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Africa Community Access Partnership

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Implementation of Technical Auditing and Training of New Batch of Local Practitioners in the DCP-DN Pavement Design Method

Training Report

J. Hongve & E. Mukandila

AFCAP Project Reference Number MAL2007C

July 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) or Cardno Emerging Markets (UK) Ltd for whom the document was prepared

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AFRICA COMMUNITY ACCESS PARTNERSHIP (AfCAP)

Safe and sustainable transport for rural communities

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

See www.afcap.org

Acronyms, Units and Currencies

AASTHO	American Association of State Highway and Transportation Officials
AfCAP	Africa Community Access Partnership
ASWAP-SP	Agriculture Sector Wide Approach Support Project
DCP	Dynamic Cone Penetrometer
DN	DCP Number (mm/blow)
EOD	Environmentally Optimised Design
km	Kilometre
LVSR	Low Volume Sealed Road(s)
m	Metre
mm	Millimetre
MDD	Maximum Dry Density
Mod	Modified
OMC	Optimum Moisture Content
RA	Roads Authority
ToT	Training of Trainers
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)

Contents

1 Executive summary

The AfCAP project MAL2007 was formulated to support the uptake and embedment of the DCP-DN Design Method in Malawi. The project is carried out in phases as follows:

- Phase 1
    - Training of the local consultant Royal Associates and staff from RA in the DCP-DN Design Method. Following this training course, Royal Associates prepared designs for 40 km of LVSRs in 5 districts, all of which are currently under construction.
    - Design Review for all five legs of the ASWAP-SP project
    - Technical Audit at start of construction of the two northerly projects, D11 Kalenge bridge - Misuku at Chitipa and the T357 Parachute Battalion - Lifuwu at Salima
- Phase 2
    - Mid-term Technical Audit of the three southerly projects, D387 Nsangwe – Dolo in Chikwawa District, S135 Mwanza - Kunenekude in Mwanza District and S134 Kasinje - Kandeu in Ntcheu District
    - Training of a new batch of local consultants and RA staff in the DCP-DN Design Method
    - Final Technical Audit of all five projects at the end of the construction period

Phase 1 was completed in September 2015 and the Mid-term Technical Audit of the three southerly projects carried out in June 2016. The following reports document the activities and outcomes of the previous activities under MAL2007:

- Training Report - February 2014
- Design Review and Training Report - October 2014
- Technical Audit Report - October 2015
- Technical Audit Report – June 2016

Upon a request from the Roads Authority who wishes to broaden the base among local consultants for undertaking LVSR design using the DCP-DN method a new training course was conducted in the period 11-22 July 2016. The course had 29 participants divided in two groups, each of which went through a one-week practical and theoretical course. The participants also included one staff member from Roads Development Agency in Zambia, where the method is to be introduced later in the year.

The training objectives of bringing all participants to an intermediate or higher level in the use of the AFCAP LVR DCP software and imparting LVR design philosophy and EOD design principles for cost-effective provision of LVSR have been achieved. This is reflected in the course evaluation by the trainees, a summary of which is shown below:

Course evaluation summary	Average score	
	Group 1	Group 2
DCP-DN design and use of AfCAP LVR DCP software	1.75	1.51
Organisation	2.52	1.95
Venue	2.27	1.71

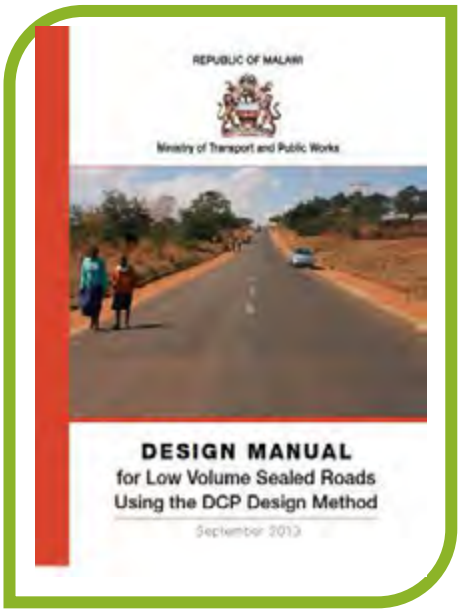
Key to score: 1 – best, 5 – worst

Some further coaching will be required to enable the trainees to undertake a full pavement design using the DCP-DN method. Development of in-country training capacity training capacity is recommended to build on the momentum from the initial training and construction of the five projects under ASWAP-SP.

The Training-of-Trainers (ToT) should include the full project cycle from planning and design to construction and long term monitoring of demonstration projects. Possible candidates for future Trainers have been identified from the participants. It is recommended that a ToT project be considered for commencement during Financial Year 2016/17 and subsequent construction of demonstration sections in FY 2017/18.

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.

Previous AFCAP activities in Malawi included the preparation of a new pavement design manual for low volume sealed roads which is based on the DCP-DN design method. The manual was developed through a highly collaborative approach in-country and an international review process. It has now been published as an official Malawi Government document and is available in hard and soft copy. It was used for the design of 40 km of low volume sealed roads under the World Bank financed Agriculture Sector-Wide Approach Support Project (ASWAP-SP) programme. A contract was signed by the Roads Authority with a locally based consulting firm, Royal Associates, to undertake the design and construction supervision of these roads. The contracted consulting firm had no previous experience with the use of the DCP-DN design method.

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- Phase 1
    - Training of the local consultant Royal Associates and staff from RA in the DCP-DN Design Method. Following this training course, Royal Associates prepared designs for 40 km of LVSRs in 5 districts, all of which are currently under construction.
    - Design Review for all five ASWAP-SP LVSR projects, each approx. 8 km long
    - Technical Audit at start of construction of the two northerly projects, D11 Kalenge bridge - Misuku at Chitipa and the T357 Parachute Battalion - Lifuwu at Salima
- Phase 2
    - Mid-term Technical Audit of the three southerly projects, D387 Nsangwe – Dolo in Chikwawa District, S135 Mwanza - Kunenekude in Mwanza District and S134 Kasinje - Kandeu in Ntcheu District

- Training of a new batch of local consultants and RA staff in the DCP-DN Design Method
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This report covers the training of a new batch of local consultants as well as staff from Roads Authority upon a request from the Roads Authority who wishes to broaden the base among local consultants for undertaking LVSR design using the DCP-DN method. To this end a new course was conducted in the period 11-22 July 2016. The course had 29 participants divided in two groups, each of which went through a one-week practical and theoretical course. The participants also included one staff member from Roads Development Agency in Zambia, where the method is to be introduced later in the year.

2.2 Objectives of the Assignment

The objective of the assignment was to provide training to local consulting firms and Roads Authority staff in 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 Malawi.

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 Golden Peacock Hotel in Lilongwe during the period 11-22 July 2016,
- to provide feed-back on 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 on a wider scale and establishment of in-country training capacity.

The Mission Itinerary and Programme is attached in Annex 1.

The report covers the following:

- **Section 3** – Implementation of Training Activities: 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 on a wider scale 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

3.2 Training Modules and Programme

With 29 participants the Training Programme was divided in two equal parts, each of one-week duration, with 12 and 17 participants in Group 1 and 2 respectively. 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 is Annex 3.

Figure 1: Group 1 participants

Figure 2: Group 2 participants

3.3 In-country preparations

The training road had been identified and agreed with Roads Authority during the Technical Audit mission in June 2016.

Due to the limited time available for the Trainers in Malawi, preparations for the training had to be done by Roads Authority and Central Materials Laboratory prior to the start of the training programme. To this end a schedule of preparatory activities was prepared and sent to Roads Authority to ensure that the preparations of samples and testing were carried out.

The preparations included:

- 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

The preparatory activities were only partially done when the training started and were only fully completed by the start of the second week. This meant that the samples for the Laboratory DN test had not had enough time for curing and that no centre line Relative Moisture Contents were available for the design exercise for the 1st Group.

3.3.1 Practical training

DCP Field tests

The field exercises were carried out on S126 Linthipe 1 – Lobi which is situated some 50 km south-east of Lilongwe. The first 4.4 km of the road from the junction with M1 is under upgrading by a local contractor. The DCP tests therefore started at km 4+400. In all 26 DCP tests divided between the two groups of trainees, were carried out at 100 m intervals up to km 6+900.

Figure 3: Training road S126 Linthipe 1 - Lobi

The field training included the following:

- 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

Figure 4: Practical exercise on S126 Linthipe 1 - Lobi

Laboratory DN test

Base material from the ongoing upgrading contract on the first part of the road had been collected and six moulds had been prepared, all at BS Heavy compaction, for the Laboratory DN test:

- 2 Soaked
- 2 at OMC
- 2 at 0.75 OMC

Each group witnessed and took part in penetration of three moulds and later used the AfCAP LVR DCP Laboratory Module to enter and analyse the data.

A Summary report for the two moulds at OMC is shown in Annex 5. This indicates that the material used for base construction may not be of sufficient quality for the assumed Traffic Load Class TLC 0.3 on this road.

3.3.2 Classroom training

Presentations

The presentations given covered the following main topics:

- Introduction and background to the DCP-DN design method (J. Hongve)
- LVSR Environmentally Optimised Design (EOD) principles (J. Hongve)

- The DCP-DN Design Method (J. Hongve & E. Mukandila)
- Importance of compaction and compaction control using the DCP (J. Hongve)
- Materials prospecting and testing procedures incl. Laboratory DN testing (E. Mukandila)

The presentations are shown in Annex 6.

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

The trainees were introduced to the AfCAP LVR DCP software as an on-screen guide exercise, explaining each feature and use of the menus and toolbar. Manual entering of DCP data was exercised before they were taught how to copy from the Excel template into the programme and eventually how to import the full project data set, which had been prepared in advance, for the design exercise. They were also explained how to do a Cumulative Sum (Cusum) analysis of the data sets in order to understand what the programme is doing in the background.

Having gone through in detail the software features and concepts of the DCP-DN design using the DCP data from the field exercise, the trainees were given full data sets from various projects in Kenya, 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.

The trainees worked both individually and in groups to produce designs. The latest revision of the software is now so user friendly that most of the trainees quickly got up to speed in the operation of the programme and learned how to define uniform sections, apply different percentiles for moisture adjustment of the DCP data and do sensitivity analysis of the designs by applying different Traffic Load Classes.

