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

Training Report

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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.

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Acronyms, Units and Currencies

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

Contents

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

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

1 Executive summary

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

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

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

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

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

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

The assessment of the Trainers is that objectives of the training have been achieved. The Trainees have got a good grasp of the DCP-DN design method and use of the software for producing an environmentally optimised pavement design and will be able to apply the method to a fully-fledged project design with some further coaching and guidance. This assessment is confirmed by the Trainees own evaluation of the course.

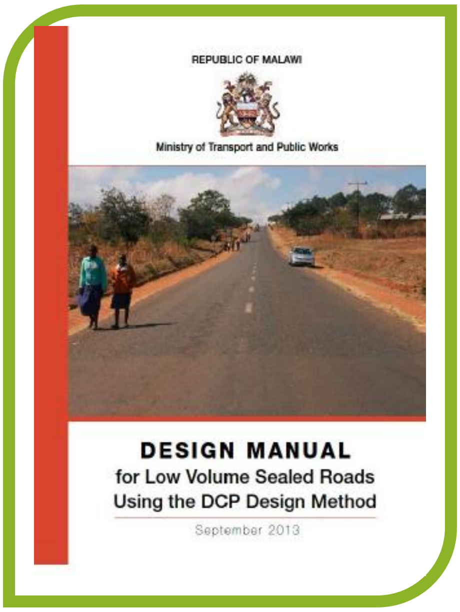
To build on the momentum from this initial training it is recommended to identify 5-6 candidates from among the Trainees to undergo a Training-of-Trainers Course. The ToT should be combined with the design and construction of Demonstration Project(s) for bringing the National Trainers up to an advanced level and enable them to sustain the training and mainstream the LVSR design approach with diminishing support from the International Trainers.

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

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

2 Introduction

2.1 Background



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

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

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

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

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

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

2.2 Objectives of the Assignment

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

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

2.3 Purpose and Scope of the Report

The purpose of this report is:

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

The Mission Itinerary and Programme is attached in Annex 1.

The report covers the following:

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

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

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

3 Training Programme

3.1 Preparations

3.1.1 Procurement of DCPs

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

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

3.2 Training Modules and Programme

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

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

Figure 2: Group 1 participants

Figure 3: Group 2 participants

3.3 In-country preparations

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

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

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

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

3.4 Training

3.4.1 Practical training

DCP Field tests

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

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

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

Figure 4: Training roads. Tinkong – Konko (left) and Tinkong – Mangoase (right)

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

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

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

Figure 5: Practical exercise on Tinkong – Konko road

Laboratory DN test

During the practical training for the first group, a visit was paid to the borrow pit from where samples had been taken for the Laboratory DN test. The material was a good quality laterite (see Figure 7) with the following basic properties:

- MDD 2,217 kg/m3
- PI 20.5%
- OMC 7.2%

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

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

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

Figure 6: Laboratory DN Test results

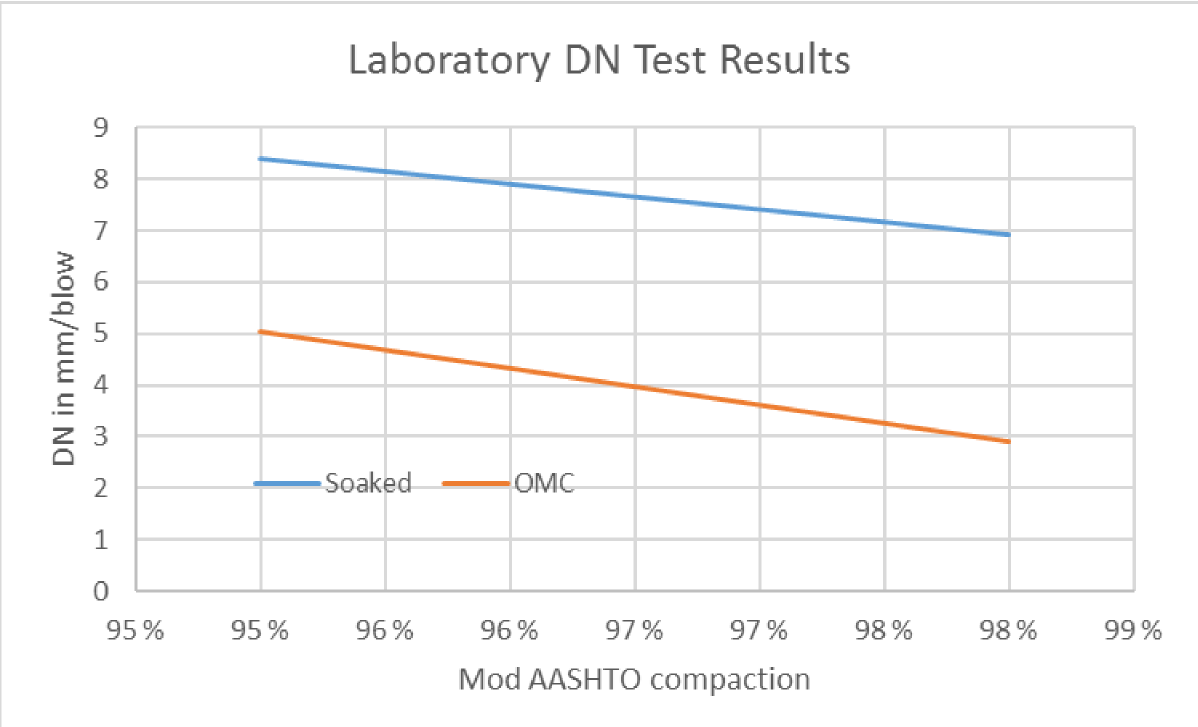


Figure 7: Laterite gravel borrow pit

Figure 8: Laboratory DN test

3.4.2 Classroom training

Presentations

Two presentations were given covering the following main topics:

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

The presentations are shown in Annex 4.

Introduction to the AfCAP LVR-DCP software

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

- Opening a new project file
- Showing the use of the various menu options
- DCP system settings
- Choosing Traffic Load Class (TLC) design curve
- Setting report options
- Entering DCP test data (from field exercises)

- Performing Single Point and Multiple Point analysis
- Explaining the use of percentiles for moisture adjustments of DN values
- Explaining the Layer Strength Diagram (LSD) and Normalised/Redefined LSD
- Explaining the Pavement Balance concept and the effect on the Power Exponent for well-balanced pavements for estimation of Design Traffic Loading

Pavement design exercises using the AfCAP LVR-DCP software

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

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

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

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

Pavement Layer (mm)	Required DN value for TLC 0.3	Section no.					
		1	2	3	4	5	6
		0.03 to 1.405 km	1.405 to 2.585 km	2.585 to 4.855 km	4.855 to 5.64 km	5.64 to 7.19 km	7.19 to 8.38 km
0-150	<= 3.2 (3.5)	2.88 (80P)	4.46 (80P)	4.84 (80P)	7.05 (80P)	5.49 (80P)	8.03 (80P)
150-300	<= 6 (6.9)	5.45 (80P)	9.99 (80P)	9.72 (80P)	13.96 (80P)	12.32 (80P)	13.64 (80P)
300-450	<= 12 (14)	10.62 (80P)	19.60 (80P)	12.60 (80P)	24.05 (80P)	21.98 (80P)	18.62 (80P)
450-600	<= 19	17.49 (80P)	28.97 (80P)	17.52 (80P)	28.60 (80P)	31.34 (80P)	24.55 (80P)
600-800	<= 25	21.97 (80P)	34.49 (80P)	21.07 (80P)	36.22 (80P)	32.45 (80P)	31.44 (80P)

Pavement Layer (mm)	Required DN value for TLC 0.3	Group 1					
		1	2	3	4	5	6
		0.03 to 1.405 km	1.405 to 2.585 km	2.585 to 4.855 km	4.855 to 5.64 km	5.64 to 7.19 km	7.19 to 8.38 km
0-150	<= 3.2 (3.5)	2.88 (80P)	3.20	3.20	3.20	3.20	3.20
150-300	<= 6 (6.9)	5.45 (80P)	4.46 (80P)	4.84 (80P)	7.05 (80P)	5.49 (80P)	6.00
300-450	<= 12 (14)	10.62 (80P)	9.99 (80P)	9.72 (80P)	13.96 (80P)	12.32 (80P)	8.03 (80P)
450-600	<= 19 (19)	17.49 (80P)	19.60 (80P)	12.60 (80P)	24.05 (80P)	21.98 (80P)	13.64 (80P)
600-800	<= 25 (25)	21.68 (80P)	28.97 (80P)	17.52 (80P)	28.60 (80P)	31.34 (80P)	18.62 (80P)

Pavement Layer (mm)	Required DN value for TLC 0.3	Group 2					
		1	2	3	4	5	6
		0.03 to 1.38 km	1.38 to 2.57 km	2.57 to 3.955 km	3.955 to 5.59 km	5.59 to 7.61 km	7.61 to 8.38 km
0-150	<= 3.2 (3.5)	2.77 (80P)	3.20	3.20	3.20	3.20	3.20
150-300	<= 6 (6.9)	4.92 (80P)	4.34 (80P)	4.79 (80P)	5.81 (80P)	6.73 (80P)	6.74 (80P)
300-450	<= 12 (14)	9.50 (80P)	9.94 (80P)	9.93 (80P)	12.43 (80P)	11.65 (80P)	14.33 (80P)
450-600	<= 19 (19)	16.53 (80P)	19.59 (80P)	13.27 (80P)	17.35 (80P)	20.54 (80P)	18.52 (80P)
600-800	<= 25 (25)	20.85 (80P)	28.35 (80P)	20.02 (80P)	19.37 (80P)	29.02 (80P)	25.57 (80P)

Pavement Layer (mm)	Required DN value for TLC 0.3	Group 3					
		1	2	3	4	5	6
		0.03 to 1.16 km	1.16 to 2.325 km	2.325 to 3.17 km	3.17 to 4.67 km	4.67 to 6.57 km	6.57 to 8.38 km
0-150	<= 3.2 (3.5)	2.67 (80P)	3.20	3.20	3.20	3.20	3.20
150-300	<= 6 (6.9)	4.16 (80P)	3.92 (80P)	5.78 (80P)	4.80 (80P)	5.59 (80P)	6.00
300-450	<= 12 (14)	8.96 (80P)	9.45 (80P)	9.59 (80P)	10.13 (80P)	12.37 (80P)	7.50 (80P)
450-600	<= 19 (19)	15.65 (80P)	18.15 (80P)	13.29 (80P)	13.77 (80P)	20.74 (80P)	13.68 (80P)
600-800	<= 25 (25)	19.67 (80P)	27.15 (80P)	18.47 (80P)	19.61 (80P)	28.30 (80P)	20.41 (80P)

