course Evaluation - Group 2 (12 Participants)

<table>
<thead>
<tr>
<th></th>
<th>Number of forms filled in</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Blank</th>
<th>W.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 1. Training

- The objectives of the course were generally achieved  
  - Average score: 1.71
- The classroom presentations were well presented and understood  
  - Average score: 1.58
- I have now got a good understanding of the characteristics of Low Volume Roads  
  - Average score: 1.67
- I have now got a good understanding of the design principles for Low Volume Roads  
  - Average score: 1.83
- I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method  
  - Average score: 1.91
- I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software  
  - Average score: 1.58
- I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results  
  - Average score: 2.09
- There was enough time for practical exercises using the software and discussions / clarifications  
  - Average score: 1.33
- I have a good understanding of the pavement balance concept and how to use this for defining User Defined Design curves  
  - Average score: 2.00
- The practical instructions were well delivered and understood  
  - Average score: 1.58

#### 2. Organisation

- The objectives of the course were generally achieved  
  - Average score: 1.76
- The classroom presentations were well presented and understood  
  - Average score: 1.83
- I have now got a good understanding of the characteristics of Low Volume Roads  
  - Average score: 1.73
- I have now got a good understanding of the design principles for Low Volume Roads  
  - Average score: 1.82
- I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results  
  - Average score: 1.67
- There was enough time for practical exercises using the software and discussions / clarifications  
  - Average score: 2.08
- I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results  
  - Average score: 2.17
- The practical instructions were well delivered and understood  
  - Average score: 2.25

#### 3. Venue

- The classroom facilities were satisfactory  
  - Average score: 1.83
- The practical training site was well organized  
  - Average score: 2.17
- The meals and refreshments were satisfactory  
  - Average score: 2.25

**Key to Scores:** 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average
Annex 6: List of participants

<table>
<thead>
<tr>
<th>NAME</th>
<th>DESIGNATION</th>
<th>ORGANISATION</th>
<th>NATIONALITY</th>
<th>EMAIL ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Patrick Amoah Bekoe</td>
<td>Civil Engineer</td>
<td>DFR</td>
<td>Ghanaian</td>
<td><a href="mailto:pabekoe@gmail.com">pabekoe@gmail.com</a></td>
</tr>
<tr>
<td>Koranteng Justice</td>
<td>Civil Engineer</td>
<td>DFR</td>
<td>Ghanaian</td>
<td><a href="mailto:just2uu@yahoo.com">just2uu@yahoo.com</a></td>
</tr>
<tr>
<td>Gregory Amissah</td>
<td>Civil Engineer</td>
<td>DFR</td>
<td>Ghanaian</td>
<td><a href="mailto:gregoryamissah@yahoo.com">gregoryamissah@yahoo.com</a></td>
</tr>
<tr>
<td>Albert Martey</td>
<td>Civil Engineer</td>
<td>DFR</td>
<td>Ghanaian</td>
<td><a href="mailto:mazose2000@yahoo.com">mazose2000@yahoo.com</a></td>
</tr>
<tr>
<td>C. Elorm Nyoagbe</td>
<td>Civil Engineer</td>
<td>DFR</td>
<td>Ghanaian</td>
<td><a href="mailto:elormnyoagbe@gmail.com">elormnyoagbe@gmail.com</a></td>
</tr>
<tr>
<td>Abdul –Gafaru Amidu</td>
<td>Civil Engineer</td>
<td>DUR</td>
<td>Ghanaian</td>
<td><a href="mailto:amidbullaabdulgafaru@yahoo.com">amidbullaabdulgafaru@yahoo.com</a></td>
</tr>
<tr>
<td>Abdul Nasser Fofanah</td>
<td>Civil Engineer</td>
<td>DFR/SLRA</td>
<td>Sierra Leone</td>
<td><a href="mailto:jamalystic@yahoo.com">jamalystic@yahoo.com</a></td>
</tr>
<tr>
<td>Tesslime Shyllon</td>
<td>Civil Engineer</td>
<td>DFR/SLRA</td>
<td>Sierra Leone</td>
<td><a href="mailto:shyllontesslime@gmail.com">shyllontesslime@gmail.com</a></td>
</tr>
<tr>
<td>Bai Maro Kamara</td>
<td>Civil Engineer</td>
<td>DFR/SLRA</td>
<td>Sierra Leone</td>
<td><a href="mailto:baimarokombor88@gmail.com">baimarokombor88@gmail.com</a></td>
</tr>
<tr>
<td>Samuel J. Macauley</td>
<td>Civil Engineer</td>
<td>DFR/SLRA</td>
<td>Sierra Leone</td>
<td><a href="mailto:Sammacauley2005@gmail.com">Sammacauley2005@gmail.com</a></td>
</tr>
<tr>
<td>Tamba K. Amara</td>
<td>Chief Engineer</td>
<td>DFR/SLRA</td>
<td>Sierra Leone</td>
<td><a href="mailto:tmannamara2003@gmail.com">tmannamara2003@gmail.com</a></td>
</tr>
<tr>
<td>Francis Gambrah</td>
<td>Civil Engineer</td>
<td>DUR</td>
<td>Ghanaian</td>
<td><a href="mailto:frangam2002@yahoo.com">frangam2002@yahoo.com</a></td>
</tr>
<tr>
<td>Kwaku Asibe Osei</td>
<td>Civil Engineer</td>
<td>GHA</td>
<td>Ghanaian</td>
<td><a href="mailto:okansah1@gmail.com">okansah1@gmail.com</a></td>
</tr>
<tr>
<td>Albert Osae Annan</td>
<td>Civil Engineer</td>
<td>GHA</td>
<td>Ghanaian</td>
<td><a href="mailto:malaicah33@gmail.com">malaicah33@gmail.com</a></td>
</tr>
<tr>
<td>Emmanuel Kwesi Rockson</td>
<td>Srn. Engineer</td>
<td>GHA</td>
<td>Ghanaian</td>
<td><a href="mailto:ekrockson@hotmail.co.uk">ekrockson@hotmail.co.uk</a></td>
</tr>
<tr>
<td>Ernest k. Obeng</td>
<td>Mech. Engineer</td>
<td>KTC</td>
<td>Ghanaian</td>
<td><a href="mailto:ernobeng2002@yahoo.com">ernobeng2002@yahoo.com</a></td>
</tr>
<tr>
<td>Opoku Adusei Emmanuel</td>
<td>Civil Engineer</td>
<td>KTC</td>
<td>Ghanaian</td>
<td><a href="mailto:eopokuadusei@gmail.com">eopokuadusei@gmail.com</a></td>
</tr>
</tbody>
</table>
## SECOND GROUP