It was, however, emphasised several times during the course that the software is only an additional tool in the designer's toolbox and not a replacement for sound engineering judgement and that getting intimately familiar with the road by walking the alignment and getting to know the materials is a prerequisite for producing reliable designs.

The result of the design exercise for the Training road is shown in Figure 5 below.

Figure 5: Design for Training road S126 Linthipe 1 - Lobi

Averages from	Weighted Average
Percentiles from	Normal Distribution

Pavement Layer (mm)	Required DN value for TLC 0.3	Section no.			
		1	2	3	4
		4.4 to 5.5 km	5.5 to 5.7 km	5.7 to 5.9 km	5.9 to 6.9 km
0-150	<= 3.2 (3.5)	4.9 (80P)	10 (80P)	3.4 (80P)	3.0 (80P)
150-300	<= 6 (6.9)	5.8 (80P)	11 (80P)	2.6 (80P)	4.5 (80P)
300-450	<= 12 (14)	7.0 (80P)	5.1 (80P)	4.6 (80P)	8.1 (80P)
450-600	<= 19	8.3 (80P)	5.6 (80P)	11 (80P)	9.0 (80P)
600-800	<= 25	10.0 (80P)	6.8 (80P)	7.0 (80P)	12 (80P)

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)

Pavement Layer (mm)	Required DN value for TLC 0.3	Section no.			
		1	2	3	4
		4.4 to 5.5 km	5.5 to 5.7 km	5.7 to 5.9 km	5.9 to 6.9 km
0-150	<= 3.2 (3.5)	3.2	3.2	3.4 (80P)	3.0 (80P)
150-300	<= 6 (6.9)	4.9 (80P)	6.0	2.6 (80P)	4.5 (80P)
300-450	<= 12 (14)	5.8 (80P)	10 (80P)	4.6 (80P)	8.1 (80P)
450-600	<= 19	7.0 (80P)	11 (80P)	11 (80P)	9.0 (80P)
600-800	<= 25	8.5 (80P)	5.3 (80P)	7.0 (80P)	12 (80P)

New base added with DN values <= 3.2
New subbase added with DN values <= 6
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)

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

The software in its current form is user friendly and a very versatile and powerful tool in the hands of a good designer. Analysis of different design options, sensitivity analysis for different Traffic Load Classes, application of different percentiles for moisture adjustment etc. can be done within minutes.

Some issues in the software still need to be sorted out, but these are minor issues and do not cause problems in producing designs. A Snaglist of things still to be fixed is provided in Annex 7.

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, although some further coaching and guidance will be required.

With 29 participants (of which one only attended sporadically and should not be regarded as having gone through the training) there will naturally be some spread in the level of proficiency attained by the trainees. Particularly those who had limited computer operating skills tended to fall behind and therefore took longer to acquaint themselves with all the features in the software. With individual attention and repetition of the exercises it is still felt that all participants had by the end of the week attained a reasonable skills level in the operation of the software as well as an appreciation of the DCP-DN design method and an understanding of the LVR design philosophy and principles.

This assessment is largely confirmed by the course evaluation by the Trainees shown in Table 2. Two participants in Group 1 were not present during the demonstration of the Laboratory DN test and the following classroom exercise on the Laboratory Module. This has contributed to the lower score on this issue compared to Group 2. Full details of the course evaluation are shown in Annex 4.

Roads Authority were quite late in inviting trainees, especially for the first group and lunch and refreshments had not been arranged for the days of the field exercise. This is reflected particularly in the score for Organisation by Group 1. The organisation at the venue Golden Peacock hotel was also not quite as expected during the first week, but improved after complaints about the services.

Table 1: Couse evaluation summary

Course evaluation summary	Average score	
	Group 1	Group 2
Training	1.75	1.51
Organisation	2.52	1.95
Venue	2.27	1.71

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.

Potential candidates for a future Training-of-Trainers course were identified. These are highlighted in the List of Participants in Annex 3.

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. The ASWAP-SP projects currently under construction will serve that purpose, but for future trainers to become fully proficient in the design of LVSR, a Training-of-Trainers course should include the design, construction and monitoring of demonstration sections.

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 during 2017.
- Identify suitable demonstration project(s) and secure funding for construction during financial year 2017/18.
- For the promotional effect, the demonstration section(s) should be within easy reach of Lilongwe.
- Pavement Design and Construction Supervision of the demonstration projects, incorporating the use of the Guideline for using the DCP for quality control, should be an integral part of the Training of Trainers course. The ToT course should 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.

Annex 1: Mission Itinerary and Programme

Sun	10.07	Arrival in Lilongwe
Mon	08.02	Field Training Group 1
Tue	09.02	Classroom Training Group 1
Wed	10.02	Classroom Training Group 1
Thu	11.02	Classroom Training Group 1
Fri	12.02	Laboratory Demo, Wrap-up and Course Evaluation Training Group 1
Sat	13.02	Rest day
Sun	14.02	Rest day
Mon	15.02	Field Training Group 2
Tue	16.02	Classroom Training Group 2
Wed	17.02	Classroom Training Group 2
Thu	18.02	Laboratory Demo and Classroom Training Group 2
Fri	19.02	Wrap-up and Course Evaluation Group 2
Sat	20.02	Departure from Lilongwe

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 field training will take place on S126 branching off from M1 at Linthipe 1 about 40 km south-east of Lilongwe.

The first 4 km of this road is currently under upgrading by a local contractor and RA has planned to continue the upgrading of this road during the next year or so. The DCP field data collection and DCP-DN pavement design exercise will be done on the following 4-5 km up to a village centre.

To re-inforce the pavement design principles and use of the AFCAP LVR-DCP Design Software, several DCP data sets from Malawi, Kenya and Tanzania will also be used for group and individual work and the trainees will be asked to present and defend their design decisions based on the available data.

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.

To prepare for the classroom and laboratory exercises, the Central Materials Laboratory has been requested to undertake the following:

For Lab DN test:

- Sample material from the base layer material that is currently being dumped on the first section of the road branching off M1 at Linthipe 1.

- Carry out MDD/OMC in CBR moulds at MOD AASHTO compaction and standard classification tests (Atterberg, Grading, PI). No CBR test required.
- Prepare six moulds at OMC compacted at MOD AASHTO compaction (5 layers, 55 blows per layer with 4.5 kg hammer) as follows:
    - 2 moulds to be dried back to 75% of OMC, then sealed in plastic bag or with wax
    - 2 moulds to be retained at OMC and sealed as above
    - 2 moulds to be soaked for 4 days, then sealed as above

Cure samples in moulds as per procedure in Malawi DCP Design Manual

Centre line samples for determination of Field Moisture Content in relation to OMC:

- At two locations (one at a high point and one at a low point) take samples from the three uppermost 150 mm layers (make sure not to mix the layers!!!). Samples have to be big enough for carrying out the following tests:
    - Carry out MDD/OMC in CBR moulds at MOD AASHTO compaction. Determine actual Field Moisture Content and FMC/OMC ratio for each layer at both points.

Each group will participate in the Laboratory DN test on three moulds per group (one soaked, one at OMC and one at 75% of OMC, all at Mod AASHTO compaction).

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. The time for the training sessions / modules may vary somewhat from the proposed programme.

Training Programme and 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
    - Surfacings
    - Pavement Design
    - Geometric design
    - Road safety
    - Sustainability
- Module 3: Materials sampling and testing
- Module 4: AfCAP LVR DCP 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 AfCAP LVR DCP software for pavement design
  - Step by step procedure using the DCP data to produce a pavement design (on screen guided exercise)
  - Individual and group work on additional DCP data sets with presentation and defence of design decisions by the trainees.

Table 2: Training Programme Outline

Week 1 – Group 1 (up to 15 participants)					
Group 1	Mon 11.07.16	Tue 12.07.16	Wed 13.07.16	Thu 14.07.16	Fri 15.07.16
Group 2	Mon 18.07.16	Tue 19.07.16	Wed 20.07.16	Thu 21.07.16	Fri 22.07.16
1. session 08.30 – 10.00	**Registration** **Introduction**	**Module 1 cont.**	**Module 3** • Materials sampling and testing	**Module 4 cont.** • Lab DN test demo	**Module 5 cont.**
Break 10.00-10.30					
2. session 10.30-12.00	**Module 1: Field work** • Road and borrow pit inspection • DCP testing	**Module 1 cont.**	**Module 3 cont.**	**Module 5** • Using WinDCP for Pavement design	**Module 5 cont.**
Lunch 12.00-13.00					
3.session 13.00 – 14.30	**Module 1 cont.**	**Module 2** • Background • LVR design	**Module 4** • WinDCP software • DCP data entry	**Module 5 cont.**	**Module 5 cont.**
Break 14.30 – 15.00					
4. session 15.00 – 16.30	**Module 1 cont.**	**Module 2 cont.**	**Module 4 cont.**	**Module 5 cont.**	**Q&A** **Course Evaluation**

Annex 3: List of participants

Registration for DCP Design Course, Lilongwe 11-22 July 2016

First group 11-15 July				
Name	Designation	Organisation	E-mail address	Cell no.
1. Lewis Phiri	Engineer	EMC Jatula Associates CE	lewis.phiri@yahoo.com	0882817924
2. Derick Manda	Maintenance Eng.	Roads Authority	dmanda@ra.org.mw	0888687111
3. Omen Metani	Highway Eng.	L. Gravam Consulting	omen.m.metani@gmail.com	0888422151
4. Ashley Kanyoza	Engineer	Polytechnic (Blantyre)	akanyoza@poly.ac.mw ashley.kanyoza@ruoconsultants.com	0888312307
5. D. Kara	Engineer	Bua Consulting Engineers	kara.daud@yahoo.com	0991851849
6. Flora Hauya	Engineer	Roads Authority	fhauya@ra.org.mw	0888843918
7. Sydney Phiri	Maintenance Eng.	Roads Authority	sphiri@ra.org.mw	0888711413
8. Emmanuel Maluwa	Maintenance Eng.	Roads Authority	emaluwa@ra.org.mw	0888209050
9. Brian Nyirongo	Maintenance Eng.	Roads Authority	brianlorringsnyirongo@gmail.com	0999469205
10. Chris Chirwa	Highway Engineer	Bua Consulting Engineers	clchirwa.bua@gmail.com	0999957753
11. Walinase Munthali	Structural Eng.	GK Works Consultants	walimunthali14@gmail.com	0881079490
12. Okendeni Kondowe	Engineer	Mphizi Consulting Engineers	okendeni001@yahoo.com	0888843903