As can be seen, none of the groups came up with the exact same design although the differences in practice would not be very big. The design exercises gave rise to useful plenary discussions on:

- How to interpret the Cusum curves for determination of uniform sections, and
- Options for treatment of in-situ layers as an alternative to import of new layers

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

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

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

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

4 Conclusion

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

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

Table 2: Couse evaluation summary

Course evaluation summary	Average score	
	Group 1	Group 2
Training	1.90	1.71
Organisation	1.77	1.76
Venue	1.69	2.08

Score: 1 (best), 5 (worst)

5 Next Steps

5.1 Training of Trainers

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

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

5.2 Demonstration projects

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

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

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

5.3 Recommendations

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

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

Annex 1: Mission Itinerary and Programme

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

Annex 2: Training Methodology and Modules

Methodology

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

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

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

Training Programme and Modules

Training Modules

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

Table 3: Training Programme Outline

Week 1 – Group 1 (up to 15 participants)						
Training sessions	Mon 08.02.15	Tue 09.02.15	Wed 10.02.15	Thu 11.02.15	Fri 12.02.15	Sat 13.02.15
1. session 08.30 – 10.00		**Module 1 cont.**	**Module 2** • Background • LVR design	**Module 4** • WinDCP software • DCP data entry	**Module 4 cont.** • Lab DN test demo	**Module 5 cont.**
Break 10.00-10.30						
2. session 10.30-12.00	**Registration** **Introduction**	**Module 1 cont.**	**Module 2 cont.**	**Module 4 cont.**	**Module 5** • Using WinDCP for Pavement design	**Module 5 cont.**
Lunch 12.00-13.00						
3.session 13.00 – 14.30	**Module 1: Field work** • Road and borrow pit inspection • DCP testing	**Module 1 cont.**	**Module 3** • Materials sampling and testing	**Module 4 cont.**	**Module 5 cont.**	**Wrap-up** • Q&A • Course evaluation
Break 14.30 – 15.00						
4. session 15.00 – 16.30	**Module 1 cont.**	**Module 1 cont.**	**Module 3 cont.**	**Module 4 cont.**	**Module 5 cont.**	

Week 2 – Group 2 (up to 15 participants)						
Training sessions	Mon 15.02.15	Tue 16.02.15	Wed 17.02.15	Thu 18.02.15	Fri 19.02.15	Sat 20.02.15
1. session 08.30 – 10.00		**Field work**	**Module 1** • Background • LVR design	**Module 3** • WinDCP software • DCP data entry	**Module 3 cont.** • Lab DN test demo	**Module 4 cont.**
Break 10.00-10.30						
2. session 10.30-12.00	**Registration &** **Introduction**	**Field work**	**Module 1 cont.**	**Module 3 cont.**	**Module 4** • Using WinDCP for Pavement design	**Module 4 cont.**
Lunch 12.00-13.00						
3.session 13.00 – 14.30	**Module 1: Field work** • Road and borrow pit inspection • DCP testing	**Field work**	**Module 2** • Materials sampling and testing	**Module 3 cont.**	**Module 4 cont.**	**Wrap-up** • Q&A • Course evaluation
Break 14.30 – 15.00						
4. session 15.00 – 16.30	**Field work**	**Field work**	**Module 2 cont.**	**Module 3 cont.**	**Module 4 cont.**	

Preparatory Activities

The preparatory activities to be completed prior to the start of the training course are summarised in the Table 2 below.

Table 4: Preparatory activities

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

Annex 3: Report on in-country preparatory activities

A: INTRODUCTION

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

B: CHOICE OF TESTING SITES (ROADS)

The selected roads are **Tinkong to Mangoase (7.1km)** and **Tinkong to Konko (6.3km)**. Figure 1 shows a location map of the roads. The roads are about 20 minutes' drive from the Koforidua Training Centre (KTC).

Location map of project roads

C: CHOICE OF BORROW PITS FOR GRAVEL

One borrow pit was located at Kokofa about 1 km from the left side of the end of the Tinkong – Konko road.

D: CHOICE OF GEOTECHNICAL AND MATERIAL LABORATORY

The Ghana Highway Materials Laboratory at Koforidua was selected. It is located about 1km from KTC.

E: TEST PITS

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

Tinkong-Konko

Low Elevation (Ch. 2+300)			
Depth (mm)	***Moisture Content***	***OMC***	***Ratio (MC/OMC)***
150	1.0	7	0.14
300	5.6	7.4	0.76
450	6.9	10.9	0.63
Intermediate Elevation (Ch. 2+100)			
150	7.1	11.2	0.63
300	12.1	18.5	0.65
450	13.0	9.4	1.38
High Elevation (Ch. 1+500)			
150	9.5	10.7	0.89
300	14.5	15.6	0.93
450	15.7	18	0.87

F: LABORATORY DCP TEST SAMPLES

F1: 6 Samples compacted at OMC and Sealed

All Samples prepared and sealed

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

All Samples prepared and sealed

F3: 6 Samples Compacted at OMC then soaked for 4 days

All Samples prepared and sealed

G: GRAVEL CLASSIFICATION TESTS

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

Gradation

BS Sieve	% Passing
25.40	100
19.05	97
12.70	87.7
9.50	73.5
6.35	54.3
4.76	44.1
2.40	28.6
1.20	26.5
600µm	25.3
400µm	24.8
300µm	24.3
150µm	22.5
75µm	20.3

Atterberg Limits

LL=46
PL=25.5
PI=20.5

Compaction Test

MDD=2.217Mg/m3
OMC=7.2%

H: TRAFFIC COUNT

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

Annex 4: Presentations

AfCAP Cardno

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

2

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 thro' research carried out over past 20 -30 years
  - question much of the accepted paradigms on LVSR provision and show quite clearly the need to revise conventional approaches.
- New, more appropriate, approaches to the provision of low-volume roads are now required if Ghana is to improve road transport efficiency and attain its broader goals of socio-economic growth, development and poverty alleviation.

3

Traditional Approaches to LVR Provision

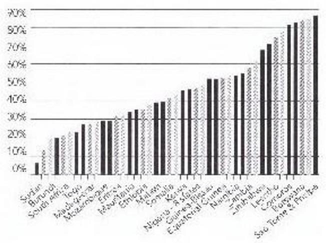
"The body of highway engineering knowledge remains empiric rather than rigorously scientific. So, the knowledge taught in our [UK, USA] universities is generally derived from a synthesis of local (UK, USA) experience. No wonder it is often irrelevant and sometimes downright misleading in other parts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

Ray Millard, Highways Advisor, World Bank. 2nd Int. Conf. on Low-volume Roads, 1979.

The Stark Facts

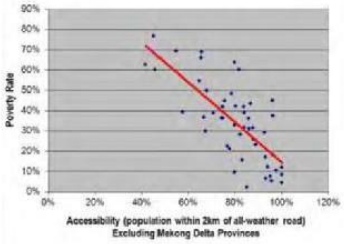
- Majority of rural roads are unsurfaced and carry relatively lightly traffic.
- They impact significantly on the livelihoods of the majority of the population of many countries in the region, who live and work in rural areas where poverty levels are generally very high
- They are central to sustained socio-economic growth and development of the region and are a key component of development programmes targeted by donors and governments in which poverty reduction strategies feature
- 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

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

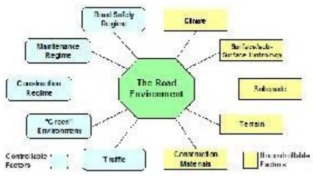
9

Typical Types of Low Volume Roads

Design Philosophy

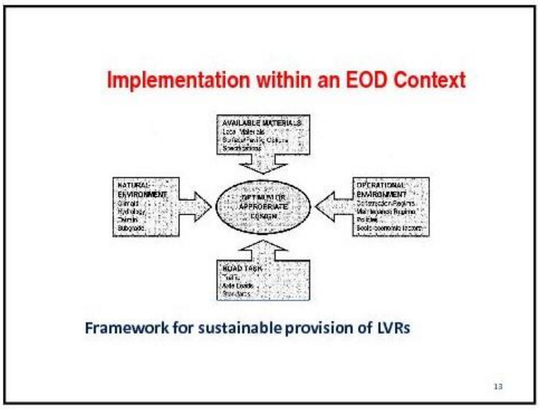
- Full understanding by the design engineer of the local environment (natural and social).
- Ability to work within the demands of the local environment and to turn these to a design advantage.
- Recognition and management of risk.
- Innovative and flexible thinking through application of appropriate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

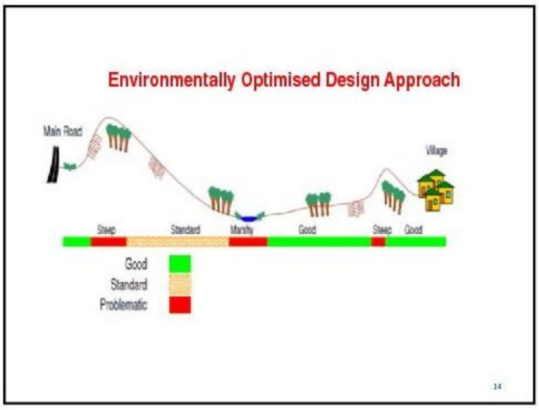
Road Environment Factors



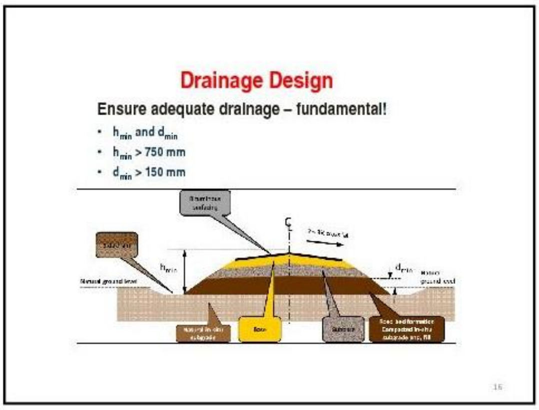
Framework for sustainable provision of LVRs

