MINISTRY OF TRANSPORT VIETNAM

SOUTH EAST ASIA COMMUNITY ACCESS PROGRAMME

CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERIORATION

BUON HO ROAD

SEACAP 24

June 2008

UNPUBLISHED PROJECT REPORT

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BUON HO REPORT

Prepared for Project Record:	**SEACAP 24. CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERRIORATION**
Client:	**DfID, South East Asian Community Access Programme (SEACAP) for the Ministry of Transport, Vietnam**

	Approvals
Team Leader **Dr J Cook**	
Quality Reviewed **Dr J Rolt**	

CONTENTS

ABBREVIATIONS & ACRONYMS

ADT	Average Daily Traffic
ARRB	Australian Road Research Board
ASEAN	Association of South East Asian Nations
Bmb	Bamboo
BRC	Bamboo Reinforced Concrete
CAFEO	Conference of ASEAN Federation of Engineering Organisations
CBR	California Bearing Ratio
CSIR	Council for Scientific and Industrial Research (South Africa)
DBM	Dry Bound Macadam
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
DST	Department of Science and Technology, Ministry of Transport
EDCs	Economically emerging and Developing Countries
esa	equivalent standard axles
FHWA	Federal Highways Association (US)
FM	Fines Modulus
FWD	Falling Weight Deflectometer
GMSARN	Greater Mekong Subregion Academic and Research Network
HDM4	Highway Development and Management Model
HQ	Headquarters
IFG	International Focus Group
ILO	International Labour Organisation
IRI	International Roughness Index
ITST	Institute of Transport Science and Technology
Km	kilometre
LCS	Low Cost Surfacing
MERLIN	Machine for Evaluating Roughness using Low-cost INstrumentation
MoT	Ministry of Transport
OM	Operations Manual
PDoT	Provincial Department of Transport
PIARC	World Road Association
PMU	Project Management Unit
PPC	Provincial Peoples Committee
PPMU	Provincial Project Management Unit
QA	Quality Assurance
RITST	Research Institute of Transportation Science & Technology
RRGAP	Rural Road Gravel Assessment Programme
RRST	Rural Road Surfacing Trials
RTU	Rural Transport Unit
RT2	Rural Transport 2nd Project
SEACAP	South East Asia Community Access Programme
SOE	State Owned Enterprise
SRC	Steel Reinforced Concrete
TBM	Temporary Bench Mark
TEDI	Transport Engineering Design Incorporated
TG	Technical Guidelines
TRL	Transport Research Laboratory
VOCs	Vehicle Operating Costs
VPD	Vehicles per day
WAN	Wide Area Network
WBM	Water Bound Macadam
WLC	Whole Life Costs

EXECUTIVE SUMMARY

Shortly after its completion in 2006 the Buon Ho RRSR trial road in Dak Lak Province was reported to have suffered rapid deterioration on some sections. These trial sections of the Buon Ho road were designed with four different pavement options based on existing Commune Class A standards and the research guidelines developed for the RRSR programme.

It was reported by local sources that uncontrolled heavy vehicle traffic had started to use the Buon Ho trial road almost immediately after completion and that rapid deterioration of the pavement had then taken place and continued until, by late 2007, the condition had deteriorated to such an extent in some places that most of this traffic opted not to use the road.

An investigation contract was agreed between SEACAP/DfID and TRL Ltd and their Associates in September 2007 and a programme of field investigations undertaken which included desk studies; walkover surveys; inspection pits; in situ testing; laboratory testing and traffic analysis.

The investigation showed that Buon Ho road has suffered significant and rapid deterioration leading in places to complete pavement failure, but that the pavement condition is not uniform and there are significant lengths with only slight or moderate deterioration and other areas where no deterioration is evident. There is significant evidence to indicate that the trial road was, at least in part, constructed with materials that did not meet the specifications and, possibly, to variable compaction standards. The markedly different performance of sections of the same design but built by different contractors, further indicates that the quality of materials and the quality of construction probably significant factors.

Analysis of traffic patterns and the results from a specially commissioned axle load survey showed that in the first six to seven months since construction the Buon Ho road had most likely carried a traffic load of 250,000 esa. This is in contrast to the design value of 100,000 esa over a ten year design life. In addition, a significant numbers of vehicles were above the Commune A axle load limit of 6T.