Okendeni Kondowe only sporadically present and should not be regarded as having taken the course

Potential future Trainers highlighted

Registration for DCP Design Course, Lilongwe 11-22 July 2016

Second group 18-22 July				
Name	Designation	Organisation	E-mail address	Cell no.
13. Elias Sisya	Chief Engineer (N)	Roads Authority	esisya@ra.org.mw	0888861640
14. Charles Mtawali	Senior Engineer	Roads Authority	cmtawali@ra.org.mw	0888209334
15. Martin Chavula	Highway Engineer	BMM/Infratech Joint Venture	martinchavula@gmail.com	0999591708
16. Paul KULEMEKA	Partner	PJK&P Consulting Engineers	paulkulemeka@yahoo.com	099983656
17. Washington Chimuzu	Associate Director (BD)	Infrastructure Consultants Ltd	washingtonchimuzu@infracon.mw	0999920644
18. Joseph Chibwe	Pavement Engineer	RDA - Zambia	jchibwe@roads.gov.zm	260 977 348140
19. Tamandani Kachiwala	Highway Engineer	MSCAT Consulting Engineers	tamakachiwala@yahoo.com	0993335455
20. Wammie D.Mkumbira	Measurement Engineer	David Consulting Engineers	wdmkumbira@yahoo.com	0999777802
21. Florence Ndenguma	Ag. Chief Engineer (S)	Roads Authority	fndenguma@ra.org.mw	22. 0888858185
10. Walker P Kaulembe	Highway Engineer	Hendereson& Partners	kaulembew@yahoo.com	0994338804
11. Steven Luwemba	Civil Engineer	TM Associates	sdaluwemba@gmail.com	0881461469
12. Samuel Kadangwe	Ag. Director of Construction	Roads Authority	skadangwe@ra.org.mw	0888843905
13. Nelson Kachali	Project Engineer	Pamodzi Consulting Limited	Nelson_kachali@yahoo.com	0992362425
14. Joel Longwe	Construction Engineer	Roads Authority	Jlongwe@ra.org.mw	0999230913
15. Francis Dimu	Dir. of Planning and Design	Roads Authority	fdimu@ra.org.mw	0888843906
16. Willard Kaunde	Chief Engineer	Roads Authoruty	wkaunde@ra.org.mw	0888844343
17. Newton Busani	Maintenance Engineer	Roads Authority	nbusani@ra.org.mw	0888208855

Potential future Trainers highlighted. In addition, the RA Director of Planning and Design identified Mr. Sharmey Banda, who has participated in training earlier, as a potential Trainer.

Annex 4: Summary of Course Evaluation

Course Evaluation - Group 1 (12 Participants)	Number of forms filled in	Scores						
	11	1	2	3	4	5	Blank	W.A.
1. Training	Average score				1,75			
The objectives of the course were generally achieved		6	4	1			0	1,55
The classroom presentations were well presented and understood		3	7	1			0	1,82
I have now got a good understanding of the characteristics of Low Volume Roads		4	6	1			0	1,73
I have now got a good understanding of the design principles for Low Volume Roads		4	4	3			0	1,91
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		4	4	3			0	1,91
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		4	6	1			0	1,73
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results		2	5	4			0	2,18
There was enough time for practical exercises using the software and discussions / clarifications		7	3		1		0	1,55
The practical instructions were well delivered and understood		7	4				0	1,36
2. Organisation	Average score				2,52			
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training		2	3		2	4	0	3,27
Arrangements for accommodation during the course was satisfactory		3	1	4		1	2	2,44
I was given satisfactory support from my employer/organization for participation in the course		3	6		1	1	0	2,18
The course was well organized		2	5	4			0	2,18
3. Venue	Average score				2,27			
The classroom facilities were satisfactory		3	7	1			0	1,82
The practical training site was well organized			6	4	1		0	2,55
The meals and refreshments were satisfactory			7	3	1		0	2,45

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Two participants were not present on Friday 18 July for the course evaluation and submitted their score sheets by e-mail. One of these had reversed the scores (5 best, 1 worst), but this has been taken into account in the summary.

Course Evaluation - Group 2 (17 Participants)	Number of forms filled in 17	Scores 1	2	3	4	5	Blank	W.A.
1. Training	Average score	1,51						
The objectives of the course were generally achieved		**11**	**6**				0	1,35
The classroom presentations were well presented and understood		11	6				0	1,35
I have now got a good understanding of the characteristics of Low Volume Roads		**11**	**6**				0	1,35
I have now got a good understanding of the design principles for Low Volume Roads		**9**	**8**				0	1,47
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		**8**	**9**				0	1,53
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		**9**	**8**				0	1,47
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results		**6**	**7**	**4**			0	1,88
There was enough time for practical exercises using the software and discussions / clarifications		**7**	**6**	**4**			0	1,82
The practical instructions were well delivered and understood		**10**	**6**				1	1,38
2. Organisation	Average score	1,95						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training		**4**	**2**	**3**	**4**	**4**	0	3,12
Arrangements for accommodation during the course was satisfactory		**8**	**3**	**2**			4	1,54
I was given satisfactory support from my employer/organization for participation in the course		**11**	**3**	**2**			1	1,44
The course was well organized		**8**	**5**	**3**			1	1,69
3. Venue	Average score	1,71						
The classroom facilities were satisfactory		**9**	**6**	**2**			0	1,59
The practical training site was well organized		**7**	**8**	**2**			0	1,71
The meals and refreshments were satisfactory		**6**	**8**	**3**			0	1,82

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

One participant had reversed the score (6 best, 1 worst), but this has been taken into account in the summary.

Annex 5: Summary Report from Laboratory Module

DCP Detailed Report - Multiple Mould Analysis

Job Ref. no Demo 1
Project date: 15 July, 2016 **Analysis date:** 21 July, 2016

Moulds included in analysis

Borrow Pit #	Test Pit #	Layer Depth in Test Pit (mm)	Sample #	Mould #	Survey Date	OMC (%)	Moisture Content	Compactive Effort
bp1	1	0	1	2	15 July 2016	16.8	OMC	Heavy
bp1	1	0	1	5	15 July 2016	16.8	OMC	Heavy

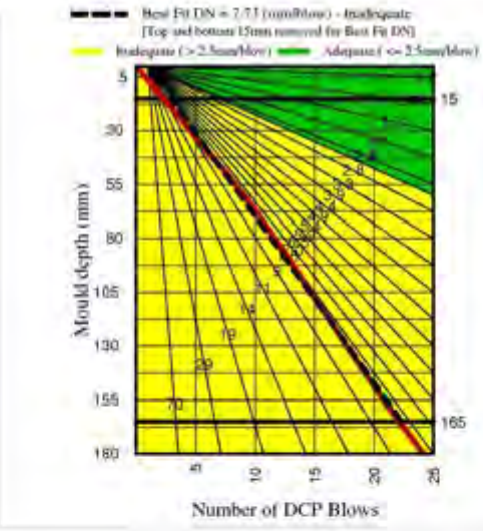
Ave. Design Structure Number (DSN$_{300}$) (Blows): 24 **Design DN (mm/blow):** 2.5

Average equivalent strength (Existing Moulds)

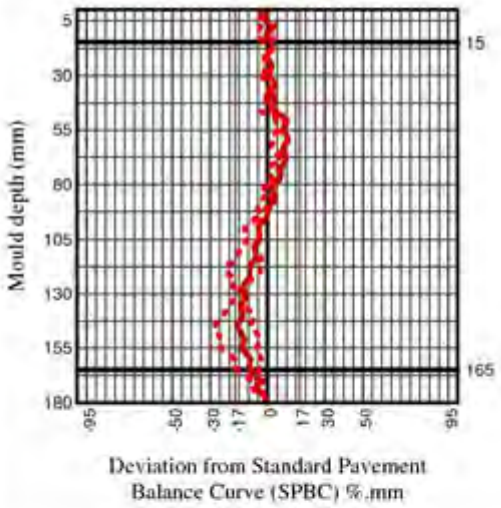
Depth (mm)	W. Ave. DN. * (mm / blow)	Best Fit DN (mm / blow)	Blows	Ave. E-Moduli (MPa)
15 - 165	7.60	7.73	22	130

** Weighted average penetration rate*

DCP Laboratory Curve Profile



Normalized Curve



Average equivalent strength (Redefined-EasyDCP Moulds)

Depth (mm)	W. Ave. DN. * (mm / blow)	Blows	Ave. E-Moduli (MPa)
0 - 60	6.67	9	149
60 - 180	8.05	15	122

** Weighted average penetration rate*

Annex 6: Presentations

July 16

AfCAP

Module 2

Overview of Low Volume Roads philosophy and the DCP design principles

Overview of Presentation

- Introduction/Background
- Design Philosophy
- Materials
- Drainage
- Surfacings
- 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 users.
- Technology, research and knowledge about LVSRs have advanced significantly in the region this research carried out over past 20-30 years
  - question much of the accepted paradigms on LVSR provision and show quite clearly the need to move conventional approaches
- New, more appropriate, approaches to the provision of low-volume roads are now required if Malawi is to improve road transport efficiency and attain its broader goals of socio-economic growth, development and poverty alleviation

Traditional Approaches to LVR Provision

"The body of highway engineering knowledge remains empiric rather than rigorously scientific. So, the knowledge taught in our [UK, USA] universities is generally derived from a synthesis of local [UK, USA] experience. No wonder it is often irrelevant and sometimes downright misleading in other parts of the world."

Ray Millard, Highways Advisor, World Bank, 2nd Int. Conf. on Low volume Roads, 1989

The Stark Facts

- Majority of rural roads are unsurfaced and carry relatively lightly 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 government and donor supported development programmes aiming to reduce poverty
- Generally poor condition of these roads has denied rural accessibility to transport services which has acted as a brake on economic development and hindered poverty alleviation efforts.