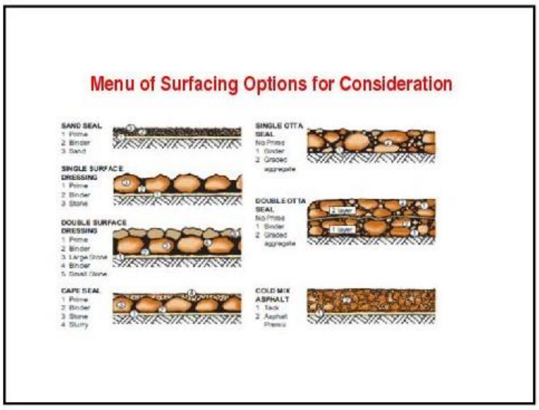
12

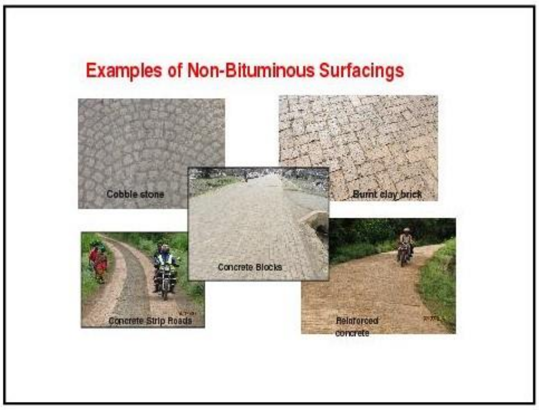

Implementation within an EOD Context
AVAILABLE MATERIALS
NATURAL ENVIRONMENT
OPTIMUM OR APPROPRIATE DESIGN
OPERATIONAL ENVIRONMENT
ROAD TASK
Framework for sustainable provision of LVRs
13


Environmentally Optimised Design Approach
Main Road
Village
Steep
Standard
Marshy
Good
Steep
Good
Good
Standard
Problematic
14


Use of Local Materials
Need to make specifications fit the materials rather than materials fit the specifications. In other words – "what appropriate road can I build with these materials" rather than "Where can I find materials to meet these general specs".
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.
15


Drainage Design
Ensure adequate drainage – fundamental!
h_{min} and d_{min}
h_{min} > 750 mm
d_{min} > 150 mm
16


Menu of Surfacing Options for Consideration
SAND SEAL
SINGLE SURFACE DRESSING
DOUBLE SURFACE DRESSING
CAPE SEAL
SINGLE OTTA SEAL
DOUBLE OTTA SEAL
COLD MIX ASPHALT


Examples of Non-Bituminous Surfacings
Cobble stone
Burnt clay brick
Concrete Blocks
Concrete Strip Roads
Reinforced concrete

Geometric Design

Option A.

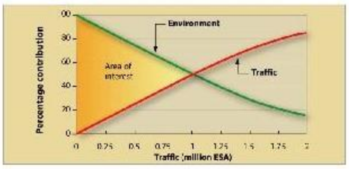
- Alignment engineered for fulfilling an <u>*access*</u> function
- *Existing alignment will fix the travel speed.*
- Accepts alignment generally as is, except at potentially problematic sections where traffic safety may be an issue for which specifically engineered measures provided
- Adoption will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

Option B

- Alignment engineered for fulfilling *a <u>mobility</u>* 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.

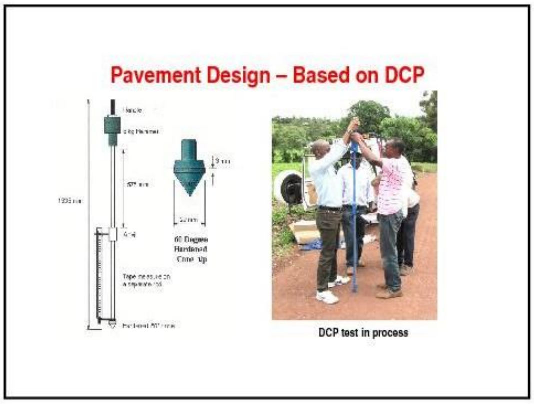
19

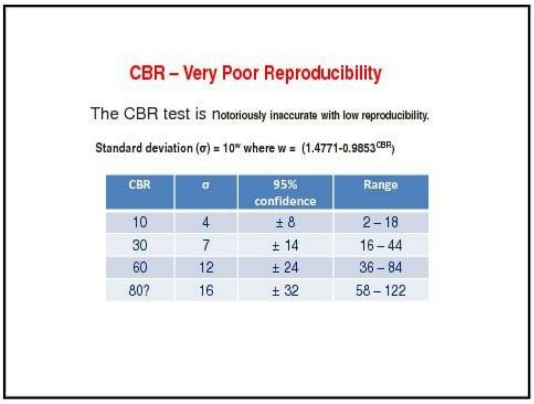
Dominant Mode of Deterioration



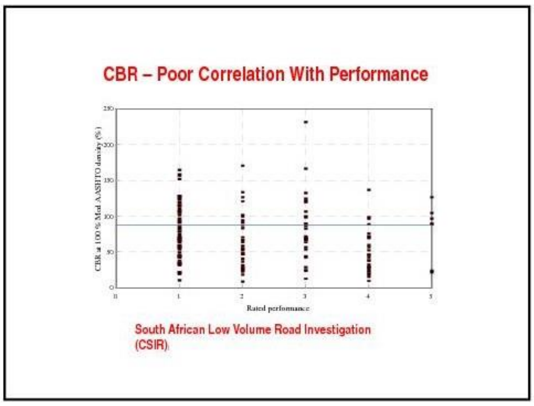
Deterioration of a LVR is driven primarily by environmental factors, with traffic being a lesser factor in deterioration

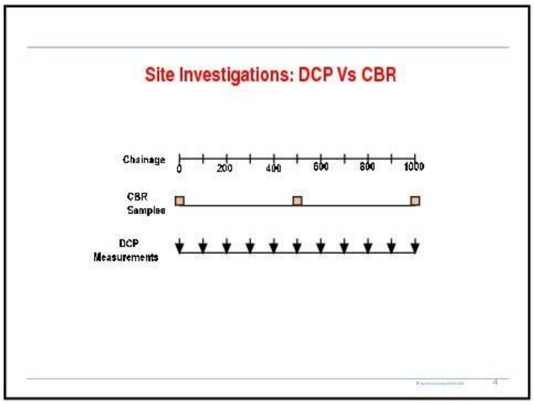
20

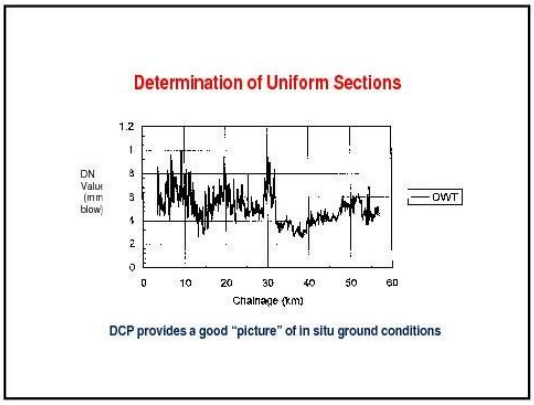


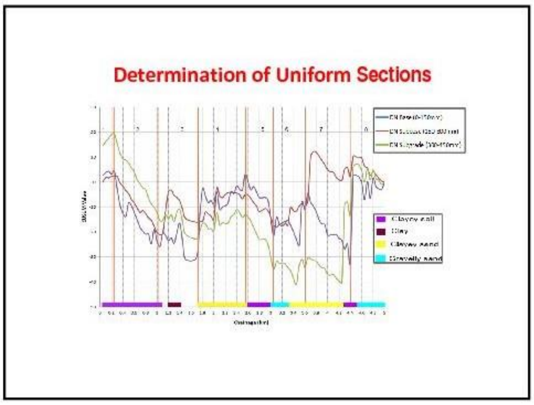


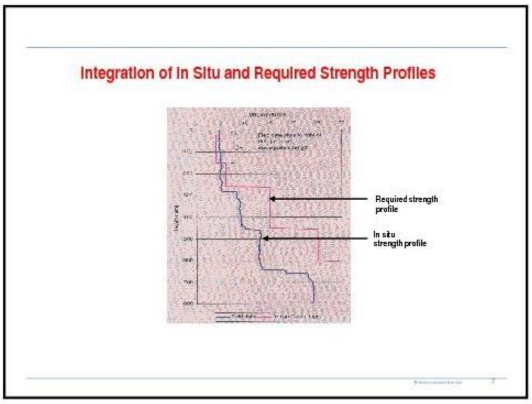
CBR	σ	95% confidence	Range
10	4	± 8	2 – 18
30	7	± 14	16 – 44
60	12	± 24	36 – 84
80?	16	± 32	58 – 122

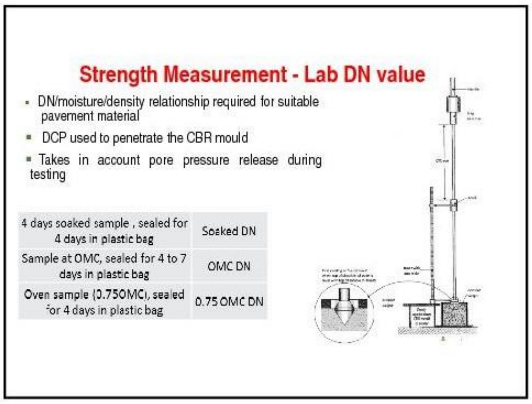


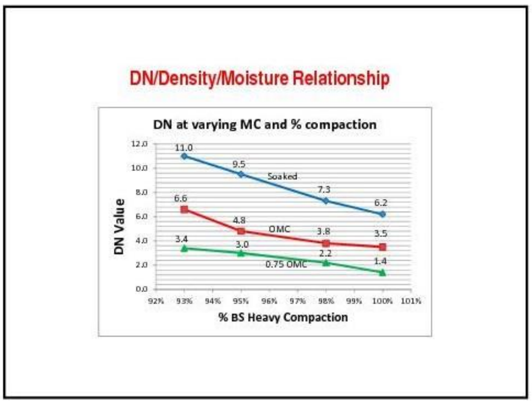


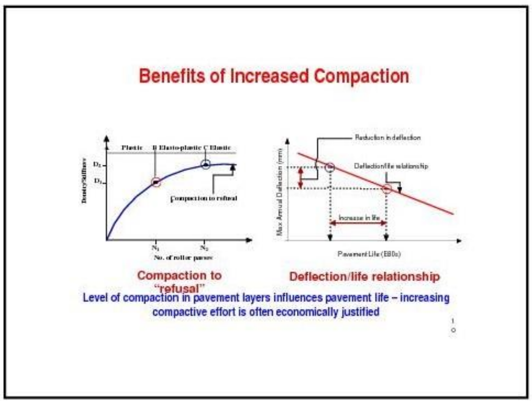




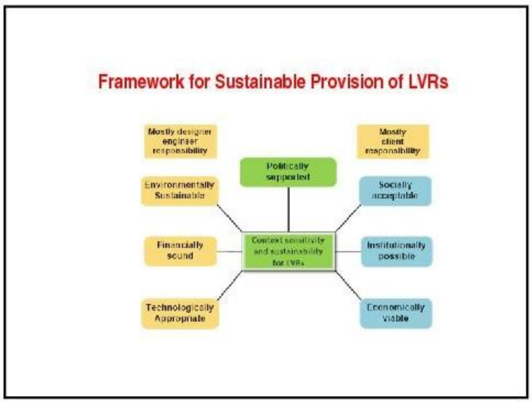

Integration of In Situ and Required Strength Profiles
Required strength profile
In situ strength profile