The principal conclusions of this report are:

1. The pavement design was suitable for Commune road A traffic.
2. Some sections of the road were constructed with materials that were out-of-specification but even so the as-built condition was generally suitable for Commune road A traffic although some sections would have required periodic maintenance during a 10-year design life.
3. The original design and hence the as-built road were totally inadequate for the traffic it actually carried.
4. The primary cause of road failure was the excessive amount of traffic load that the road had carried within 6-7months of its completion, but that the rate of this deterioration was aided to some extent by marginal or poor construction in some sections.
5. It is recommended to reconstruct the road to meet Province Road standards of pavement strength and geometry, taking full account of the likely heavy traffic. However if the intention is to retain the Buon Ho as a Commune Road then any rehabilitation must be accompanied by stringent measures to restrict large and overloaded trucks.

Additional recommendations are made as to:

1. The importance of appropriate asset management of rural infrastructure.
2. The need to re-assess of rural road design standards based on the actual and anticipated tasks they will be asked to perform.
3. The need to improve levels of effective site control on construction procedures and material usage.

1 Introduction

1.1 Background

In response to the increasing recognition that gravel surfacing was not a universal solution for rural roads in Vietnam, the Ministry of Transport (MoT) in 2002 requested studies of alternative surfaces for rural roads as part of the World Bank-funded Rural Transport Programme 2 (RTP2). These studies became known as the Rural Road Surfacing Research (RRSR) initiative, through which the Rural Road Surfacing Trials (RRST I and RRST II) were carried out. This research programme and its extensions were incorporated into the DfID-funded South East Asia Community Access Programme (SEACAP).

Three trial roads were constructed in Dak Lak province under the RRST-II programme (2005-2006), which followed on from the earlier RRST-I (2002-2005) programme. The RRST-II programme was undertaken in a wider set of physical environments than RRST-I and was seen as an important step in the roll out and mainstreaming of sustainable and appropriate rural surfacing solutions. Supervision was undertaken by local consultants with Intech-TRL taking an overall Quality Assurance and strategic guidance role. This was in contrast to RRST–I where Intech-TRL took a lead role in supervision.

The trial roads in Dak Lak were completed by July 2006 and shortly after that in December 2006 two roads Buon Ho and Ea Soup were reported to have suffered rapid deterioration on some of their trial sections.

The Dak Lak trial roads are located within the Central Highlands region of Vietnam, Figure 1

Figure 1 Trials Location

The Buon Ho deterioration was confirmed during a condition monitoring survey in March 2007 and recommendations were made as a research programme to investigate the causes[1]. The Vietnam

[1] Intech-TRL (2007) Report on Interim Monitoring of the RRST Trial Sections (Module 6.1)

Ministry of Transport (MoT) subsequently requested SEACAP to investigate the causes of these problems as a case study.

1.2 Project Aims

The objective of this project is, as defined in the Terms of Reference, "…. *to understand the causes of the unexpected deterioration of the RRST roads in Dak Lak Province in order to reduce the risk of recurrence in the future"*.

This has been interpreted to mean, in practical terms, that the project will research the background and current pavement conditions to determine the contributing cause, or causes, of early failure and to make recommendations on the prevention of similar situations occurring elsewhere.

1.3 Contractual Arrangements

On 17th August 2007, Crown Agents for Overseas Governments and Administrations Ltd (the "Contracting Agent"), acting for and on behalf of their Principal, the Department for International Development (DFID), invited technical and financial proposals from TRL Ltd for the work under the South East Asia Community Access Programme (SEACAP). The project was designated as SEACAP 24.

Proposals were submitted in September 2007 and, following a period of negotiation, a contract was signed between TRL Ltd and Crown Agents in November 2007.

The project is being carried out primarily by two organisations, TRL Ltd as the Lead Consultants and the Dak Lak Provincial Project Management Unit (PPMU), the latter acting as the designated Data Collection Consultant. Formal contractual arrangements were agreed and signed between TRL and the Dak Lak PPMU in December 2007.

In addition, TRL Ltd signed agreements to work in association with OtB Engineering (International) Ltd, who are supplying local support together with the professional services of Dr J R Cook and TEDI, the local Vietnamese consulting group, who are supplying local professional expertise.

1.4 Report Objectives

The objectives of this report are to summarise the SEACAP 24 work undertaken on the Buon Ho road, present the results of this work, and then discuss them in relation to the likely cause or causes of the pavement deterioration. Recommendations as to the prevention of similar failures occurring in the future programmes are also presented.

A separate report deals with the partial deterioration of the Ea Soup Road.

2 Background

2.1 General

The trial roads in Dak Lak were selected by the PDoT and PPMU. The pavement options for the trial evolved from a period of consultation between the PDoT/PPMU and the Intech-TRL team and were the result of balancing the following general issues;

- The need to comply with RT2 guidelines on road standard (in this case Commune Class A)
- Research objectives of the RRST-II programme
- Available materials
- PDoT design preferences
- Budget constraints

Contracts for construction of the trial roads were awarded, on a single tender basis, under RT2 guidelines managed by PMU18. Direct construction supervision of the trial sections was undertaken by ITST under a SEACAP contract. Intech-TRL, under a separate contract, was responsible only for advising ITST on supervision issues and for the final quality assurance assessment of the completed roads.