Rural Accessibility Index (2007)

Source: World Bank, 2007

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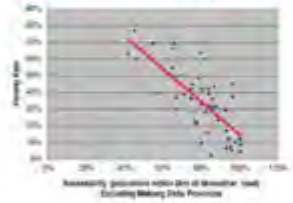
Poverty and Accessibility (Vietnam, 2002)



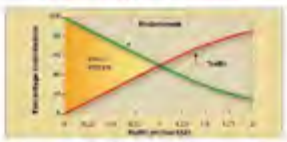
Our Challenge

- 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, most often 40-60 km/h would be acceptable

Dominant Mode of Deterioration



Deterioration of a LVR is driven primarily by environmental factors, with traffic being a lesser factor in deterioration

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.

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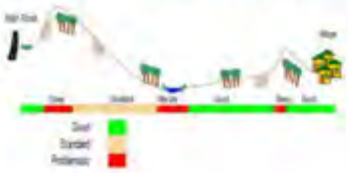
Road Environment Factors

Implementation within an EOD Context

Framework for sustainable provision of LVRs

Environmentally Optimised Design Approach



Use of Local Materials

- The art of the engineer consists for a good part in utilising 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 innovation have suppressed the more wide-spread use of innovative technology"
- In order to capitalize on the use these local materials, a better understanding of their properties and behaviour is necessary.

Drainage Design

Ensure adequate drainage – fundamental!

- h_{min} and d_{min}
- h_{min} > 750 mm
- d_{min} > 150 mm

Menu of Surfacing Options for Consideration

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Examples of Non-Bituminous Surfacings

Geometric Design

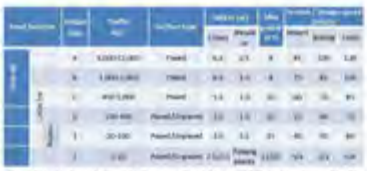
Option A

- 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 new alignment
- Existing alignment improved to satisfy various prescribed GD requirements,
- Adoption will incur potentially significant earthworks costs for which the benefits, in relation to relatively low levels of traffic likely to be outweighed by costs.

Geometric Design

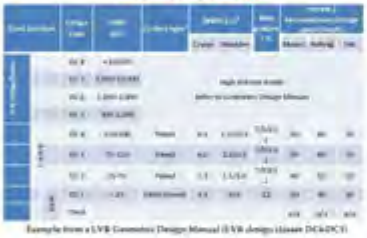


Road Standards as defined in Overseas Road Note 6 (LVR design classes D1 – E)

Geometric Design

Example from a typical Road Geometric Design Manual (LVR design classes DC5-DC8)

Geometric Design



Example from a LVR Geometric Design Manual (LVR design classes DC4-DC5)

Geometric Design

*"Oglesby and Altenhofen (1969) found accidents to be rare on low-volume rural roads. Furthermore, there was almost no evidence to indicate that higher standards of formation width or surface type would reduce the already small number, **although they found that highway engineers appeared to believe the opposite**. From an economic standpoint, accident costs were found to be of a lower order of magnitude than construction and operating costs".*

(Boyce, McDonald, Pearce & Robinson, 1988)

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Geometric Design

Conflicts/km/hr = $AADT^2$/Speed/30/16

- LVR with ADT<300 vpd function as single lane roads most of the time

Geometric Design

Low volume rural road in Norway, 5.50 m wide with AADT 2000

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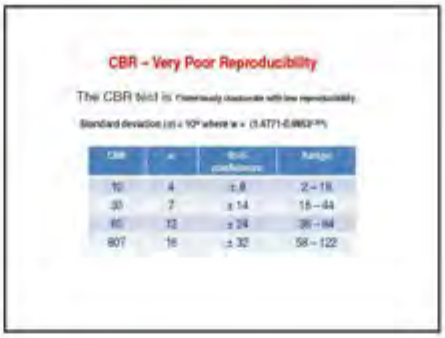
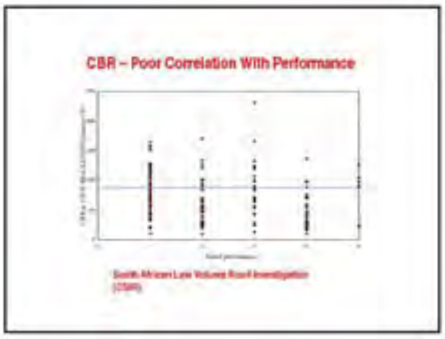
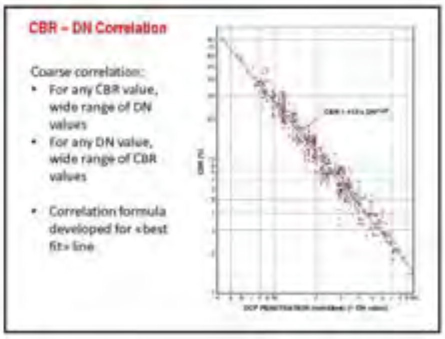
Pavement Design – Based on DCP
DCP test in process


CBR – Very Poor Reproducibility
The CBR test is
10 4 ± 8 2 – 18
30 7 ± 14 16 – 44
807 16 ± 32 58 – 122


CBR – Poor Correlation With Performance


CBR – DN Correlation
Coarse correlation:
• For any CBR value, wide range of DN values
• For any DN value, wide range of CBR values
• Correlation formula developed for «best fit» line


Site Investigations: DCP Vs CBR
Chainage
CBR Samples
DCP Measurements


Determination of Uniform Sections
DCP provides a good "picture" of in situ ground conditions

1

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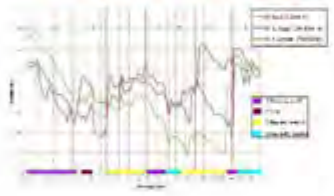
Determination of Uniform Sections



Integration of In Situ and Required Strength Profiles

Average penetration rates "DN" (DCP penetration number)

- The simple arithmetic average is not always representative if the effective penetration rate differs through the layer and ideally a weighted average penetration should be determined.
- When the top 50 mm of a 150 mm base layer for instance has a penetration rate of 1.1 mm/blow and the lower 100 mm has a value of 4.0 mm/blow,
  - the simple arithmetic average would be 2.55 mm/blow (1.1 + 4.0)/2)
  - the weighted average would be 3.03 mm/blow (((1.1*50)+(4.0*100)/150))

DCP Structural Number

DSN_{800} and DSN_{450}

- A full DCP penetration profile should be obtained to a depth of 800 mm. Last reading should be "zero error" plus 800mm
- The DCP structural number (DSN800) is the number of blows required to reach a depth of 800 mm.
- Typically, when a depth of 800 mm is not attained, the penetration profile can be extrapolated either based on the last few readings or using a specified or expected penetration rate.
- "DSN_{450}" is the number of blow to penetrate 450 mm, i.e. the three top 150 mm layers. These are the most significant layers for LVRs

Adjusting for moisture

- Moisture samples should be taken from the top three layer, at least 2 samples per km or uniform section
- The designer must ask:

Will the pavement be:

Drier than at the time of DCP Survey	20th percentile of DN
Same as at the time of DCP Survey	50th percentile of DN
Wetter than at the time of DCP Survey	80th percentile of DN

Adjusting for moisture

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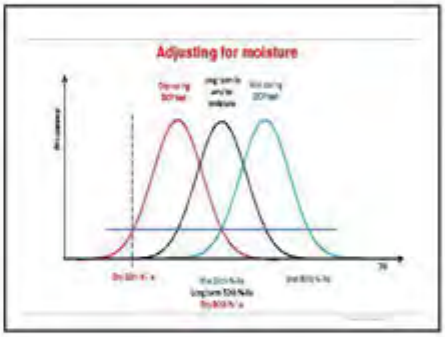
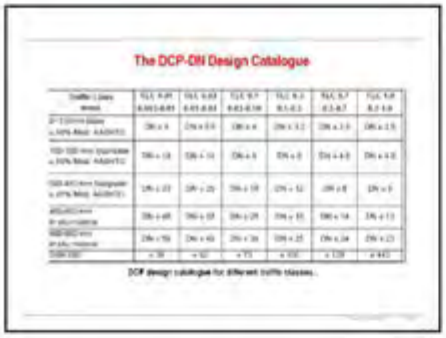
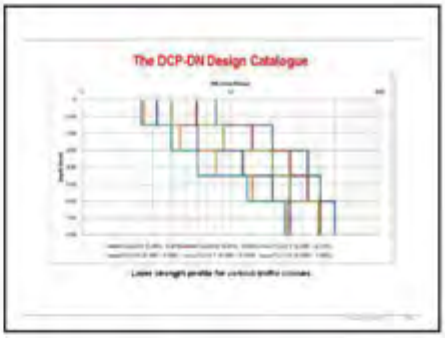
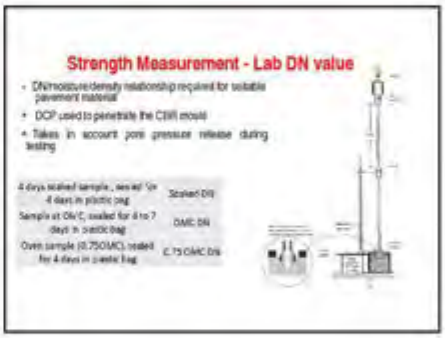
Adjusting for moisture


Adjusting for moisture


The DCP-DN Design Catalogue


The DCP-DN Design Catalogue


Determine upgrading requiements


Strength Measurement - Lab DN value
DN/moisture/density relationship required for workable pavement material
DCP used to penetrate the CBR mould
Takes in account pore pressure release during testing
Soaked DN
OMC DN
0.75 OMC DN

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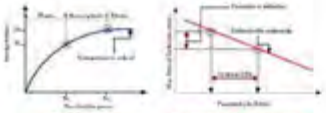
Strength Measurement - Lab DN value

Correction for confinement

DN/Density/Moisture Relationship

Benefits of Increased Compaction



Compaction to "refusal"

Deflection/life relationship

Level of compaction in pavement layers influences pavement life – increasing compactive effort is often economically justified

Appreciation of Risk Factors

Five main risks:

- Drainage
- 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

Examples of DCP Designed Roads

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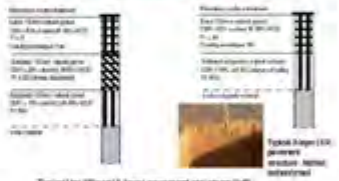
Benefits of Adopting New Approaches

Malawi experience

Pavement Structure Comparisons



Typical traditional 3-layer pavement structure (left) and 2-layer LVR structure (right)

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 bafflement and resistance that major technological change provokes... Champions of new ventures must display persistence and courage of heroic quality.