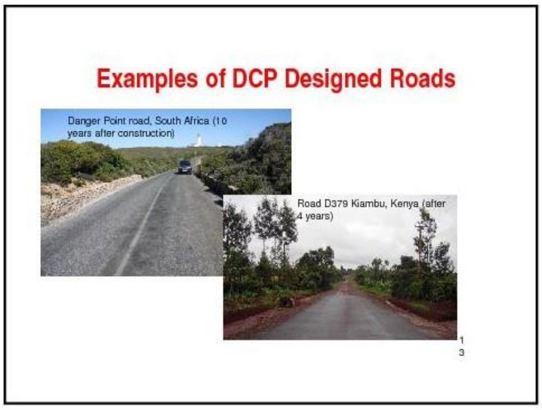

Strength Measurement - Lab DN value
DN/moisture/density relationship required for suitable pavement material
DCP used to penetrate the CBR mould
Takes in account pore pressure release during testing
4 days soaked sample , sealed for 4 days in plastic bag
Soaked DN
Sample at OMC, sealed for 4 to 7 days in plastic bag
OMC DN
Oven sample (0.75OMC), sealed for 4 days in plastic bag
0.75 OMC DN


DN/Density/Moisture Relationship
DN at varying MC and % compaction
DN Value
% BS Heavy Compaction
Soaked
OMC
0.75 OMC
11.0
9.5
7.3
6.2
6.6
4.8
3.8
3.5
3.4
3.0
2.2
1.4

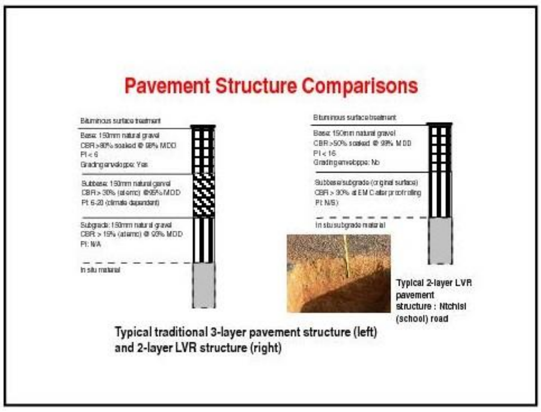

Benefits of Increased Compaction
Compaction to "refusal"
Deflection/life relationship
Level of compaction in pavement layers influences pavement life – increasing compactive effort is often economically justified

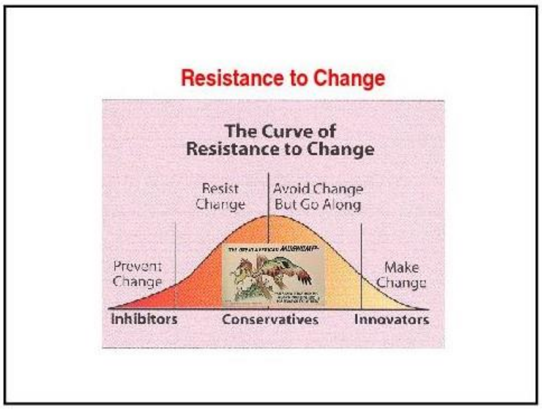

Appreciation of Risk Factors
Five main risks:
Drainage
Material quality
Construction control
Maintenance
Traffic (overloading)
Relax ONE and keep control of others. Risk increases BUT probably acceptable
Relax TWO and risk possible failure

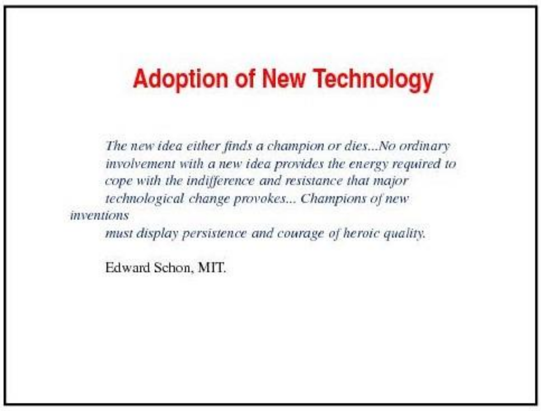

Framework for Sustainable Provision of LVRs
Mostly designer engineer responsibility
Mostly client responsibility
Politically supported
Environmentally Sustainable
Socially acceptable
Financially sound
Context sensitivity and sustainability for LVRs
Institutionally possible
Technologically Appropriate
Economically viable


Examples of DCP Designed Roads
Danger Point road, South Africa (10 years after construction)
Road D379 Kiambu, Kenya (after 4 years)
13


Benefits of Adopting New Approaches
Application of locally derived appropriate technology
Reduced life cycle costs of LVSR provision
Facilitating socio-economic growth and development and poverty alleviation
LVR construction
Standard construction
$150,000/km
$300,000/km
Malawi experience


Pavement Structure Comparisons
Bituminous surface treatment
Base: 150mm natural gravel
CBR >80% soaked @ 98% MDD
PI < 6
Grading envelope: Yes
Subbase: 150mm natural gravel
CBR > 30% (at emc) @95% MDD
PI 6-20 (climate dependent)
Subgrade: 150mm natural gravel
CBR > 15% (at emc) @ 93% MDD
PI: N/A
In situ material
Bituminous surface treatment
Base: 150mm natural gravel
CBR >50% soaked @ 98% MDD
PI < 16
Grading envelope: No
Subbase/subgrade (original surface)
CBR > 30% at EMC after proof rolling
PI: N/S
In situ subgrade material
Typical 2-layer LVR pavement structure : Ntchisi (school) road
Typical traditional 3-layer pavement structure (left) and 2-layer LVR structure (right)


Resistance to Change
The Curve of Resistance to Change
Resist Change
Avoid Change But Go Along
Prevent Change
Make Change
Inhibitors
Conservatives
Innovators


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 indifference and resistance that major technological change provokes... Champions of new inventions must display persistence and courage of heroic quality.
Edward Schon, MIT.


Thank You

Materials investigation and choice of suitable road Materials

CENTRE LINE TEST PITTING

•Materials testing requirements

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

CENTRE LINE TEST PITTING

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

BORROWPIT TEST PITTING

•Materials testing requirements

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

BORROWPIT TEST PITTING

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

TEST PIT

•Example of test pits

TEST PIT

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

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

7

FIELD MOISTURE CONTENT (FMC) COLLECTION

- Collection of FMC using Auger

8

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, transported soil

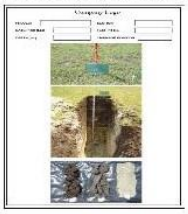
9

SPECIFICATIONS FOR PROFILING

- Special notes on the log sheet
  - Depth at 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

10

SPECIFICATIONS FOR PROFILING



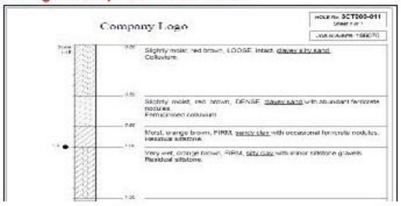
11

TYPICAL PROFILING

12

TYPICAL PROFILING

•Profiling description and details



13

TYPICAL PROFILING

•Profiling description and details

14

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

15

TESTING & RESULTS PRESENTATION

•Presentation of Results

- Centre line material results

Test Pit No	Sample depth (mm)	PI (%)	GM	MDD	OMC	FMC	FMC/OMC ratio
TP1	0.0- 200	6.7	2.58	2098	7.5	3	40%
TP1	200- 650	15	2.69	1929	12	11	92%
TP1	650 -900	5	2.45	2155	5	4	80%
TP2	0.0 - 150	NP	2.57	2059	8.2	5	63%
TP2	150- 1400	NP	2.70	1983	8.8	6	68%

GM = cumulative percentages by mass of material retained on the 2,00 mm, 0,425 mm and 0,075 mm sieves, divided by 100

16

TESTING & RESULTS PRESENTATION

•Presentation of Results

- Borrowpit material results

Test Pit No	Sample depth (mm)	material description	PI (%)		GM		MDD		OMC	
			per pit	average	per pit	average	per pit	average	per pit	average
BP1-TP1	700 - 1500	weathered granite	17	16	2.78	2.77	2053	2081	10.4	9.7
BP1-TP2	100 -700	weathered granite	14		2.78		2089		9.9	
BP1-TP3	300 -1500	weathered granite	13		2.79		2077		11.2	
BP1-TP4	150 - 1500	weathered granite	17		2.77		2088		9.3	
BP1-TP5	200 -1000	weathered granite	16		2.75		2101		8.5	
BP1-TP6	300 -1750	weathered granite	19		2.79		2079		8.4	

17

Annex 5: Course Evaluation

Course Evaluation - Group 1 (17 Participants)	Number of forms filled in 17	Scores						
		1	**2**	**3**	**4**	**5**	Blank	W.A.
1. Training	Average score	1,90						
The objectives of the course were generally achieved		**7**	**10**	**0**	0		0	1,59
The classroom presentations were well presented and understood		4	11	2			0	1,88
I have now got a good understanding of the characteristics of Low Volume Roads		**4**	**11**	**2**			0	1,88
I have now got a good understanding of the design principles for Low Volume Roads		**6**	**10**		**1**		0	1,76
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		**3**	**10**	**4**			0	2,06
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		**7**	**8**	**2**			0	1,71
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results		**5**	**7**	**4**			1	1,94
There was enough time for practical exercises using the software and discussions / clarifications		**3**	**11**	**3**			0	2,00
I have got a good understanding of the pavement balance concept and how to use this for defining User Defined Design curves		**2**	**7**	**6**	1		1	2,38
The practical instructions were well delivered and understood		**6**	**7**	**3**			1	1,81
2. Organisation	Average score	1,77						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training		**8**	**7**	**1**	**1**		0	1,71
Arrangements for accommodation during the course was satisfactory		**13**	**3**				1	1,19
I was given satisfactory support from my employer/organization for participation in the course		**4**	**8**		**3**	**1**	1	2,31
The course was well organized		**6**	**7**	**4**			0	1,88
3. Venue	Average score	1,69						
The classroom facilities were satisfactory		**10**	**6**	**1**			0	1,47
The practical training site was well organized		**5**	**9**	**3**			0	1,88
The meals and refreshments were satisfactory		**7**	**9**		**1**		0	1,71