2.2 Buon Ho Design

Prior to the trials programme the Buon Ho road was primarily of unsealed gravel construction with some sections of Penetration Macadam. Visits were made by Intech-TRL to Buon Ho as part of the consultation process and relevant information gathered by a walk-over survey in June 2005. This included in situ (DCP) testing evaluation of the existing road surface, (see Figure 2 and Figure 3). The existing surface was seen to be in poor condition and composed of sub-standard quality gravely silty clay.

Figure 2 In Situ Strength of Existing Pre-Trial Road

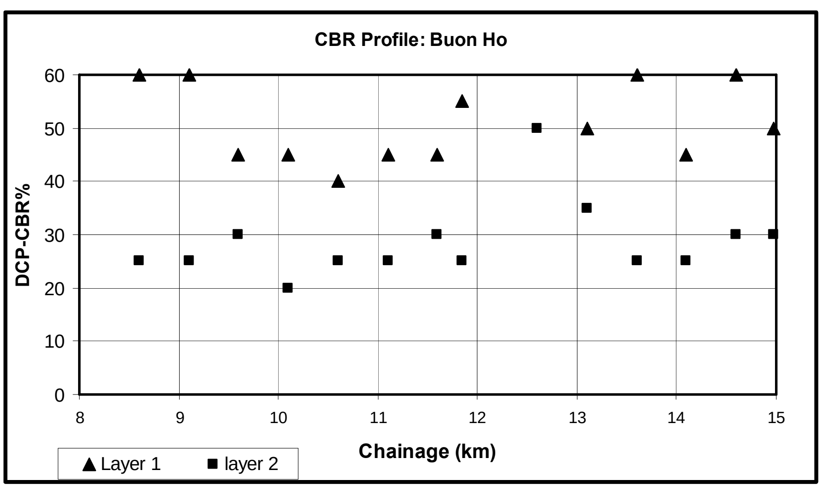
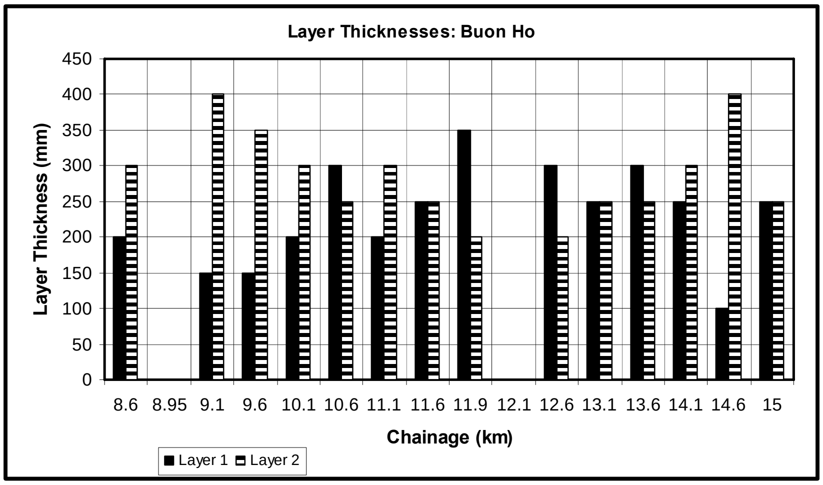


Figure 3 Existing Layer Thicknesses of the Pre-Trial Road



The RRST-II section of the Buon Ho road was designed with four different pavement options as described in Table 1. The designs were based on existing Commune Class A guidelines and taking into account the following key points

- A minimum sub-grade in situ CBR of 15%
- Established local Penetration Macadam design for control sections
- Estimation of likely traffic based on available traffic counts (approximately equivalent to 75,000-100 000 ESA for a 10 year design life)
- 6T maximum axle load

The RRST trial pavement designs were included within standard RT3 contract documents with the additional requirement that they should be built in compliance with temporary RRST Trial Specifications. Key aspects of these specifications are summarised in Appendix A.