Edward Schon, MIT.

Thank You

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Materials investigation and choice of suitable road Materials

Materials for Low Volume Roads

- LVR Pavement Materials usually consist of local gravels derived from weathering of in situ rock or materials that have been transported by some natural force (e.g. water, wind, gravity).
- Expensive aggregates from the crushing of hard rock are not often used . Only limited to bituminous surfacings or concrete structures.

Types of Materials for Low Volume Roads

- Weathered and Residual Materials:
  Chemical alteration of the minerals in the rocks to form different minerals such as clays (except quartz, which is relatively resistant), and changes the hard rock to a residual material that could be used as a natural gravel
- Transported Materials
  Surficial soils moved to different locations by wind, rain, rivers, ice or gravity. This process also involve break down of large particles, washing away of finer materials, and sorting of different size fractions of materials (e.g. pebbles,coral rock in coast area)
- Pedogenic Materials:
  Pedogenic materials are a unique type of soil in which the existing material is fully or partially cemented by certain minerals (e.g. Laterite, calcrete)
- Other Materials: Volcanic tuff (containing natural pozzolan)...

Weathering classification system

Typical properties of residual materials derived from various rock types

BORROW PIT MANAGEMENT

- The identification and development of good sources of pavement construction material for LVR is essential to the cost effective use of construction and maintenance funds
- Up to 70% of the construction cost of LVR relate to pavement materials production and supply.
- Aggregate replacement costs often 60% of the maintenance costs of an unpaved road.
- Therefore need proper investigation and borrow pit management for cost efficiency

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BORROW PIT INVESTIGATION

- Using test pits
  - Number of test pits: to cover the all borrow pit area
- Materials testing requirements

Tests	Frequency	Comments
Atterberg Limits (PI,LL,LS)	Every 2000m²	Increase frequency if variable or marginal suitability
Grading Analysis	Every 3000m²	Increase frequency if variable or marginal suitability
Compaction and CBR	Every 4000m²-6000m²	Dependent on uniformity of material
Particle Strength (AIV, ACV)	Every 4000m²-6000m²	Dependent on uniformity of material

BORROW PIT TEST PITTING

- Investigation is done for existing Borrow pits.
- A search for new borrow pits in the area can also be done.

BORROW PIT MANAGEMENT

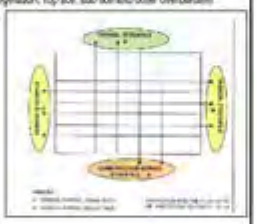
- Environmental and social considerations
  - potential to cause significant negative impacts on the local environment and its inhabitants :
    - Land repossession
    - Noise
    - Dust
    - Water course pollution
    - Safety
    - Access roads to borrow pit

BORROW PIT MANAGEMENT

- Environmental and social considerations
  - Access roads to borrow pit

BORROW PIT MANAGEMENT

- Borrow pit preparation and Material extraction
  - Site Clearance (Removal of vegetation, Top soil, sub soil and other overburden)
  - Borrow pit material extraction



Borrow pit material extraction, labour based methods

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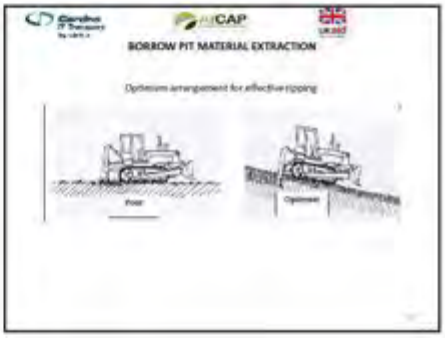
BORROW PIT MATERIAL EXTRACTION


BORROW PIT MATERIAL EXTRACTION, LABOUR BASED METHODS
•Trailer loading height


Plant for Borrow pit extraction by mechanised methods


BORROW PIT MATERIAL EXTRACTION
Optimum arrangement for effective ripping


STOCKPILING


BORROW PIT MATERIAL EXTRACTION
•Blending of material

3

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MATERIAL PROCESSING AND CONTROL

•Dealing with Oversize

- Manual removal
- Appropriate excavation method
- Screening
- Crushing

BORROW PIT CLOSURE AND REINSTATEMENT

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 1 required layer per test pit
- Atterberg limit testing: at least 1 required layer per test pit
- MDD, OMC, FMC testing: least 1 required layer per test pit

CENTRE LINE TEST PITTING

- Centre line test pitting using a backhoe (TLB) to excavate test pits to a depth of about 1metre.
- Test pits can also be dug manually.

TEST PIT

•Example of test pits

TEST PIT

•Test pit size

- Centre line: area: 1.25 X 0.75m; depth: 800 mm

- Borrow pit: ± 3m or refusal, but not less than 2m

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FIELD MOISTURE CONTENT (FMC) COLLECTION

•Collection of FMC using Auger

SPECIFICATIONS FOR PROFILING

- Based on ; Jennings, Brink and Williams 1973
- Principles : MCCSSO
  - Moisture: slightly moist
    - Dry, slightly moist, moist, very moist, wet
  - Colour: Use color chart
  - Consistency: measure of hardness, toughness
    - Very loose, Loose, medium dense, dense, very dense (non cohesive)
    - Very soft, soft, firm, stiff, very stiff (cohesive soil)
  - Structure: presence of absence of joints for cohesive soil
    - Intact, fissured, shattered, stratified, laminated ..
  - Soil type : based on grain size:
    - Boulders (>200mm), gravel (200-2.45), sand (2.45-0.075), silt(0.075-0.02), clay (<0.02)
  - Origin: residual soil, Colluvium, transported soil

SPECIFICATIONS FOR PROFILING

- Special notes on the log sheet
  - Depth of which the water table or seepage is encountered;
  - Refusal depth and the material the refusal occurred on;
  - Conceivable geological formations and considerations, etc.;
  - Type of samples taken and their corresponding depths;
  - Testing that will be required; and
- Other required information :
  - graves, dwellings, agricultural activities, obstacles and obstructions, etc.
  - environmental sensitive areas.
  - rock outcrops encountered, possible rock hardness.
  - expected borrow pit excavation hardness and material oversize.
  - material quantity in general

SPECIFICATIONS FOR PROFILING

TYPICAL PROFILING

TYPICAL PROFILING

•Profiling description and details

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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

TESTING & RESULTS PRESENTATION

•Presentation of Results

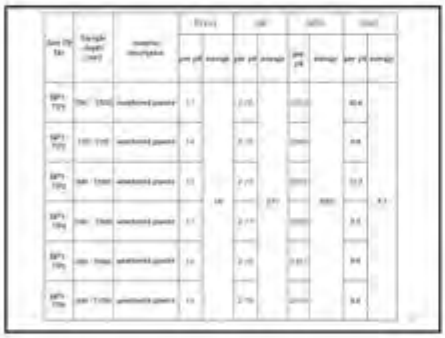
- Centre line material results

Test Pit No	Sample depth (mm)	PI (%)	LS	MDD	OMC	TMC	TMC/OMC ratio
TP1	0.0-3.00	8.7	3.0	2.048	7.3	6	82%
TP1	300- 600	7.3	2.5	1.922	12	11	92%
TP1	600- 900	5	1.5	2.110	10	8	80%
TP2	0.0 - 150	NP	0.0	2.005	8.2	6	73%
TP2	150- 1400	NP	0.0	1.954	9.0	9	100%

RESULTS PRESENTATION

•Presentation of Results

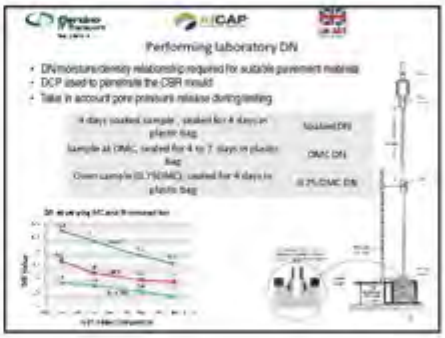
- Borro wpit materials results



Performing laboratory DN

- DN moisture/density relationship required for suitable pavement material
- DCP used to penetrate the CBR mould
- Take in account pore pressure release during testing

4 days soaked sample , soaked for 4 days in plastic bag	Soaked DN
Sample at OMC, sealed for 4 to 7 days in plastic bag	OMC DN
Oven sample (0.75OMC), sealed for 4 days in plastic bag	@ 75 OMC DN



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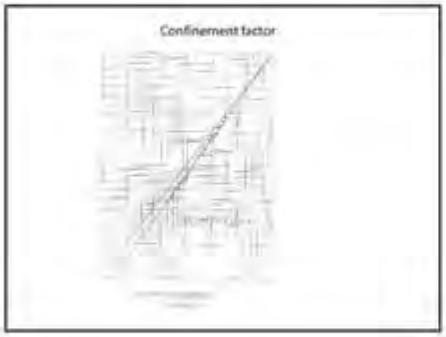

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Overview of Presentation

- Importance of compaction
- Factors affecting compaction
- Methods of compaction quality control
- Compaction trials
- Compaction control procedure using the DCP
- Evaluation procedure
- Strengths and limitations of using the DCP

Importance of compaction

- Compaction is arguably the most important aspect of road construction
- Materials typically account for large proportion of construction costs (up to 70%)
- Compaction accounts for small proportion of construction costs
- Substantial influence on durability, performance and whole-life costs

Factors affecting compaction

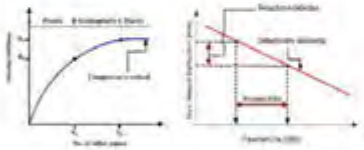
Effectiveness of compaction procedure depends on interrelated factors such as:

- Soil type
- Compaction moisture content
- Compactive effort
- Number of roller passes
- Loose layer thickness
- Other factors (contact pressure, speed of rolling, soil temperature)

Compaction phases

During compaction the soil goes through three phases:

- Plastic phase
- Elasto-plastic phase
- Elastic phase



Benefits of proper compaction

- Improved strength/bearing capacity and stiffness
- Increased density with decreased susceptibility to deformation / rutting
- Decreased permeability and susceptibility to moisture ingress and resultant loss of strength