<table>
<thead>
<tr>
<th>NAME</th>
<th>DESIGNATION</th>
<th>ORGANISATION</th>
<th>NATIONALITY</th>
<th>EMAIL ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. Prosper Gladxah Foli</td>
<td>DFR, Tamale</td>
<td>Ghanaian</td>
<td><a href="mailto:Kofi62gladzah@gmail.com">Kofi62gladzah@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>19. Meredith Kuunyem</td>
<td>DFR</td>
<td>Ghanaian</td>
<td><a href="mailto:Mello2uu@gmail.com">Mello2uu@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>20. Michael Orleans Fransisco Ribeiro</td>
<td>KTC, Koforidua</td>
<td>Ghanaian</td>
<td><a href="mailto:kwodwogh@gmail.com">kwodwogh@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>21. Roland Osel-Akoto Offeh</td>
<td>DFR, Koforidua</td>
<td>Ghanaian</td>
<td><a href="mailto:ronoseiakoto@gmail.com">ronoseiakoto@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>22. Kwame Boating Amoako</td>
<td>DFR, Kumasi</td>
<td>Ghanaian</td>
<td><a href="mailto:excelgh@gmail.com">excelgh@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>23. E. A. Gbadago</td>
<td>MRH, Accra</td>
<td>Ghanaian</td>
<td><a href="mailto:unifamenyo@rockmail.com">unifamenyo@rockmail.com</a></td>
<td></td>
</tr>
<tr>
<td>24. Abraham Quansah</td>
<td>GHA, Accra</td>
<td>Ghanaian</td>
<td><a href="mailto:Abraham_qnsh@yahoo.com">Abraham_qnsh@yahoo.com</a></td>
<td></td>
</tr>
<tr>
<td>25. Bathemel Ansah Appiah</td>
<td>DFR HQ</td>
<td>Ghanaian</td>
<td><a href="mailto:bathemel@yahoo.com">bathemel@yahoo.com</a></td>
<td></td>
</tr>
<tr>
<td>26. Rilys A. Agyemang</td>
<td>GHA, Accra</td>
<td>Ghanaian</td>
<td><a href="mailto:rilysagyemang@gmail.com">rilysagyemang@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>27. Samuel Sarfo</td>
<td>GHA, Accra</td>
<td>Ghanaian</td>
<td><a href="mailto:Samsarf34@yahoo.com">Samsarf34@yahoo.com</a></td>
<td></td>
</tr>
<tr>
<td>28. Nancy Donkor</td>
<td>GHA, Accra</td>
<td>Ghanaian</td>
<td><a href="mailto:nancy.donkor@gmail.com">nancy.donkor@gmail.com</a></td>
<td></td>
</tr>
<tr>
<td>29. Mesiwotso Kwame Zawor</td>
<td>GHA, Koforidua</td>
<td>Ghanaian</td>
<td><a href="mailto:kzawor@yahoo.com">kzawor@yahoo.com</a></td>
<td></td>
</tr>
</tbody>
</table>
Annex 7: Roads 2000 – Central Province, Kenya