Table 1 Buon Ho Trial Pavement Designs

Section	Surface/Base	Sub-Base	Design Reference	Chainage (km)
1. BH1	60mm of Penetration Macadam	100mm of water-bound macadam (WBM)	CH8	3.700 – 4.166
2. BH2	60mm of Penetration Macadam	100mm of water-bound macadam (WBM)	CH8	5.100 – 5.316
3. BH3	Double stone (hot bitumen) chip seal on 100mm dry-bound macadam (DBM)	100mm DBM	CH5	8.600 – 9.100
4. BH4	Sand and stone chip emulsion seals on 100mm dry-bound stone macadam (DBM)	100mmDBM	CH4	9.100 – 10.100
5.BH5	Double stone chip emulsion seal on 100mm dry-bound stone macadam (DBM)	200mm of natural gravel placed and compacted in two layers	CH3	10.100 – 12.600
6. BH6	Double stone chip emulsion seal on 100mm dry-bound stone macadam (DBM)	200mm of natural gravel placed and compacted in two layers	CH3	12.600 – 14.980

2.3 Buon Ho Construction

The RRST-II Buon Ho trial section was construction during February to May 2006 in three contract packages each with a different local contractor, as follows:

- Package I: Sections BH1; BH2; BH3 and BH4
- Package II Section BH5
- Package III Section BH6

The formal supervision of road construction was, as per RT2 guidelines, the responsibility of the Dak Lak PPMU. However, under special arrangements agreed by the MoT for the RRST trials, the following additional supervision procedures were also in place:

- ITST were responsible for on site supervision and contractor compliance with the trial pavements designs and specifications in conjunction with the PPMU. This included undertaking quality control tests during construction and agreeing the satisfactory completion of the pavement layers.
- Intech-TRL had an overall advisory role during construction with a responsibility to comment on the final quality of the as-built road.

During the construction period, Intech-TRL staff made periodic visits to Dak Lak to comment on progress and quality control. During one of these visits the poor quality of the gravel sub-base for Sections BH5 and BH 6 was noted and a change of materials was recommended. It should be noted that test results for as-delivered construction materials were not submitted to Intech-TRL until after completion of construction.

An Intech-TRL Quality Assurance team visited the completed roads in June 2006 to conduct an assessment of as-built quality based on available evidence. This survey was then combined with an assessment of available test data to give an overall Quality Assessment as summarised in Table 2.

Table 2 As-Built Quality Assessment

Section	As Built Survey	
	Visual Assessment	Materials
1. BH1	B	B
2. BH2	B	B
3. BH3	A	B
4. BH4	B	C
5.BH5	B	B
6. BH6	A	B

Where A: Satisfactory
B: Some unsatisfactory issues or missing data
C: Unsatisfactory

In addition, the following specific points were made;

1. Crossfalls were not as specified in all sections except section 6
2. The sand seal was not satisfactory (CH4)

3. There was a lack of some quality control DCP test results
4. Some CBR laboratory test results from as-delivered material were low
5. Some particle size distributions for DBM and WBM aggregate were poor
6. There was insufficient site and laboratory data from section 4

During the construction period, the PDoT indicated that they proposed to upgrade this road to provincial level and observations by Intech-TRL of traffic using completed sections indicated that there was already a significant risk of heavy traffic using the road. Recommendations on this were made to the PDoT in regard to the unsuitability of using a Commune A pavement design for provincial level traffic and the consequent desirability of restricting heavy vehicles using the Buon Ho road.

This point was again raised at the Knowledge Exchange Workshop in Dak Lak in September 2006 as follows:

"PDoT Comment: Heavy traffic and overloading is a problem on rural roads in the area and the roads should be wider (5m) and road designed for 10t.

Intech-TRL Reply: The RRST programme was concerned with Rural Road Trials and had to design within the existing standards. Upgrading standards were not an issue for RRST. Axle overloading is a social, legal and asset management issue that cannot be dealt with alone by road designers".

2.4 Buon Ho Post-Construction

In December 2006, approximately 6 months after completion of the road, the Dak Lak PDoT reported in a letter to the MoT that sections of the Buon Ho road were significantly damaged and they requested advice and support from the RRSR Steering Committee. The following sections were reported as suffering from severe rutting of the pavement, cracking of the surface seals and erosion of some base aggregate:

Km 5+286 – 5+316 (BH2)
Km 8+900 – 8+950 (BH3)
Km 9+770 – 9+800 (BH4)
Km 12+600 – 12+620 (BH5)

The PDoT also indicated that according to local reports, the road was being subjected to significant heavy vehicle traffic and that it was not possible to restrict this with the use of width barriers..

During 2nd-4th March 2007 an Intech-TRL team led by Mr Bach The Dzung visited the Buon Ho trials and held discussions with the PDo/PPMU[2]. The following were the principal points raised in the subsequent report.