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Compaction to refusal

- Compacting the soil to its elastic state is called «compaction to refusal», i.e. that for a given compactive effort and moisture content the soils cannot be densified any further
- Additional roller passes would therefore be a waste of time and money
- With a light roller the soil reaches the elastic state at a lower density than with a heavy roller
- The only way to achieve the required density/stiffness with a light roller is to reduce the loose layer thickness
- «Refusal» is when the roller no longer makes an indent and starts to bounce off the surface
- Compaction to refusal makes optimal use of available materials

Compaction to refusal

Warning

- Certain materials may break down due to excessive crushing of the coarse fractions
- Compaction must then stop at lower than desired density and stiffness of the layer

Methods of compaction quality control

Traditional:

- Density specs (93% subgrade, 95% subbase, 98% base)
- Do not reflect the more important engineering properties of the soil such as stiffness
- Problems with density as measure of compaction:
  - Large ratio between volume of material tested to that compacted (typically 1:100 000)
  - Poor correlation between laboratory and field compaction and poor reproducibility of results
  - Not sufficient account is taken in the test method for inherent variability of natural, unprocessed materials

Methods of compaction quality control

Methods for measurement of dry density:

- Sand replacement method
- Nuclear method

Shortcomings:

- Sand replacement method
  - Cumbersome, time consuming
  - Results not immediately available
- Nuclear method
  - Requires calibration of device
  - Potentially hazardous
- Both methods
  - Unreliable for natural materials with inherent variability

Methods of compaction quality control

Preferred methods:

- RCCP (Rapid Compaction Control Device)
  - Similar in function to DCP
  - Spring loaded mechanism
  - Different cone than DCP
- DCP
  - Good correlation with stiffness
  - Can be used as supplement to dry density methods or as a standalone method for compaction control
  - Criteria must be established for assessing when satisfactory compaction has been achieved through carefully executed compaction trials

Compaction trials

- Control sections
  - As short as practibly possible
  - At regular intervals or whenever material changes
  - Recommended minimum frequency every 2000 m3 of material. At 6.5 m width this equates to one control section every 2 km.
- Control of compaction moisture
  - At or close to OMC (+1% / -2% from OMC)
  - Control of adding and mixing of compaction water
  - Manual control of compaction moisture most effective after calibration in laboratory to get the «feel» of the material at OMC

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Compaction trials

- Control of compaction moisture
  - Hand squeeze method
    - Should be practised in laboratory to develop the -feel- for the material at various moisture contents during MDD/OMC determination

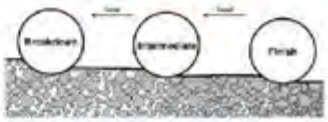
Compaction trials

- Control of compaction moisture
  - Frying pan method
    - Place small sample on frying pan and weigh to accuracy within +/- 1 gram
    - Soak it with kerosene and light it. This may have to be repeated twice
    - When flames are out, weigh again and calculate moisture content
    - Method should be calibrated against over drying since all moisture may not be removed
    - A correction factor for the method can then be established

Compaction trials

- Establish optimal compaction procedure for the material
  - Compaction amplitude at the various passes
  - No of passes required to attain elastic state
  - Compaction to be done only in one direction (forward moving roller)

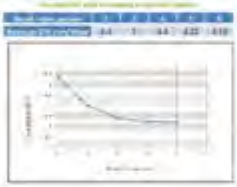
Compaction trials



- The first passes with maximum amplitude to break down oversize material and compact to the bottom of the layer
- Intermediate passes with medium amplitude to densify the middle and top of the layer
- Finishing passes at low or no amplitude to achieve an even surface with a tightly knit texture and no surface cracks

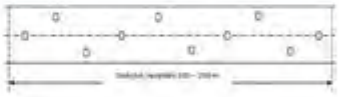
Compaction trials

- Establish Target DN for compaction control
- Check the density at which Target DN has been determined
- Target DN not same as Design DN since compaction control is done immediately after compaction before material has set and cured and when pore pressure is still present



Compaction control procedure

- For each lot (200 – 250 m), do 10 DCP tests to the full depth of the layer in a staggered pattern
- Pattern not the same for each lot, but following general guideline
- Offset from CL to be varied
- No tests closer to start/end of lot or edge of layer than 0.2 m



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Evaluation procedure

- Check for outliers in the sample

$$T_n = \frac{x_n - \bar{x}_n}{s_n}$$

n	4	5	6	7	8	9	10	11	12
T_1	1.46	1.67	1.82	1.94	2.03	2.11	2.18	2.23	2.29

n= No of tests in sample
T_1 = critical value of T_0

Evaluation procedure

- Check for outliers in the sample

Step 1: Identify outliers

Test no	DN	T_0		
1	4,6	-0,066272	STDEV =	1,06
2	4,2	-0,44497	Mean =	4,67
3	3,9	-0,728993		
4	5,4	0,6911235		
5	7,0	2,2059146	$T_0 > 2,18$	
6	4,3	-0,350295		
7	3,1	-1,486389		
8	4,9	0,2177512		
9	5,2	0,5017746		
10	4,1	-0,539644		

Evaluation procedure

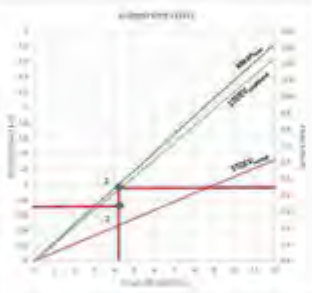
- Remove outlier and recalculate

Step 2: Recalculate STDEV, Mean for the sample without the outlier(s)

Test no	DN	T_0		
1	4,6	-0,066272	STDEV =	0,71
2	4,2	-0,44497	Mean =	4,41
3	3,9	-0,728993		
4	5,4	0,6911235		
		-4,421297		
6	4,3	-0,350295		
7	3,1	-1,486389		
8	4,9	0,2177512		
9	5,2	0,5017746		
10	4,1	-0,539644		

Evaluation procedure

- Plot the STDEV and Mean for the sample without the outlier in the Judgement Chart for the Target DN that has been established
- Acceptance
  - Mean ≤ $Mean_{max}$
  - STDEV ≤ $STDEV_{accept}$
- Conditional Acceptance
  - Mean ≤ $Mean_{max}$
  - $STDEV_{accept}$ ≤ STDEV ≤ $STDEV_{conditional}$



Strengths and limitations of using the DCP

Strengths:

- Equipment inexpensive, commonly available and portable
- Maintenance of the equipment can be done by reasonably skilled mechanical workshops
- No calibration of equipment is required
- Test is easy and quick to carry out, hence more tests can be done for greater statistical validity than with traditional density tests
- Technicians can easily be trained to carry out the test confidently
- The DCP test is more repeatable than the CBR test
- The same test can be used for field investigations and design, laboratory tests and compaction quality control without the need to convert the DN values to equivalent CBR values or dry densities

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Strengths and limitations of using the DCP

Limitations:

- Research has identified effect on DN value due to vertical confinement pressure. However, this is deemed to be negligible for layers less than 200 mm thick
- DCP test can be affected by stones or coarse gravel in the pavement layers

Reliable results depend on:

- DCP equipment in good order
- Correct use

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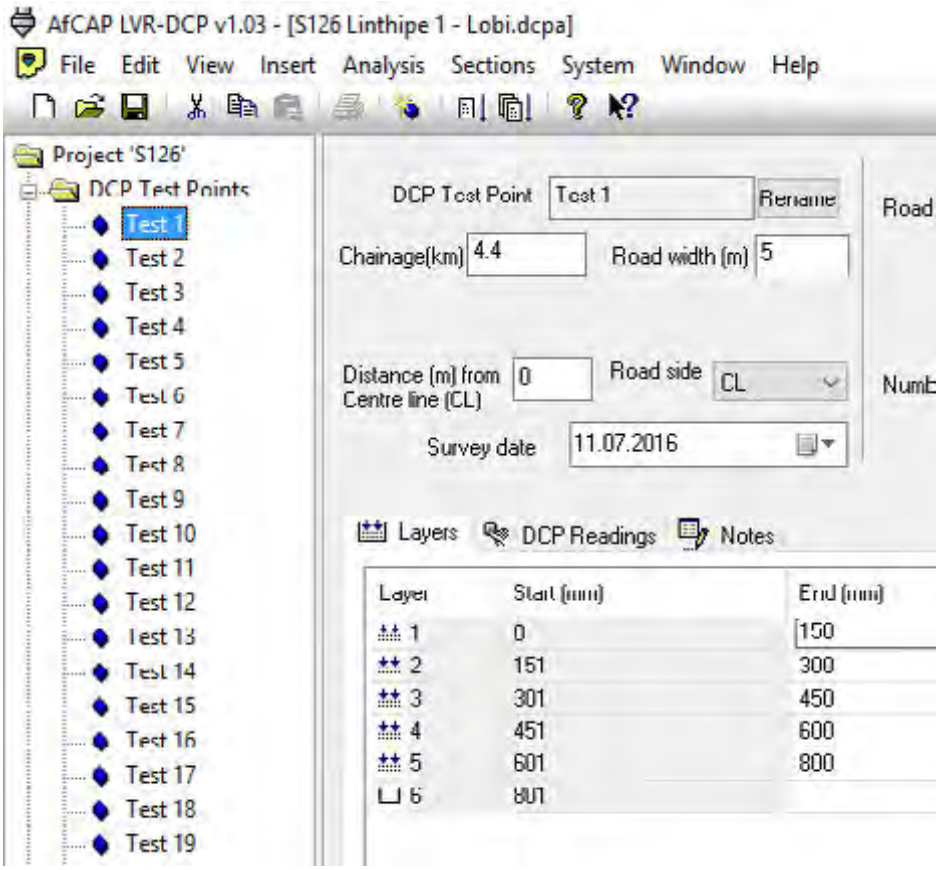
Annex 7: AfCAP LVR-DCP v1.03 Snaglist

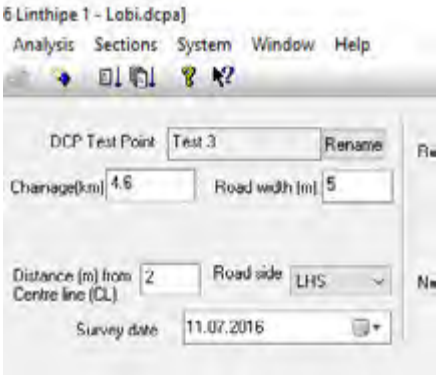
1. Tab-order for data to be entered in the left panel for new points should be:

Chainage –> Road width -> Dist. From CL -> Road side -> Survey date

2. Common data should be retained (inherited) for new points when set for the first point, e.g. Road width 5 m to be retained and user to change as/when width changes
3. If dist from CL has been set to zero, Road side should automatically be set to CL or vice versa.
4. Chainage to be formatted with 3 decimals, Dist. From CL and Road Width to be formatted with 1 decimal

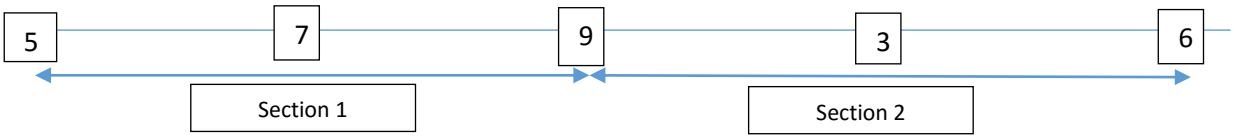


5. Point at xx m from CL at LHS does not display correctly in the analysis window, shows as CL:2
6. Position in analysis window to be displayed as say 2.0 m LHS



7. Calculation of averages for uniform section

I asked the question during our last meeting in Pretoria of how the programme calculates averages for uniform sections and there seemed to be some disagreement on this. Below is an illustration of how I think the programme does it at the moment and how I think it should be done:

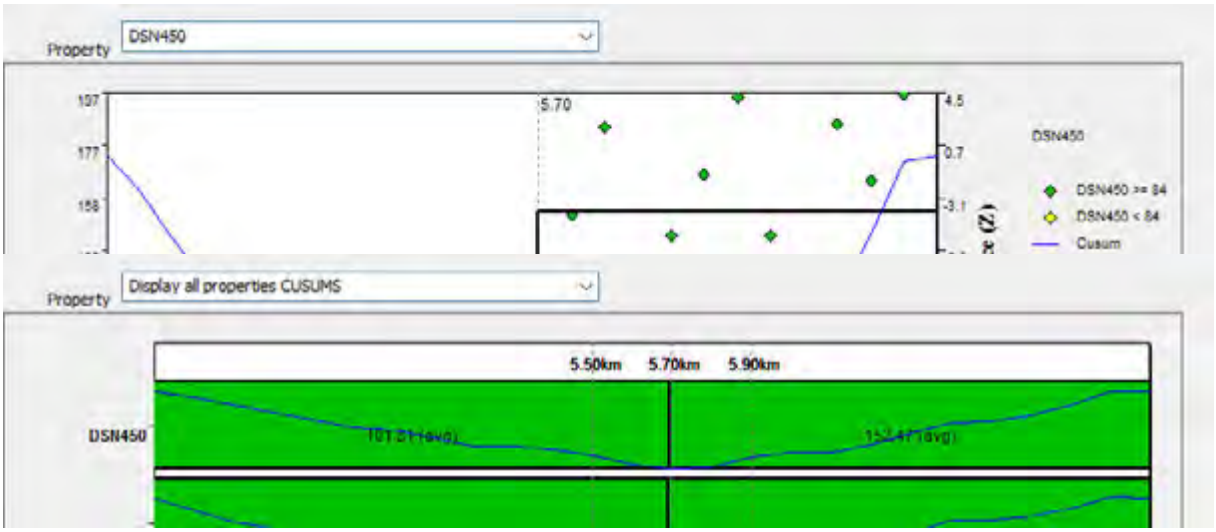


Currently:
Average Section 1 = (5+7+9)/3=7
Average Section 2= (3+6)/2=4.5

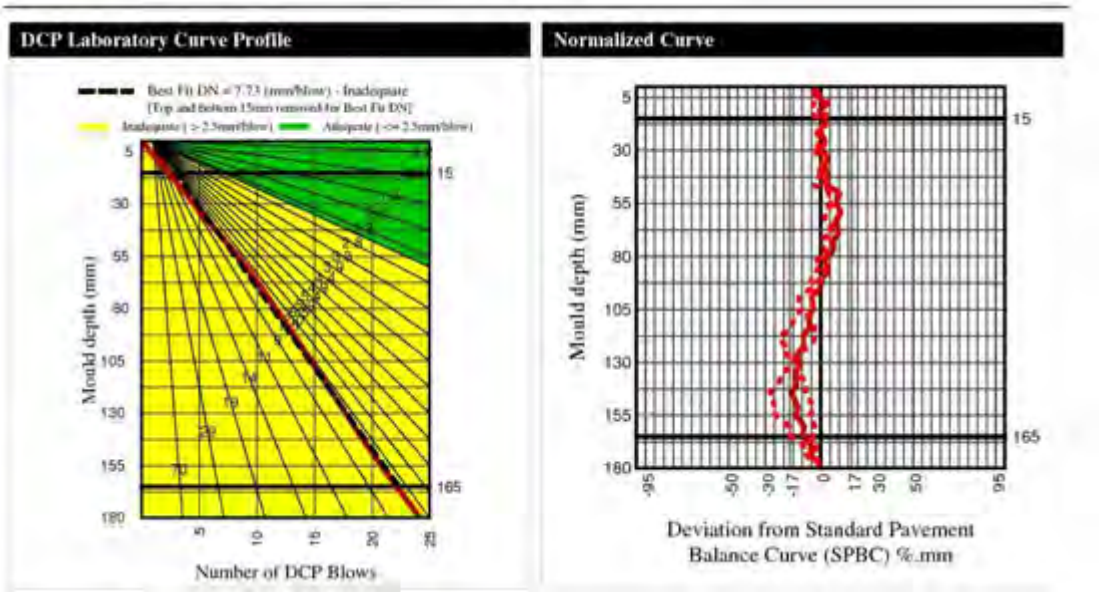
Correctly:
Average Section 1 = (5+7+9)/3=7
Average Section 2 = (9+3+6)/3=6

The point at the section delimiter must be included in average for both sections, otherwise there will be discontinuity and in this case too low average for section 2 in the current method. The DN just after point 3 is more likely to be close to 9 than close to 3, hence if point 3 is included the average for section 2 it will be more representative.

8. The chainages in the "Determine Sections from Properties" and "DCP Sections" screens to be displayed with 3 decimals, the section delimiters may display as say 5.10 in those windows and 5.095 in the DCP Sections Report. The adjustment of section delimiters is very sensitive and one needs to zoom in to do it accurately at the moment. Would be easier if 3 decimals are displayed.



9. The Normalised curve to be removed from Report from Lab Module. Does not make sense to have it there.


DCP Laboratory Curve Profile
Best Fit DN = 7.73 (mm/blow) - Inadequate
[Top and Bottom 15mm removed for Best Fit DN]
Inadequate (> 2.5mm/blow)
Adequate (<= 2.5mm/blow)
Mould depth (mm)
5
30
55
80
105
130
155
180
15
165
5
10
15
20
25
Number of DCP Blows
Normalized Curve
Mould depth (mm)
5
30
55
80
105
130
155
180
15
165
-95
-50
-30
-17
0
17
30
50
95
Deviation from Standard Pavement
Balance Curve (SPBC) %.mm

Annex 8: Evaluation forms

Group 1:

Course Evaluation - Group 1 (12 Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved			✓				0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads			✓				0	#####
I have now got a good understanding of the design principles for Low Volume Roads			✓				0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method			✓				0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results				✓			0	#####
There was enough time for practical exercises using the software and discussions / clarifications		✓					0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training						✓	0	#####
Arrangements for accommodation during the course was satisfactory				✓			0	#####
I was given satisfactory support from my employer/organization for participation in the course			✓				0	#####
The course was well organized				✓			0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory		✓					0	#####
The practical training site was well organized				✓			0	#####
The meals and refreshements were satisfactory				✓			0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

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The practical training site was well organized						✓	0	#####
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The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood			✓				0	#####
I have now got a good understanding of the characteristics of Low Volume Roads			✓				0	#####
I have now got a good understanding of the design principles for Low Volume Roads			✓				0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		✓					0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results				✓			0	#####
There was enough time for practical exercises using the software and discussions / clarifications			✓				0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training			✓				0	#####
Arrangements for accommodation during the course was satisfactory							0	#####
I was given satisfactory support from my employer/organization for participation in the course			✓				0	#####
The course was well organized			✓				0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized				✓			0	#####
The meals and refreshments were satisfactory			✓				0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 1 (12 Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood			✓				0	#####
I have now got a good understanding of the characteristics of Low Volume Roads			✓				0	#####
I have now got a good understanding of the design principles for Low Volume Roads				✓			0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method				✓			0	#####
I have now got a good understanding of the design process for Low Volume Roads using the ARCAAP LVR-DCP software				✓			0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓				0	#####
There was enough time for practical exercises using the software and discussions / clarifications		✓					0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training		✓					0	#####
Arrangements for accommodation during the course was satisfactory							0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized			✓				0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized			✓				0	#####
The meals and refreshments were satisfactory			✓				0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 1 (12 Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads		✓					0	#####
I have now got a good understanding of the design principles for Low Volume Roads		✓					0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method			✓				0	#####
I have now got a good understanding of the design process for Low Volume Roads using the ARCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓				0	#####
There was enough time for practical exercises using the software and discussions / clarifications		✓					0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training						✓	0	#####
Arrangements for accommodation during the course was satisfactory		✓					0	#####
I was given satisfactory support from my employer/organization for participation in the course			✓				0	#####
The course was well organized			✓				0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized			✓				0	#####
The meals and refreshments were satisfactory			✓				0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 1 (12 Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved			✓				0	#####
The classroom presentations were well presented and understood			✓				0	#####
I have now got a good understanding of the characteristics of Low Volume Roads			✓				0	#####
I have now got a good understanding of the design principles for Low Volume Roads				✓			0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method			✓	✓			0	#####
I have now got a good understanding of the design process for Low Volume Roads using the ARCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓				0	#####
There was enough time for practical exercises using the software and discussions / clarifications			✓				0	#####
The practical instructions were well delivered and understood			✓				0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training			✓				0	#####
Arrangements for accommodation during the course was satisfactory				✓			0	#####
I was given satisfactory support from my employer/organization for participation in the course					✓		0	#####
The course was well organized				✓			0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized				✓			0	#####
The meals and refreshments were satisfactory			✓				0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 1 (12 Participants)	Number of forms filled in	Scores 1	2	3	4	5
1. Training	Average score	4.67				
The objectives of the course were generally achieved						1
The classroom presentations were well presented and understood						1
I have now got a good understanding of the characteristics of Low Volume Roads						1
I have now got a good understanding of the design principles for Low Volume Roads						1
I have now got a good understanding of the strengths and limitations of the DCP DN Design Method					1	
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software						1
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results				1		
There was enough time for practical exercises using the software and discussions / clarifications						1
The practical instructions were well delivered and understood						1
2. Organisation	Average score	3.50				
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training					1	
Arrangements for accommodation during the course was satisfactory		1				
I was given satisfactory support from my employer/organization for participation in the course						1
The course was well organized					1	
3. Venue	Average score	4.33				
The classroom facilities were satisfactory						1
The practical training site was well organized					1	
The meals and refreshments were satisfactory					1	