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

Course Evaluation - Group 2 (12 Participants)	Number of forms filled in	Scores						
	12	**1**	**2**	**3**	**4**	**5**	Blank	W.A.
1. Training	Average score	1,71						
The objectives of the course were generally achieved		**5**	**7**				0	1,58
The classroom presentations were well presented and understood		6	6				0	1,50
I have now got a good understanding of the characteristics of Low Volume Roads		**4**	**8**				0	1,67
I have now got a good understanding of the design principles for Low Volume Roads		**3**	**8**	**1**			0	1,83
I have now got a good understanding of the strengths and limitations of the DCP-DN Design Method		**3**	**6**	**2**			1	1,91
I have now got a good understanding of the design process for Low Volume Roads using the AfCAAP LVR-DCP software		**5**	**7**				0	1,58
I have got a good understanding of the Laboratory DN testing procedure and how to interpret the results		**1**	**8**	**2**			1	2,09
There was enough time for practical exercises using the software and discussions / clarifications		**8**	**4**				0	1,33
I have got a good understanding of the pavement balance concept and how to use this for defining User Defined Design curves		**3**	**6**	**3**			0	2,00
The practical instructions were well delivered and understood		**6**	**5**	**1**			0	1,58
2. Organisation	Average score	1,76						
I was informed about the course in time for me to organize my personal arrangements for travel to and participation in the training		**4**	**6**	**2**			0	1,83
Arrangements for accommodation during the course was satisfactory		**4**	**6**	**1**			1	1,73
I was given satisfactory support from my employer/organization for participation in the course		**5**	**3**	**3**			1	1,82
The course was well organized		**5**	**6**	**1**			0	1,67
3. Venue	Average score	2,08						
The classroom facilities were satisfactory		**4**	**6**	**2**			0	1,83
The practical training site was well organized		**2**	**6**	**4**			0	2,17
The meals and refreshments were satisfactory		**2**	**6**	**3**	**1**		0	2,25

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

Annex 6: List of participants

FIRST GROUP

NAME	DESIGNATION	ORGANISATION	NATIONALITY	EMAIL ADDRESS
1. Dr. Patrick Amoah Bekoe	Civil Engineer	DFR	Ghanaian	pabekoe@gmail.com
2. Koranteng Justice	Civil Engineer	DFR	Ghanaian	just2uu@yahoo.com
3. Gregory Amissah	Civil Engineer	DFR	Ghanaian	gregoryamissah@yahoo.com
4. Albert Martey	Civil Engineer	DFR	Ghanaian	mazose2000@yahoo.com
5. C. Elorm Nyoagbe	Civil Engineer	DFR	Ghanaian	elormnyoagbe@gmail.com
6. Abdul –Gafaru Amidu	Civil Engineer	DUR	Ghanaian	amidbullaabdulgafaru@yahoo.com
7. Abdul Nasser Fofanah	Civil Engineer	DFR/SLRA	Sierra Leonean	jamalystic@yahoo.com
8. Tesslime Shyllon	Civil Engineer	DFR/SLRA	Sierra Leonean	shyllontesslime@gmail.com
9. Bai Maro Kamara	Civil Engineer	DFR/SLRA	Sierra Leonean	baimarokombor88@gmail.com
10. Samuel J. Macauley	Civil Engineer	DFR/SLRA	Sierra Leonean	Sammacauley2005@gmail.com
11. Tamba K. Amara	Chief Engineer	DFR/SLRA	Sierra Leonean	tmannamara2003@gmail.com
12. Francis Gambrah	Civil Engineer	DUR	Ghanaian	frangam2002@yahoo.com
13. Kwaku Asibe Osei	Civil Engineer	GHA	Ghanaian	okansah1@gmail.com
14. Albert Osae Annan	Civil Engineer	GHA	Ghanaian	malaicah33@gmail.com
15. Emmanuel Kwesi Rockson	Snr. Engineer	GHA	Ghanaian	ekrockson@hotmail.co.uk
16. Ernest k. Obeng	Mech. Engineer	KTC	Ghanaian	ernobeng2002@yahoo.com
17. Opoku Adusei Emmanuel	Civil Engineer	KTC	Ghanaian	eopokuadusei@gmail.com

SECOND GROUP

NAME	DESIGNATION	ORGANISATION	NATIONALITY	EMAIL ADDRESS
18. Prosper Gladxah Foli		DFR, Tamale	Ghanaian	Kofi62gladzah@gmail.com
19. Meredith Kuunyem		DFR	Ghanaian	Mello2uu@gmail.com
20. Michael Orleans Fransisco Ribeiro		KTC, Koforidua	Ghanaian	kwodwogh@gmail.com
21. Roland Osel-Akoto Offeh		DFR, Koforidua	Ghanaian	ronoseiakoto@gmail.com
22. Kwame Boating Amoako		DFR, Kumasi	Ghanaian	excelgh@gmail.com
23. E. A. Gbadago		MRH, Accra	Ghanaian	unifamenyo@rockmail.com
24. Abraham Quansah		GHA, Accra	Ghanaian	Abraham_qnsh@yahoo.com
25. Bathemel Ansah Appiah		DFR HQ	Ghanaian	bathemel@yahoo.com
26. Rilys A. Agyemang		GHA, Accra	Ghanaian	rilysagyemang@gmail.com
27. Samuel Sarfo		GHA, Accra	Ghanaian	Samsarf34@yahoo.com
28. Nancy Donkor		GHA, Accra	Ghanaian	nancy.donkor@gmail.com
29. Mesiwotso Kwame Zawor		GHA, Koforidua	Ghanaian	kzawor@yahoo.com

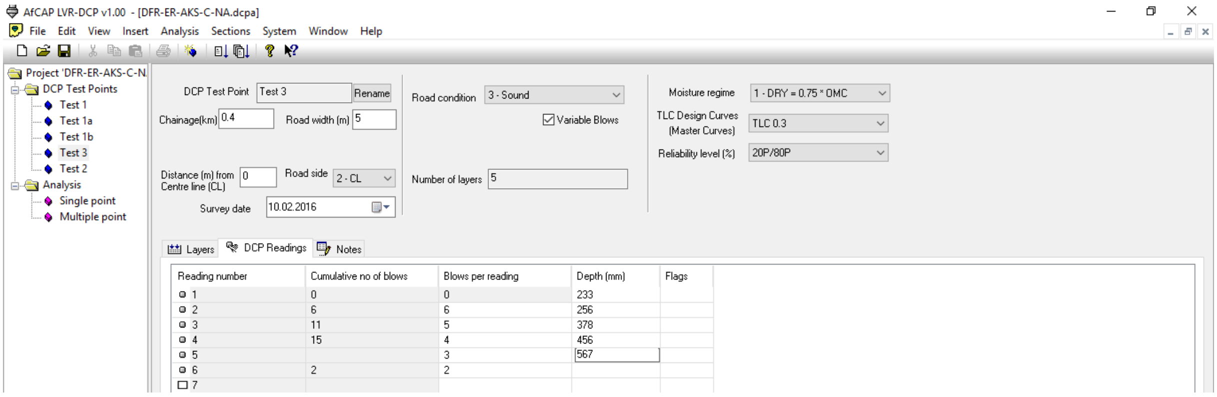
Annex 7: Roads 2000 – Central Province, Kenya

Low Volume Sealed Roads:

- Mix construction approach
  - Improved subgrade formation – Machine based
  - 100 mm Base, Cold Mix Asphalt surfacing, drainage works – Labour based
- Total sealed width: 7.0 m (incl. shoulders)
- Cost / km: 200-250,000 USD/km
- Casual Labour wage: approx. 4 USD/day
- Labour cost: About 10% or 20-25,000 USD/km
- Employment creation: About 5,000 workerdays/km

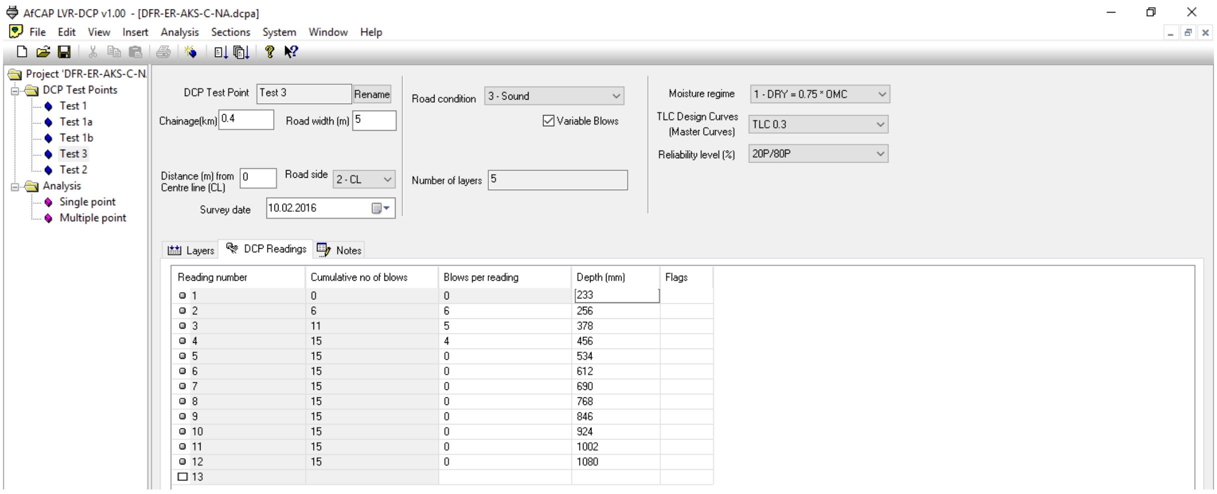
Annex 8: Summary of findings in AfCAP LVR-DCP v1.0 and proposals for improvements