Low Volume Sealed Roads:
- Mix construction approach
  - Improved subgrade formation – Machine based
  - 100 mm Base, Cold Mix Asphalt surfacing, drainage works – Labour based
- Total sealed width: 7.0 m (incl. shoulders)
- Cost / km: 200-250,000 USD/km
- Casual Labour wage: approx. 4 USD/day
- Labour cost: About 10% or 20-25,000 USD/km
- Employment creation: About 5,000 workerdays/km
Annex 8: Summary of findings in AfCAP LVR-DCP v1.0 and proposals for improvements

1. **DCP data entry screen for Variable Blows option**

   ![DCP Data Entry Screen](image)

   a. Using TAB instead of Enter after entering Depth 456 moved the cursor on step down to the next Depth cell instead of down and to the left to the next Blows per Reading.

   b. Then, using left arrow to enter 3 Blows per reading, then Enter to type 567, then Enter again to type 2 Blows per reading, the Cumulative Blows are not added up (the cell is left empty as shown on the screenshot.

   c. Likewise, when using Tab after entering Blows per reading, the cursor moves down to the next Blows per reading causing the same problem.

   d. To correct the error and get correct Cumulative no of Blows, all entries after Reading number 4 must be deleted, then start data entry again from Reading 5.

   e. To guard against this potential problem, the Tab and Enter key should be programmed (which I assume can be done) to function in exactly the same manner during data entry.

2. **Automatic extrapolation function for Variable Blows option**

   ![Automatic Extrapolation Function](image)

   Automatic extrapolation to reach 800 mm depth does not work properly as shown. Blows per reading are entered as zero with the resulting analysis screen as shown below. User must manually enter Blow per reading, in this case 4, from reading 5 down.
3. **Numbering of Test points**

In the above example I had entered five test points 1, 1a, 1b, 2 and 3. Then the next Test point is automatically given the number 6. Can this be changed to the next higher number, in this case 4, instead of assigning it the number actual number of the test point to avoid having to rename all following test points to be entered?

4. **DCP Section Report**

a. The first table with “as is” values is ok except for faint type faces in the two bottom rows. All Section numbers could also be either bold or normal.

b. All legend text for both tables should be left aligned in column under Section 1. Suggest additional text as shown below for the amber legend text.
c. In the second “design” table, the last layer has been split in two, i.e. 650-750 and 750-800, unknown for what reason. Probably just a remnant in the programming from trials with different layer thicknesses.

d. Programming errors resulting in unnecessary New Subbase for section 2 and 4. Correct design (in excel) shown below:

<table>
<thead>
<tr>
<th>Pavement Layer (mm)</th>
<th>Required DN value for TLC 0.3</th>
<th>Section no.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>0.03 to 1.26 km</td>
<td>3.2</td>
<td>4.35</td>
</tr>
<tr>
<td>1.26 to 2.625 km</td>
<td>6.62</td>
<td>7.79</td>
</tr>
<tr>
<td>1.26 to 2.625 km</td>
<td>7.97</td>
<td>9.28</td>
</tr>
<tr>
<td>2.625 to 4.83 km</td>
<td>12.90</td>
<td>13.62</td>
</tr>
<tr>
<td>4.83 to 7.175 km</td>
<td>19.60</td>
<td>21.22</td>
</tr>
<tr>
<td>7.175 to 8.38 km</td>
<td>27.40</td>
<td>30.02</td>
</tr>
</tbody>
</table>

Inadequate (non-compliance) in situ layer
Adequate (marginal compliance) in situ layer(s) that need to be improved
Adequate (full compliance) in situ layer(s)

e. DN values should be rounded off to max one decimal. Suggest also that DN values ≥ 10 are rounded off to zero decimals. The programme should use the displayed one or zero decimal value for assignment of colours to avoid, say, 6.0 being coloured amber when the actual value in the cell is 6.01xxx (see Section 4 above).

f. This raises the question whether the DCP Section Report should only show the “as is” table and leave the user to do the final design in Excel, which has now become easy with the “save as excel” option. Automating this last step may cause the users to accept the programme design as shown for Section 4, without thinking how they can improve isitu layers, e.g. by drainage improvements, and avoid import of material, in this case for new subbase.

g. Another option could be to present only the “as is” table first, then ask the user to identify sections and layers that need improvement, e.g. by import of new layer(s) or improvement using a coding system. On the basis of these user inputs would the final design table be presented. This would force the user to think through the final design decisions in the same way they would do in Excel.