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Submitted by e-mail, scores reversed

Course Evaluation - Group 1 (12 Participants)	Number of forms filled in	Scores 1	2	3	4	5	Blank	W.A.
1. Training	Average score	1,56						
The objectives of the course were generally achieved			2					2,00
The classroom presentations were well presented and understood			2					2,00
I have now got a good understanding of the characteristics of Low Volume Roads		1						1,00
I have now got a good understanding of the design principles for Low Volume Roads		1						1,00
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		1						1,00
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		1						1,00
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results				3				3,00
There was enough time for practical exercises using the software and discussions / clarifications		1						1,00
The practical instructions were well delivered and understood			2					2,00
2. Organisation	Average score	3,75						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training						5		5,00
Arrangements for accommodation during the course was satisfactory				3				3,00
I was given satisfactory support from my employer/organization for participation in the course						5		5,00
The course was well organized			2					2,00
3. Venue	Average score	2,67						
The classroom facilities were satisfactory			2					2,00
The practical training site was well organized				3				3,00
The meals and refreshments were satisfactory				3				3,00

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Submitted by e-mail

Group 2:

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads		✓					0	#####
I have now got a good understanding of the design principles for Low Volume Roads		✓					0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		✓					0	#####
I have now got a good understanding of the design process for Low Volume Roads using the ARCAAP LVR-DCP software		✓					0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results		✓					0	#####
There was enough time for practical exercises using the software and discussions / clarifications			✓				0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training			✓				0	#####
Arrangements for accommodation during the course was satisfactory		✓					0	#####
I was given satisfactory support from my employer/organization for participation in the course			✓				0	#####
The course was well organized		✓					0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory		✓					0	#####
The practical training site was well organized		✓					0	#####
The meals and refreshments were satisfactory				✓			0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 1 (12 Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved			✓				0	#####
The classroom presentations were well presented and understood			✓				0	#####
I have now got a good understanding of the characteristics of Low Volume Roads			✓				0	#####
I have now got a good understanding of the design principles for Low Volume Roads			✓				0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method			✓				0	#####
I have now got a good understanding of the design process for Low Volume Roads using the ARCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓				0	#####
There was enough time for practical exercises using the software and discussions / clarifications				✓			0	#####
The practical instructions were well delivered and understood			✓				0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training		✓					0	#####
Arrangements for accommodation during the course was satisfactory			✓				0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized			✓				0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized			✓				0	#####
The meals and refreshments were satisfactory			✓				0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads			✓				0	#####
I have now got a good understanding of the design principles for Low Volume Roads			✓				0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method			✓				0	#####
I have now got a good understanding of the design process for Low Volume Roads using the ARCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results		✓					0	#####
There was enough time for practical exercises using the software and discussions / clarifications		✓					0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training		✓					0	#####
Arrangements for accommodation during the course was satisfactory			✓				0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized		✓					0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory				✓			0	#####
The practical training site was well organized			✓				0	#####
The meals and refreshments were satisfactory			✓				0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in:	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved			✓				0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads		✓					0	#####
I have now got a good understanding of the design principles for Low Volume Roads		✓					0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method			✓				0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		✓					0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results		✓					0	#####
There was enough time for practical exercises using the software and discussions / clarifications		✓					0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training					✓		0	#####
Arrangements for accommodation during the course was satisfactory				✓			0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized		✓					0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory		✓					0	#####
The practical training site was well organized			✓				0	#####
The meals and refreshments were satisfactory		✓					0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in:	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads		✓					0	#####
I have now got a good understanding of the design principles for Low Volume Roads		✓					0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		✓					0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		✓					0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results		✓					0	#####
There was enough time for practical exercises using the software and discussions / clarifications		✓					0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training		✓					0	#####
Arrangements for accommodation during the course was satisfactory		✓					0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized		✓					0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory		✓					0	#####
The practical training site was well organized		✓					0	#####
The meals and refreshments were satisfactory		✓					0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in:	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads		✓					0	#####
I have now got a good understanding of the design principles for Low Volume Roads		✓					0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		✓					0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		✓					0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓				0	#####
There was enough time for practical exercises using the software and discussions / clarifications			✓				0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training				✓			0	#####
Arrangements for accommodation during the course was satisfactory		✓					0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized		✓					0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory		✓					0	#####
The practical training site was well organized		✓					0	#####
The meals and refreshments were satisfactory		✓					0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved			✓				0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads		✓					0	#####
I have now got a good understanding of the design principles for Low Volume Roads			✓				0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method			✓				0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓				0	#####
There was enough time for practical exercises using the software and discussions / clarifications			✓				0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training		✓					0	#####
Arrangements for accommodation during the course was satisfactory		✓					0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized			✓				0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized			✓				0	#####
The meals and refreshments were satisfactory			✓				0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads		✓					0	#####
I have now got a good understanding of the design principles for Low Volume Roads		✓					0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		✓					0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		✓					0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results		✓					0	#####
There was enough time for practical exercises using the software and discussions / clarifications		✓					0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training						✓	0	#####
Arrangements for accommodation during the course was satisfactory				✓			0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized		✓					0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory		✓					0	#####
The practical training site was well organized		✓					0	#####
The meals and refreshments were satisfactory		✓					0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood			✓				0	#####
I have now got a good understanding of the characteristics of Low Volume Roads			✓				0	#####
I have now got a good understanding of the design principles for Low Volume Roads			✓				0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method			✓				0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓				0	#####
There was enough time for practical exercises using the software and discussions / clarifications				✓			0	#####
The practical instructions were well delivered and understood			✓				0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training			✓				0	#####
Arrangements for accommodation during the course was satisfactory		✓					0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized			✓				0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized			✓				0	#####
The meals and refreshments were satisfactory			✓				0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved			✓				0	#####
The classroom presentations were well presented and understood			✓				0	#####
I have now got a good understanding of the characteristics of Low Volume Roads		✓					0	#####
I have now got a good understanding of the design principles for Low Volume Roads			✓				0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		✓					0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		✓					0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓				0	#####
There was enough time for practical exercises using the software and discussions / clarifications				✓			0	#####
The practical instructions were well delivered and understood			✓				0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training				✓			0	#####
Arrangements for accommodation during the course was satisfactory		✓					0	#####
I was given satisfactory support from my employer/organization for participation in the course		✓					0	#####
The course was well organized			✓				0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory		✓					0	#####
The practical training site was well organized		✓					0	#####
The meals and refreshments were satisfactory		✓					0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved		✓					0	#####
The classroom presentations were well presented and understood		✓					0	#####
I have now got a good understanding of the characteristics of Low Volume Roads		✓					0	#####
I have now got a good understanding of the design principles for Low Volume Roads		✓					0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		✓					0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓	✓			0	#####
There was enough time for practical exercises using the software and discussions / clarifications			✓				0	#####
The practical instructions were well delivered and understood		✓					0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training					✓		0	#####
Arrangements for accommodation during the course was satisfactory			✓				0	#####
I was given satisfactory support from my employer/organization for participation in the course			✓				0	#####
The course was well organized				✓			0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized			✓	✓			0	#####
The meals and refreshments were satisfactory			✓				0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

Course Evaluation - Group 2 (?? Participants)	Number of forms filled in	Scores						
		1	2	3	4	5	Blank	W.A.
1. Training	Average score	#DIV/0!						
The objectives of the course were generally achieved			✓				0	#####
The classroom presentations were well presented and understood			✓				0	#####
I have now got a good understanding of the characteristics of Low Volume Roads			✓				0	#####
I have now got a good understanding of the design principles for Low Volume Roads			✓				0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method			✓				0	#####
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results			✓				0	#####
There was enough time for practical exercises using the software and discussions / clarifications			✓				0	#####
The practical instructions were well delivered and understood			✓				0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training					✓		0	#####
Arrangements for accommodation during the course was satisfactory			✓				0	#####
I was given satisfactory support from my employer/organization for participation in the course			✓				0	#####
The course was well organized				✓			0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized			✓	✓			0	#####
The meals and refreshments were satisfactory			✓				0	#####

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I have now got a good understanding of the design principles for Low Volume Roads			✓				0	#####
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		✓					0	#####
I have now got a good understanding of the design process for Low Volume Roads using the ARCAAP LVR-DCP software			✓				0	#####
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results				✓			0	#####
There was enough time for practical exercises using the software and discussions / clarifications			✓				0	#####
The practical instructions were well delivered and understood			✓				0	#####
2. Organisation	Average score	#DIV/0!						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training						✓	0	#####
Arrangements for accommodation during the course was satisfactory							0	##### N/A
I was given satisfactory support from my employer/organization for participation in the course							0	##### N/A
The course was well organized			✓				0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory				✓			0	#####
The practical training site was well organized			✓				0	#####
The meals and refreshments were satisfactory			✓				0	#####

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I have now got a good understanding of the design process for Low Volume Roads using the ARCAAP LVR-DCP software		✓					0	#####
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The course was well organized				✓			0	#####
3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory		✓					0	#####
The practical training site was well organized				✓			0	#####
The meals and refreshments were satisfactory				✓			0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

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3. Venue	Average score	#DIV/0!						
The classroom facilities were satisfactory			✓				0	#####
The practical training site was well organized			✓				0	#####
The meals and refreshments were satisfactory				✓			0	#####

Key to Scores: 1=Strongly agree, 2=Agree, 3=Partially agree, 4=Disagree, 5=Strongly disagree, WA=Weighted average

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The classroom facilities were satisfactory							0	#####
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