1. After completion of construction, the truck traffic on the Buon Ho road has increased substantially and very quickly as trucks preferred to go along Buon Ho – EaDrong (Trial Road) from Khanh Hoa province to Buon Ho town (Krong Buk district). Thus not only do they avoid going through Buon Ma Thuot city, thereby saving 70km, they also avoid the toll station near Buon Ho town.
2. Some short sections of trial road are damaged because of the overloaded vehicles. Provinces in the Central Highland are unwilling or unable to use barriers to control the heavy vehicles. There are load limit signs along the road but drivers do not comply with these restrictions.
3. Numerous heavy vehicles were noted and photographed using the road.
4. According to local residents, the heavy vehicle traffic continues during the night up to around 0200hrs.

[2] RRST-II Vietnam field trip report, Dak Lak March 2007, Bach The Dzung

The following damaged sections were noted:

- Km 8 +950 (BH3) badly damaged length about 80m
- Km 9 + 400 (BH4)badly damaged length about 20m.
- Km 10 + 200 (BH5)badly damaged length about 30m

5. The defects of damaged sections were reported as including not only the surface but also "roadbase layers, with surface and base materials stripped and depressions on the road surface (and cracks)".

It is understood that uncontrolled heavy vehicle traffic continued to use the Buon Ho trial road and that rapid deterioration of the pavement continued until, by late 2007, the condition had deteriorated to such an extent in some places that most of this traffic opted not to use the road.

A site visit by SEACAP in July 2007 confirmed the continuing deterioration[3].

[3] Report on the Relevant Discussions During Dak Lak Field Trip, by Bach The Dzung, July 2007

3 Road Investigation

3.1 Background Information

The following background information has been accessed for the Buon Ho road investigation

1) Original pre-trial site visit notes and photographs
2) In situ and laboratory testing for trials design
3) Pre-construction materials testing
4) In situ and laboratory testing during construction
5) ITST construction supervision notes
6) Relevant Intech-TRL technical correspondence with the PPMU and the Steering Committee
7) Intech-TRL quality assurance notes and records
8) ITST completion report
9) Relevant Intech-TRL SEACAP 1 reports
10) Post construction monitoring data.

3.2 Summary of Fieldwork

A programme of field investigations was undertaken, as summarised in Table 3.

Table 3. SEACAP 24 Site Work

Activity	Date	Personnel
Preliminary Site Visit	27th-29th November 2007	Dr J R Cook Nick Elsworth P G Tuan
Main Data Collection	9th -15th January 2008	Nick Elsworth P G Tuan B T Dzung
Follow-up Site Visit	29th-31st January 2008	Dr J R Cook Dr J Rolt B T Dzung
Axle Load Survey	6th-8th March 2008	B T Dzung Heng Kackada

A preliminary site visit in conjunction the PPMU was undertaken to confirm general status of the Bun Ho road and to identify key areas for in situ investigation. The general locations for inspection pits were identified on site. In order to gain maximum research information it was agreed that these pits would be on a variety of pavement conditions. Discussions with local PPMU/PDoT staff indicated that although numerous large vehicles had been using the road, this activity had since decreased due to the damage to the road and, in particular, to one culvert.

The main data collection phase comprised the following:

1) Excavation of inspection pits in the trial pavements
2) In situ testing (DCP)

3) Sampling of as-constructed materials
4) Visual inspection of whole trial road lengths
5) Collection of relevant traffic data (in conjunction with SEACAP 27)

A follow-up site visit was undertaken to enable the OtB-TRL pavement and materials specialists to review the interim results of the main investigation on site and to focus the planning of further analytical work.

An axle loading survey was conducted on the Buon Ho and adjacent provincial roads using portable weigh pad equipment hired from KACE Ltd (Cambodia). The survey was managed on site by Heng Kackada (KACE) and Bach The Dzung (TRL-OtB) in close cooperation with the relevant provincial authorities. A separate report on this survey is incorporated as Appendix B to this document and discussion of its results included in Chapter 4 below.

3.3 Trial Pits and In Situ Testing

A total of 10 inspection pits were excavated and sampled on the Buon Ho road and 4 on the Ea Soup road. Locations of these pits are listed in Table 4. Inspection pit records are included as Appendix C. In situ DCP testing was undertaken on pavement layers within the inspection pits where appropriate. Results are summarised in Appendix D

Table 4, Inspection Pit Positions

Section- Pit	Chainage (km)	GPS Coordinates (degrees, minutes)
BH 1.01	3+800	N12 54.342 E108 17.783
BH 2 01	5+070	N12 54.282 E108 18.449
BH 2 .02	5+190	N12 54.224 E108 18.482
BH 3.01	8+960	N12 53.413 E108 20.034
BH 3 02	8+990	N12 53.407 E108 20.049
BH 4.01	9+935	N12 53.094 E108 20.411
BH 5 01	10+275	N12 52.997 E108 20.575
BH 5 02	10+620km	N12 52.939 E108 20.756
BH 6 01	12+800km	N12 52.504 E108 21.863
BH 6 02	14+435km	N12 52.237 E108 22.702