5. Export/import project to/from Excel and Excel Templates

a. Export/Import is seemingly working fine both ways.

b. Decimal places in template for Blows per reading and Depth should be zero (default). See screenshot below.

c. Templates should be formatted as Forms only allowing entries in the specific cells and giving warnings if all required data are not entered before file is saved.
d. Road width should be taken out, both from the Templates and from the opening screen for creating a new project file, as the width can vary significantly along the road and width is to be recorded for each DCP Test Point.

6. Data validation

It was suggested by some of the trainees to display the Test no and Chainage on the screen as shown. Possible, but not recommended as it would make the screen too cluttered. Test No and Chainage is displayed when cursor hovers on point.
7. Proposed layout for Lab DN data entry screen

<table>
<thead>
<tr>
<th>No of blows</th>
<th>DCP Reading</th>
<th>DN per n blows</th>
<th>Avg. DN per blow</th>
<th>Avg. DN per blow</th>
<th>Avg. DN per blow</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>284</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>295</td>
<td>11</td>
<td>11,00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>303</td>
<td>8</td>
<td>8,00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>311</td>
<td>8</td>
<td>8,00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>323</td>
<td>12</td>
<td>6,00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>333</td>
<td>10</td>
<td>5,00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>349</td>
<td>16</td>
<td>5,33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>360</td>
<td>11</td>
<td>5,50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>371</td>
<td>11</td>
<td>5,50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Penetration depth: 87

Weighted Average DN: 6.64

Diagram showing penetration depth and weighted average DN.
Notes to Lab DN data entry screen proposal:

- Provision made for three tests from same sample. More lines to be added to fill the available space.
- Curves automatically plotted in diagram to the right as tests are carried out. User to add “best fit” line for the three samples from the middle of the moulds to determine representative Lab DN for the sample. Clicking on the diagram should enlarge it for fitting of line, enable copying etc. similar to the LSD etc in the field module.
- Top panel:
  - Delete field for “Mould #”, since this is recorded for each mould as shown below.
  - “Depth of mould” should rather be “Depth of sample in mould”. The user can then monitor the penetration depth as test progresses to ensure that the tip of the cone does not hit the base plate. Effective max penetration depth will be: Depth of sample in mould – 23 mm (height of cone plus 3 mm shoulder).
  - Fields for “Compaction effort” (e.g. BS Heavy) and “Confinement factor” to be added.
  - Effective Field DN automatically calculated as Lab DN x Confinement Factor.
  - “Sample reliability” to be taken out, not relevant for Lab DN test.

The current version of the Lab module suffers from the same shortcomings as described above for data entry and automatic extrapolation in the field module when using the “variable blows” option. For the Lab module the user must be able to stop the test before the tip hits the base plate without being forced to extrapolate the data set.

8. Determination of Sections from Properties

The following screen shots illustrates what happens when the user first determines sections, then right-clicks and selects Uniform Sections from the pop-up menu. The section delimiters are moved and one deleted altogether.

Questions are:

- Which algorithm is used for this automatic selection of Sections?
- Do we need it?
9. How to record for “layer removed”

It's quite common for existing gravel wearing course layers to be virtually impossible to penetrate due to coarse aggregates and dryness of the layer. Therefore removing the layer, say 150-200 mm, would in many cases be the best option before proceeding with the test of the lower layers. A facility for recording this in the data input screen and assigning an assumed DN value for the layer removed would be handy, otherwise in extreme cases an entire section may be nearly impossible to test.
10. Example of User Defined Design Curve (for User Manual)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness (mm)</th>
<th>DSN Range</th>
<th>DN Limit (mm/blow)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base 100 mm</td>
<td>0-100 = 43%</td>
<td>≤ 100/43 = 2.3</td>
</tr>
<tr>
<td>2</td>
<td>Subbase 150 mm</td>
<td>100-250 = 29%</td>
<td>≤ 150/29 = 5.2</td>
</tr>
<tr>
<td>3</td>
<td>Subgrade 150mm</td>
<td>250-400 = 14%</td>
<td>≤ 150/14 = 11</td>
</tr>
<tr>
<td>4</td>
<td>Subgrade 200 mm</td>
<td>400-600 = 9%</td>
<td>≤ 200/9 = 22</td>
</tr>
<tr>
<td>5</td>
<td>Subgrade 200 mm</td>
<td>600-800 = 5%</td>
<td>≤ 200/5 = 40</td>
</tr>
</tbody>
</table>