1. DCP data entry screen for Variable Blows option

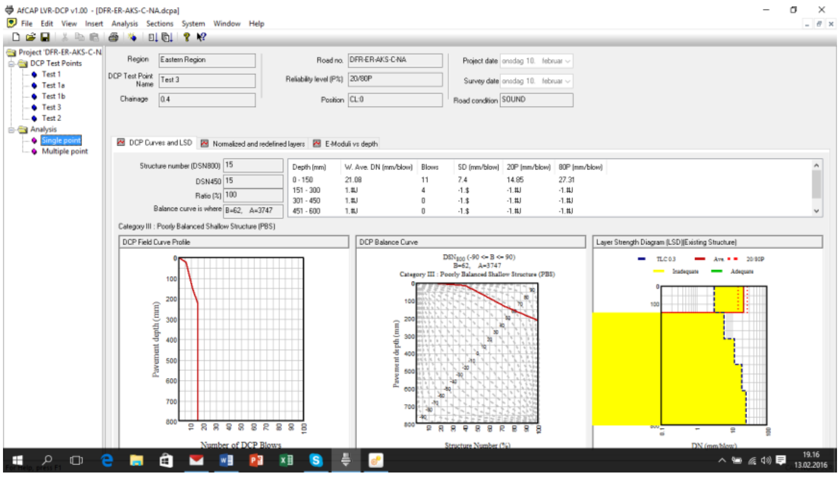


a. Using TAB instead of Enter after entering Depth 456 moved the cursor on step down to the next Depth cell instead of down and to the left to the next Blows per Reading.
b. Then, using left arrow to enter 3 Blows per reading, then Enter to type 567, then Enter again to type 2 Blows per reading, the Cumulative Blows are not added up (the cell is left empty as shown on the screenshot.
c. Likewise, when using Tab after entering Blows per reading, the curser moves down to the next Blows per reading causing the same problem.
d. To correct the error and get correct Cumulative no of Blows, all entries after Reading number 4 must be deleted, then start data entry again from Reading 5.
e. To guard against this potential problem, the Tab and Enter key should be programmed (which I assume can be done) to function in exactly the same manner during data entry.

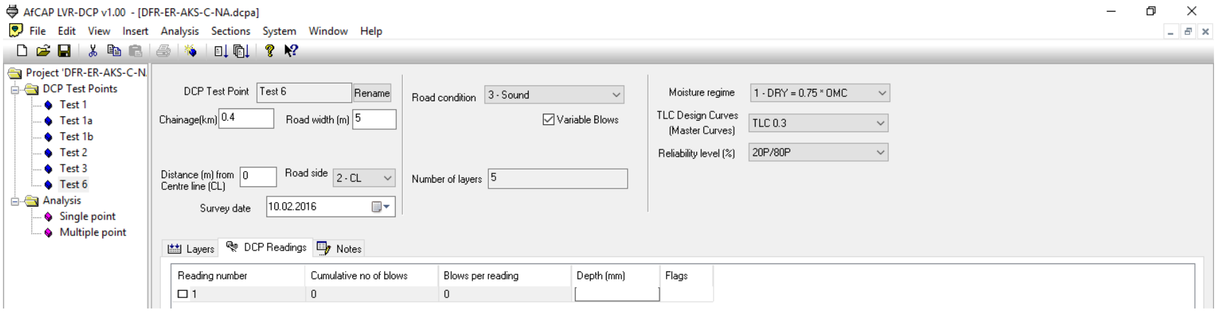
2. Automatic extrapolation function for Variable Blows option



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

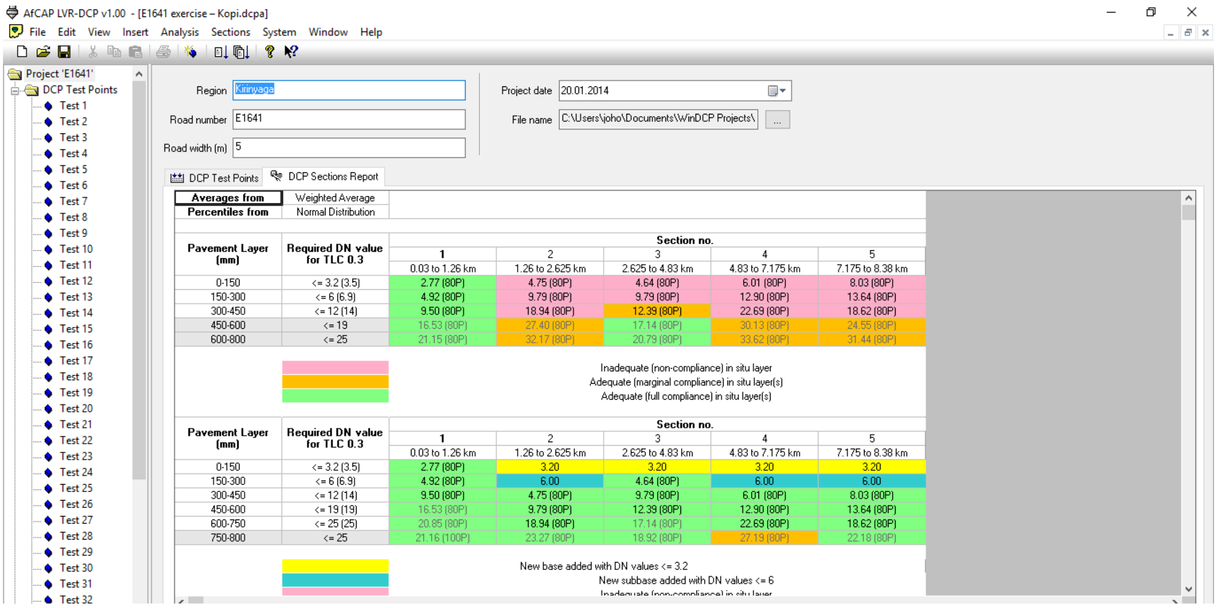


3. Numbering of Test points



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

4. DCP Section Report



Pavement Layer (mm)	Required DN value for TLC 0.3	Section no. 1 0.03 to 1.26 km	2 1.26 to 2.625 km	3 2.625 to 4.83 km	4 4.83 to 7.175 km	5 7.175 to 8.38 km
0-150	<= 3.2 (3.5)	2.77 (80P)	4.75 (80P)	4.64 (80P)	6.01 (80P)	8.03 (80P)
150-300	<= 6 (6.9)	4.92 (80P)	9.79 (80P)	9.79 (80P)	12.90 (80P)	13.64 (80P)
300-450	<= 12 (14)	9.50 (80P)	18.94 (80P)	12.39 (80P)	22.69 (80P)	18.62 (80P)
450-600	<= 19	16.53 (80P)	27.40 (80P)	17.14 (80P)	30.13 (80P)	24.55 (80P)
600-800	<= 25	21.15 (80P)	32.17 (80P)	20.79 (80P)	33.62 (80P)	31.44 (80P)

Pavement Layer (mm)	Required DN value for TLC 0.3	Section no. 1 0.03 to 1.26 km	2 1.26 to 2.625 km	3 2.625 to 4.83 km	4 4.83 to 7.175 km	5 7.175 to 8.38 km
0-150	<= 3.2 (3.5)	2.77 (80P)	3.20	3.20	3.20	3.20
150-300	<= 6 (6.9)	4.92 (80P)	6.00	4.64 (80P)	6.00	6.00
300-450	<= 12 (14)	9.50 (80P)	4.75 (80P)	9.79 (80P)	6.01 (80P)	8.03 (80P)
450-600	<= 19 (19)	16.53 (80P)	9.79 (80P)	12.39 (80P)	12.90 (80P)	13.64 (80P)
600-750	<= 25 (25)	20.85 (80P)	18.94 (80P)	17.14 (80P)	22.69 (80P)	18.62 (80P)
750-800	<= 25	21.16 (100P)	23.27 (80P)	18.92 (80P)	27.19 (80P)	22.18 (80P)

a. The first table with "as is" values is ok except for faint type faces in the two bottom rows. All Section numbers could also be either bold or normal.
b. All legend text for both tables should be left aligned in column under Section 1. Suggest additional text as shown below for the amber legend text.

c. In the second "design" table, the last layer has been split in two, i.e. 650-750 and 750-800, unknown for what reason. Probably just a remnant in the programming from trials with different layer thicknesses
d. Programming errors resulting in unnecessary New Subbase for section 2 and 4. Correct design (in excel) shown below:

Averages from	Weighted Average
Percentiles from	Normal Distribution

Pavement Layer (mm)	**Required DN value for TLC 0.3**	**Section no.**				
		1	**2**	**3**	**4**	**5**
		0.03 to 1.26 km	**1.26 to 2.625 km**	**2.625 to 4.83 km**	**4.83 to 7.175 km**	**7.175 to 8.38 km**
0-150	<= 3.2 (3.5)	2.77 (80P)	4.75 (80P)	4.64 (80P)	6.01 (80P)	8.03 (80P)
150-300	<= 6 (6.9)	4.92 (80P)	9.79 (80P)	9.79 (80P)	12.90 (80P)	13.64 (80P)
300-450	<= 12 (14)	9.50 (80P)	18.94 (80P)	12.39 (80P)	22.69 (80P)	18.62 (80P)
450-600	<= 19	16.53 (80P)	27.40 (80P)	17.14 (80P)	30.13 (80P)	24.55 (80P)
600-800	<= 25	21.15 (80P)	32.17 (80P)	20.79 (80P)	33.62 (80P)	31.44 (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**	**5**
		0.03 to 1.26 km	**1.26 to 2.625 km**	**2.625 to 4.83 km**	**4.83 to 7.175 km**	**7.175 to 8.38 km**
0-150	<= 3.2 (3.5)	2.77 (80P)	3.20	3.20	3.20	3.20
150-300	<= 6 (6.9)	4.92 (80P)	4.75 (80P)	4.64 (80P)	6.01 (80P)	6.00
300-450	<= 12 (14)	9.50 (80P)	9.79 (80P)	9.79 (80P)	12.90 (80P)	8.03 (80P)
450-600	<= 19 (19)	16.53 (80P)	18.94 (80P)	12.39 (80P)	22.69 (80P)	13.64 (80P)
600-800	<= 25 (25)	21.15 (80P)	27.40 (80P)	17.14 (80P)	30.13 (80P)	18.62 (80P)