3.4 Laboratory Tests

Samples recovered from the inspection pits were assigned for testing at a local laboratory and at a selected geotechnical laboratory in Hanoi, as follows:

- DBM/WBM base or sub-base (10 samples) – for grading
- Pen Mac/ DBST (10 samples) for bitumen content

- Gravel sub-grade/sub-base (17 samples) for grading, moisture content, plasticity, compaction and soaked CBR.

Key test results are summarised in Tables 5 and 6.

3.5 Visual Condition Survey

A visual condition survey was undertaken of the whole of the Buon Ho trial road using a slightly modified version of the procedure used for the more detailed surveys for individual monitoring sections for SEACAP 27 with the length of assessment 'block' increased to 25m.

The coded visual survey sheets are included in Appendix F along with tabulated summary descriptions. Figures 4 to 8 present the wheel-track rut depths measured as part of the visual survey procedure.

Descriptions are grouped into 5 general levels of condition as defined below and presented in Figure 9, which also includes test pit locations, pavement design references and contractor boundaries.

Pavement condition groups:

1. Pavement in **good** condition, with only occasional isolated cracking and occasional minor ruts <20mm
2. Pavement in **fair** condition, with some slight stripping of seals leading to occasional shallow potholes; occasional rutting up to 20mm, occasional interconnected or crocodile cracking
3. Pavement in **moderately poor** condition, with significant crocodile cracking and scattered potholes, rutting may be up to 70-80mm
4. Pavement in **bad** condition, extensive crocodile cracking and potholes with rutting up to 200mm
5. Pavement in **very bad** condition – essentially pavement has lost seal and lost integrity with severe ruts and loosening of base material.