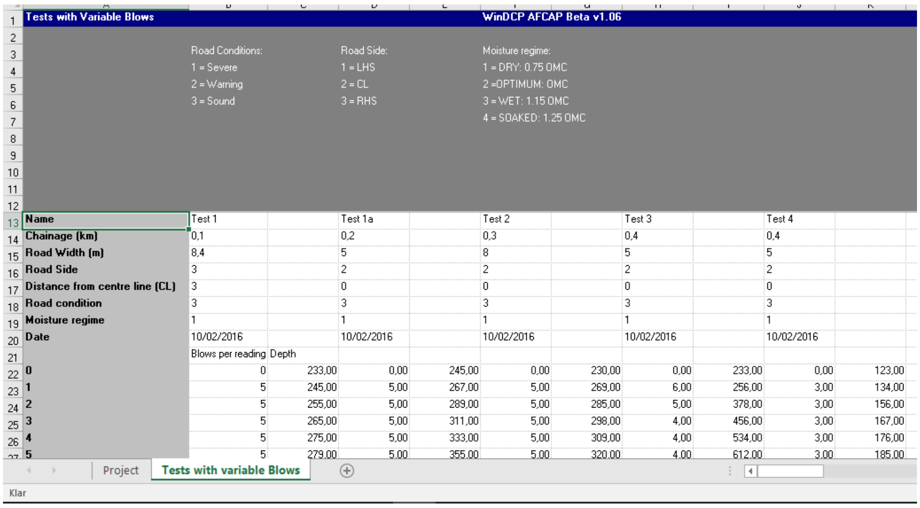
New base added with DN values <= 3.2
New subbase added with DN values <= 6
Inadequate (non-compliance) in situ layer
Adequate (marginal compliance) in situ layer(s) that need to be improved
Adequate (full compliance) in situ layer(s)

e. DN values should be rounded off to max one decimal. Suggest also that DN values ≥ 10 are rounded off to zero decimals. The programme should use the displayed one or zero decimal value for assignment of colours to avoid, say, 6.0 being coloured amber when the actual value in the cell is 6.01xxx (see Section 4 above)
f. This raises the question whether the DCP Section Report should only show the "as is" table and leave the user to do the final design in Excel, which has now become easy with the "save as excel" option. Automating this last step may cause the users to accept the programme design as shown for Section 4, without thinking how they can improve is situ layers, e.g. by drainage improvements, and avoid import of material, in this case for new subbase.
g. Another option could be to present only the "as is" table first, then ask the user to identify sections and layers that need improvement, e.g. by import of new layer(s) or improvement using a coding system. On the basis of these user inputs would the final design table be presented. This would force the user to think through the final design decisions in the same way they would do in Excel.

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

a. Export/Import is seemingly working fine both ways.
b. Decimal places in template for Blows per reading and Depth should be zero (default). See screenshot below.
c. Templates should be formatted as Forms only allowing entries in the specific cells and giving warnings if all required data are not entered before file is saved.

d. Road width should be taken out, both from the Templates and from the opening screen for creating a new project file, as the width can vary significantly along the road and width is to be recorded for each DCP Test Point.



Tests with Variable Blows WinDCP AFCAP Beta v1.06

Road Conditions: 1 = Severe 2 = Warning 3 = Sound

Road Side: 1 = LHS 2 = CL 3 = RHS

Moisture regime: 1 = DRY: 0.75 OMC 2 = OPTIMUM: OMC 3 = WET: 1.15 OMC 4 = SOAKED: 1.25 OMC

Name	Test 1		Test 1a		Test 2		Test 3		Test 4	
Chainage (km)	0,1		0,2		0,3		0,4		0,4	
Road Width (m)	8,4		5		8		5		5	
Road Side	3		2		2		2		2	
Distance from centre line (CL)	3		0		0		0		0	
Road condition	3		3		3		3		3	
Moisture regime	1		1		1		1		1	
Date	10/02/2016		10/02/2016		10/02/2016		10/02/2016		10/02/2016	
	Blows per reading	Depth								
0	0	233,00	0,00	245,00	0,00	230,00	0,00	233,00	0,00	123,00
1	5	245,00	5,00	267,00	5,00	269,00	6,00	256,00	3,00	134,00
2	5	255,00	5,00	289,00	5,00	285,00	5,00	378,00	3,00	156,00
3	5	265,00	5,00	311,00	5,00	298,00	4,00	456,00	3,00	167,00
4	5	275,00	5,00	333,00	5,00	309,00	4,00	534,00	3,00	176,00
5	5	279,00	5,00	355,00	5,00	320,00	4,00	612,00	3,00	185,00

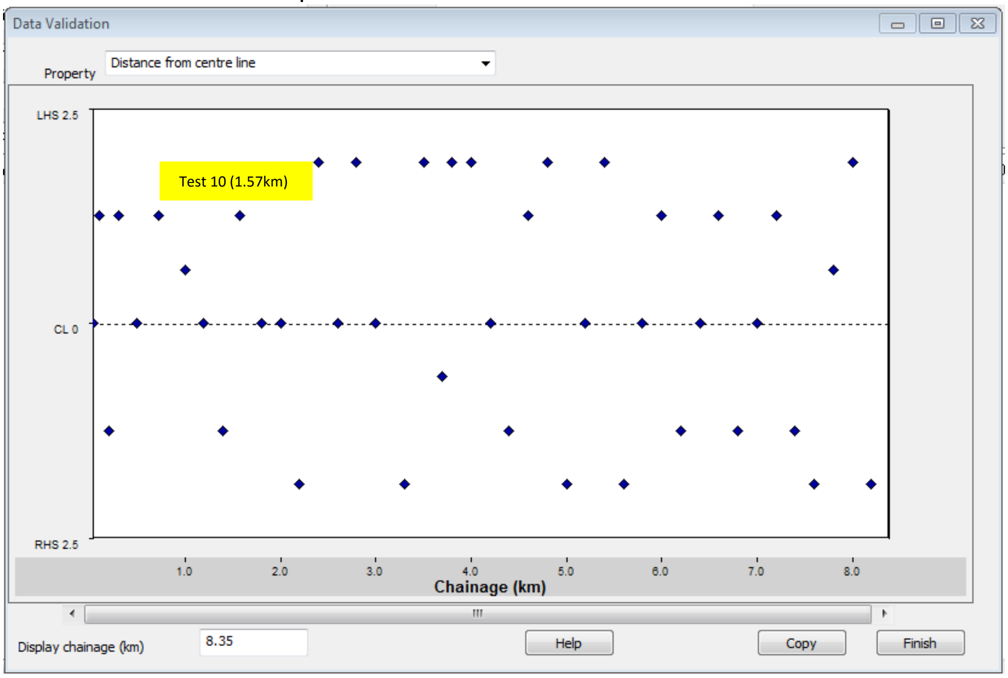
Project | Tests with variable Blows

Klar

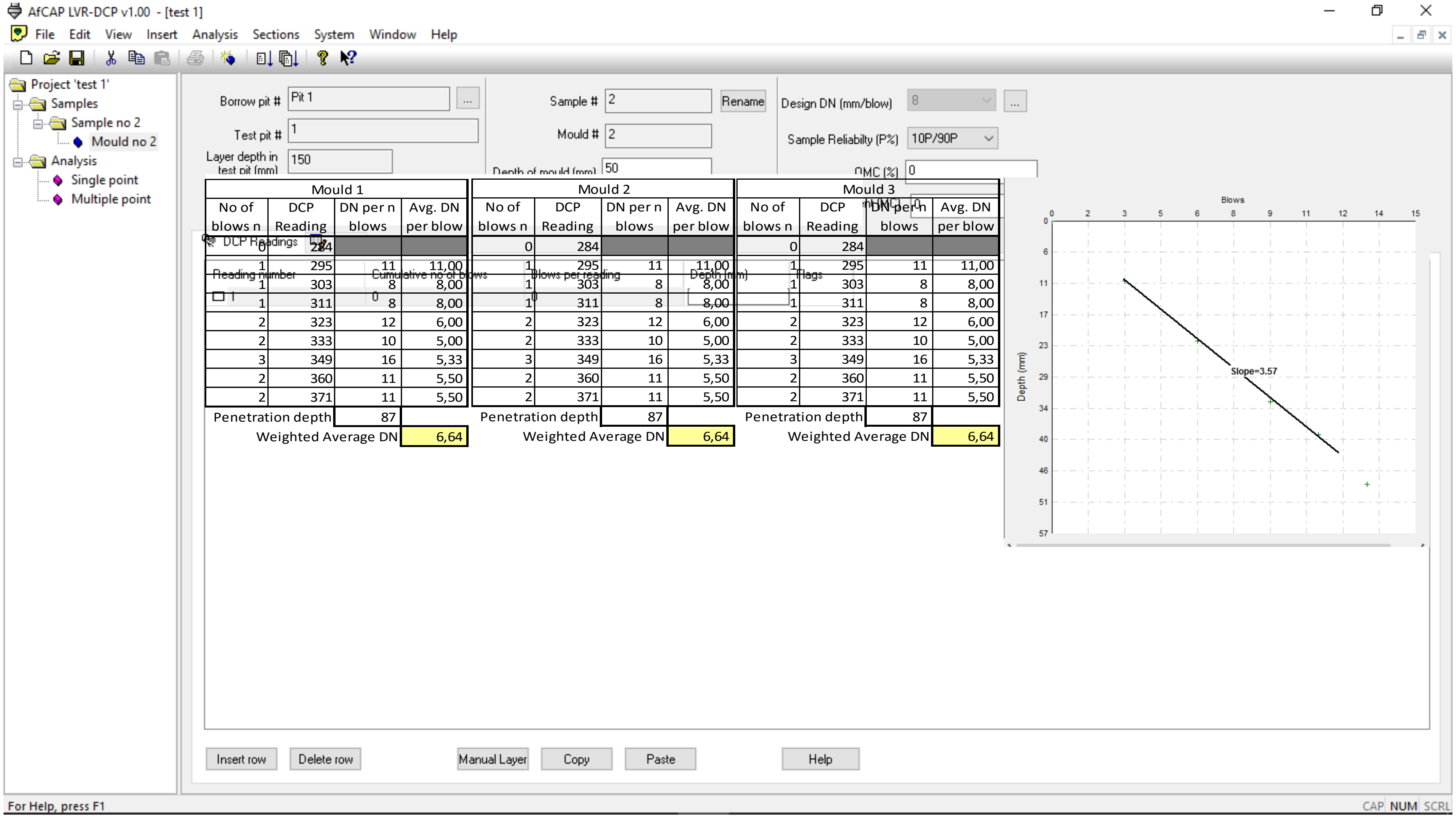
6. Data validation

It was suggested by some of the trainees to display the Test no and Chainage on the screen as shown.