Figure 4. Rut Depths for Sections BH1 and BH2

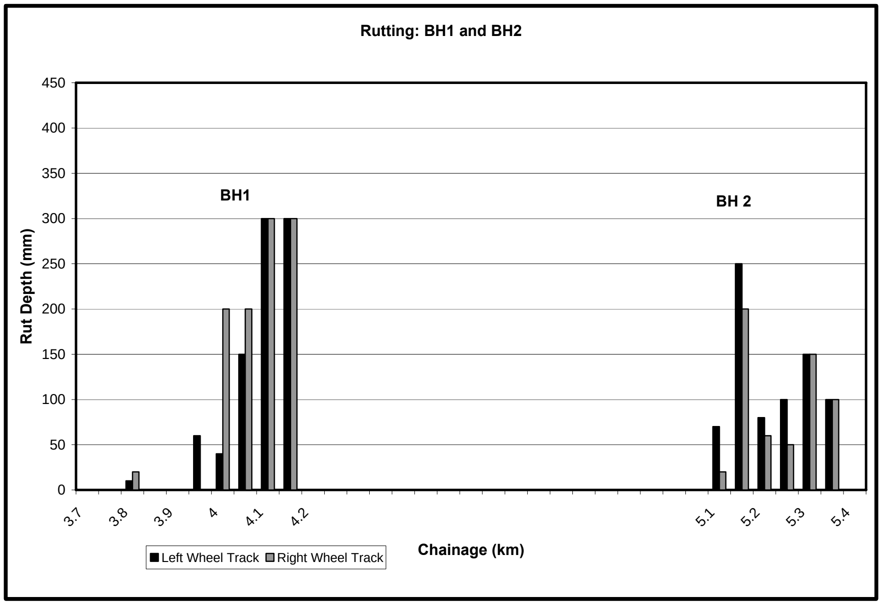


Figure 5. Rut depths for Section BH3

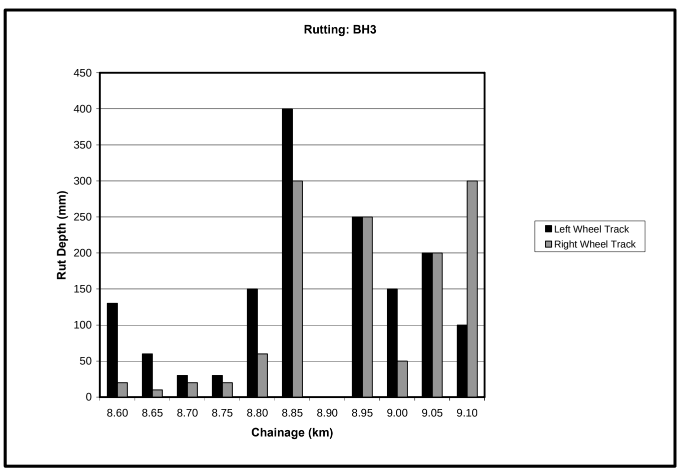


Figure 6. Rut Depths for Section BH 4