Possible, but not recommended as it would make the screen too cluttered. Test No and Chainage is displayed when cursor hovers on point.



7. Proposed layout for Lab DN data entry screen



Mould 1				Mould 2				Mould 3			
No of blows n	DCP Reading	DN per n blows	Avg. DN per blow	No of blows n	DCP Reading	DN per n blows	Avg. DN per blow	No of blows n	DCP Reading	DN per n blows	Avg. DN per blow
0	284			0	284			0	284		
1	295	11	11,00	1	295	11	11,00	1	295	11	11,00
1	303	8	8,00	1	303	8	8,00	1	303	8	8,00
1	311	8	8,00	1	311	8	8,00	1	311	8	8,00
2	323	12	6,00	2	323	12	6,00	2	323	12	6,00
2	333	10	5,00	2	333	10	5,00	2	333	10	5,00
3	349	16	5,33	3	349	16	5,33	3	349	16	5,33
2	360	11	5,50	2	360	11	5,50	2	360	11	5,50
2	371	11	5,50	2	371	11	5,50	2	371	11	5,50
Penetration depth		87		Penetration depth		87		Penetration depth		87	
Weighted Average DN			6,64	Weighted Average DN			6,64	Weighted Average DN			6,64

Notes to Lab DN data entry screen proposal:

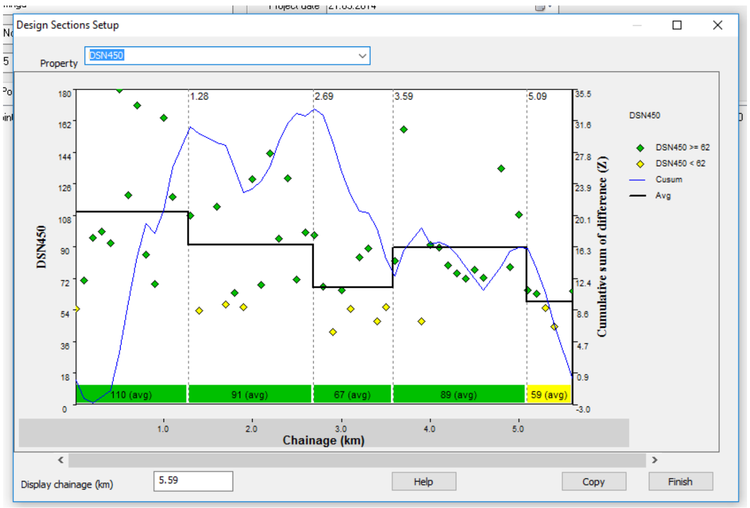
- Provision made for three tests from same sample. More lines to be added to fill the available space
- Curves automatically plotted in diagram to the right as tests are carried out. User to add "best fit" line for the three samples from the middle of the moulds to determine representative Lab DN for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

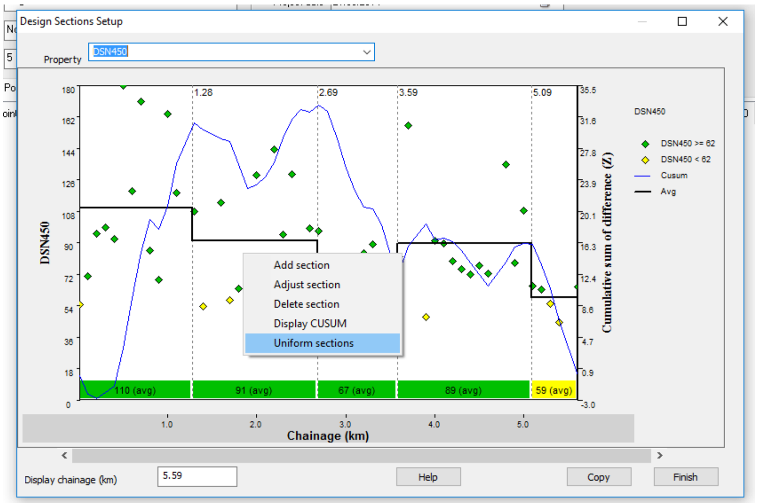
The current version of the Lab module suffers from the same shortcomings as described above for data entry and automatic extrapolation in the field module when using the "variable blows" option. For the Lab module the user must be able to stop the test before the tip hits the base plate without being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

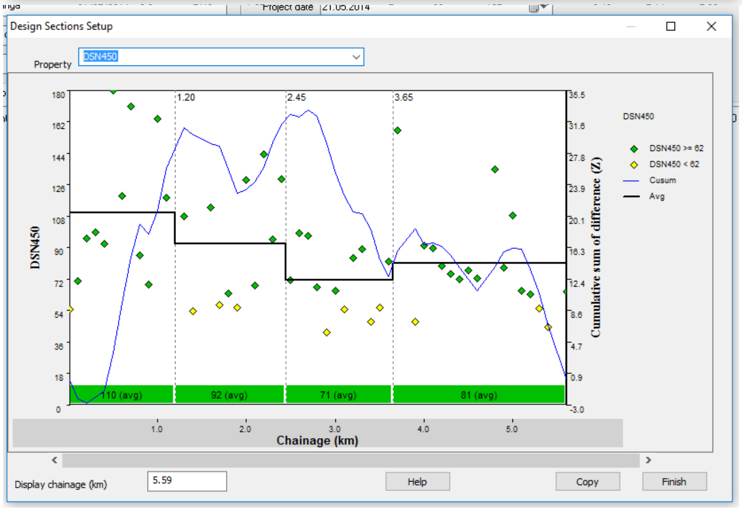
8. Determination of Sections from Properties

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

- Which algorithm is used for this automatic selection of Sections?
- Do we need it?



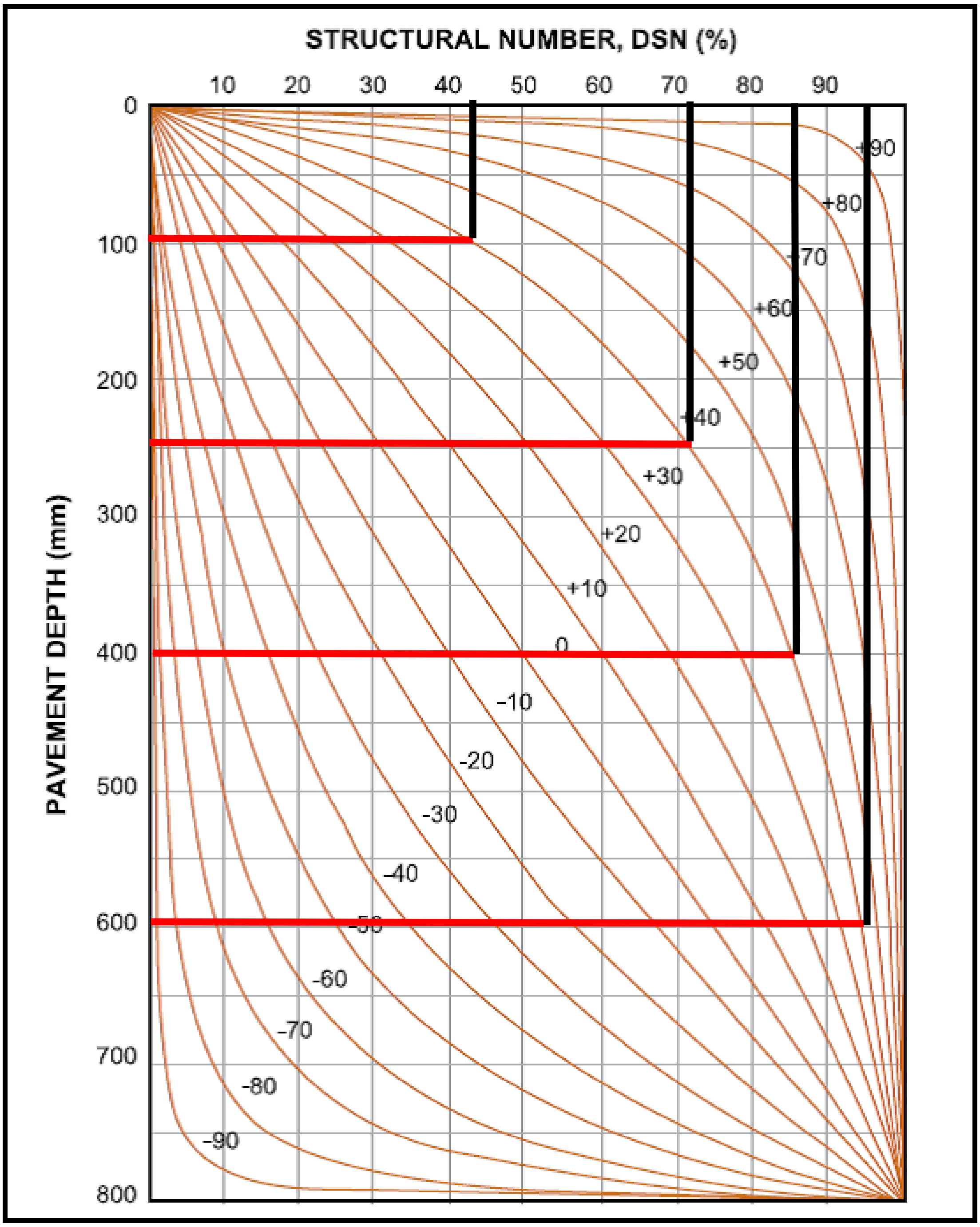




9. How to record for "layer removed"

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

10. Example of User Defined Design Curve (for User Manaul)



TLC 0.3: DSN800 ≥ 100 (from DCP-DN Catalogue)
SPBC B=40

New User Defined Design Curve

Layer 1: Base 100 mm	DSN 0-100 = 43%	DN ≤ 100/43 = 2.3 mm/blow
Layer 2: Subbase 150 mm	DSN 100-250 = 29%	DN ≤ 150/29 = 5.2 mm/blow
Layer 3: Subgrade 150mm	DSN 250-400 = 14%	DN ≤ 150/14 = 11 mm/blow
Layer 4: Subgrade 200 mm	DSN 400-600 = 9%	DN ≤ 200/9 = 22 mm/blow
Layer 5: Subgrade 200 mm	DSN 600-800 = 5%	DN ≤ 200/5 = 40 mm/blow