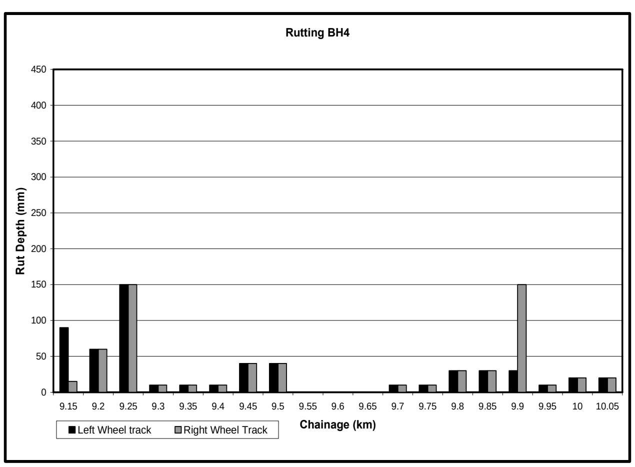


Figure 7. Rut Depths for Section BH 5

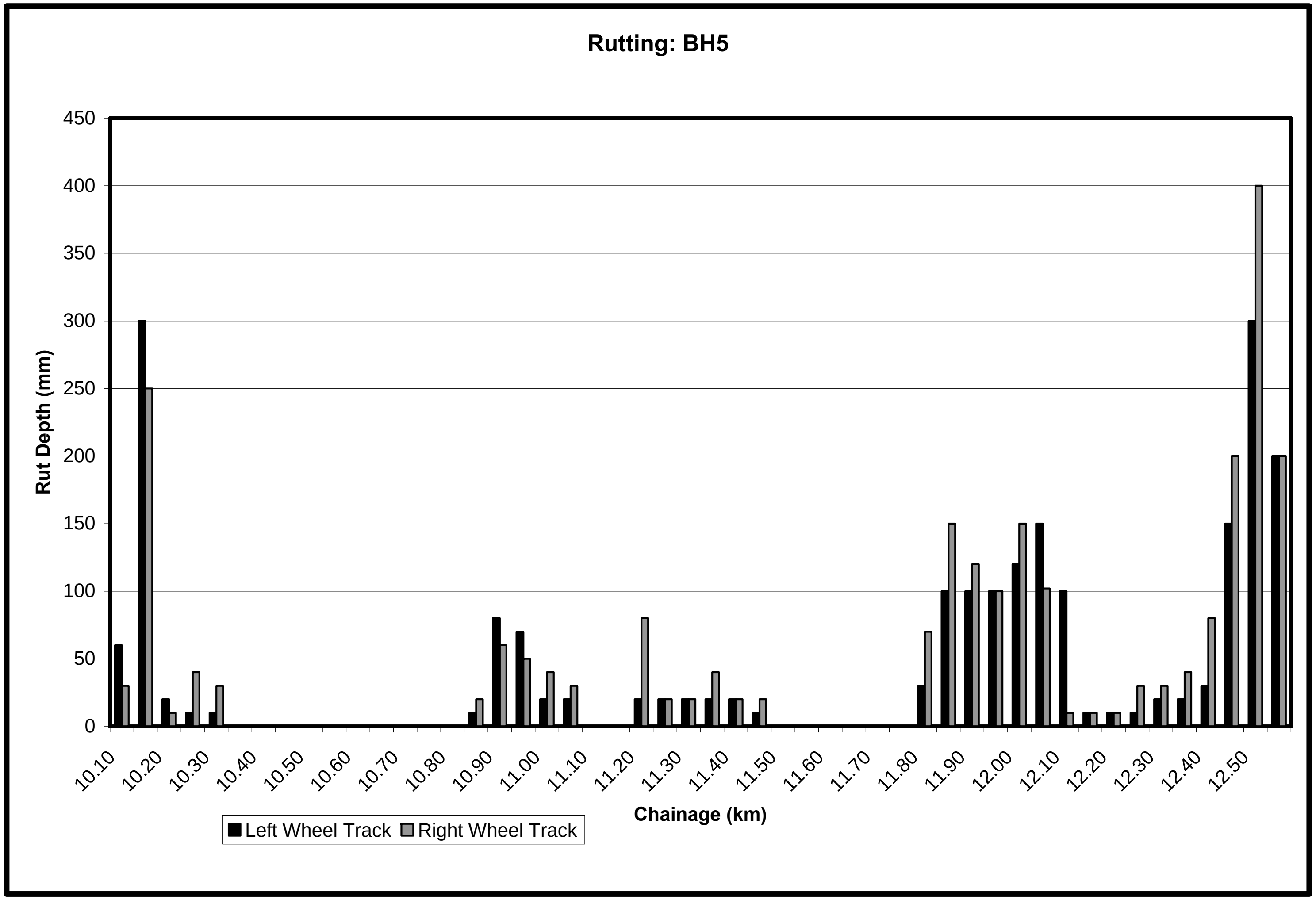


Figure 8 Rut Depths for Section BH 6

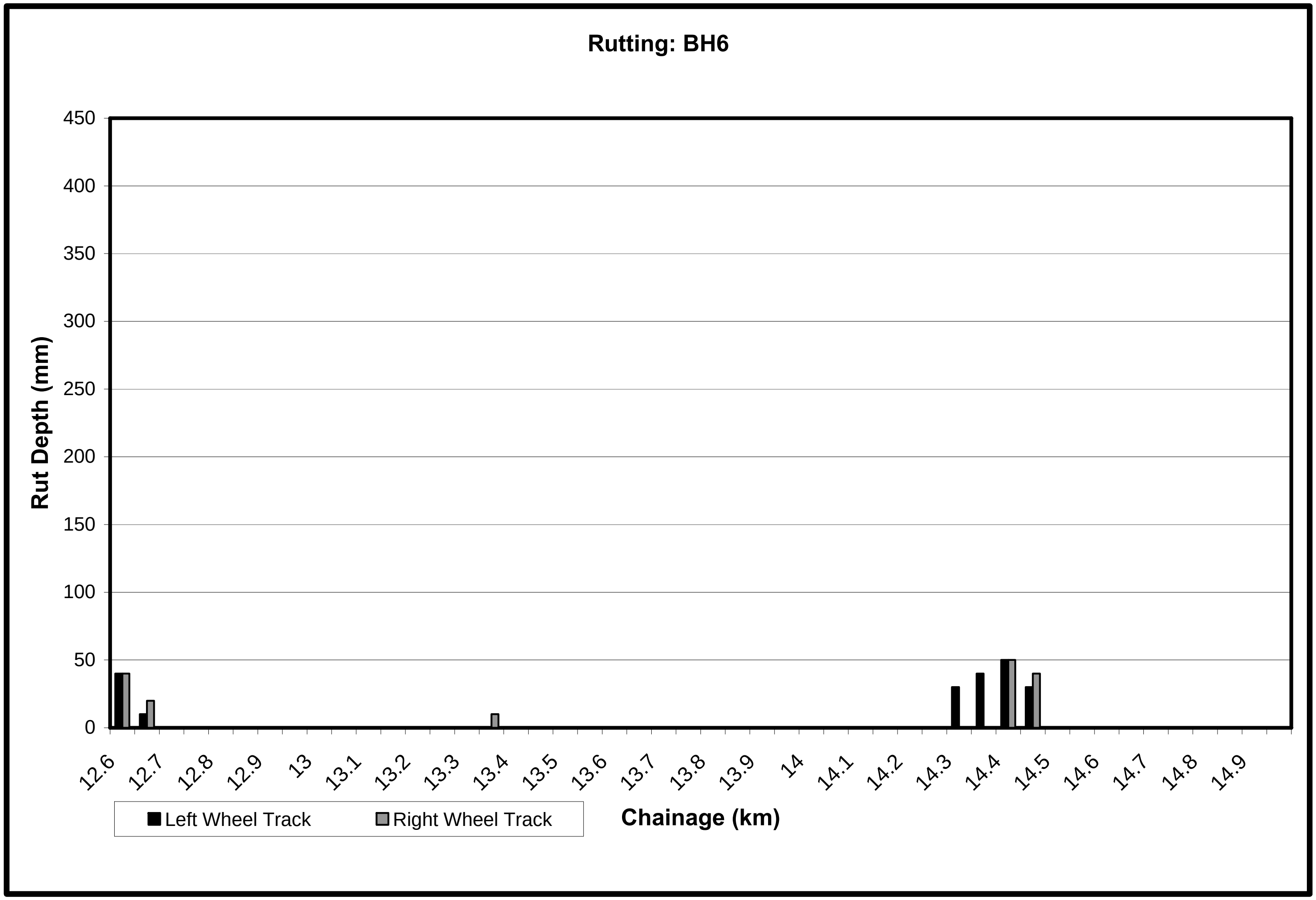


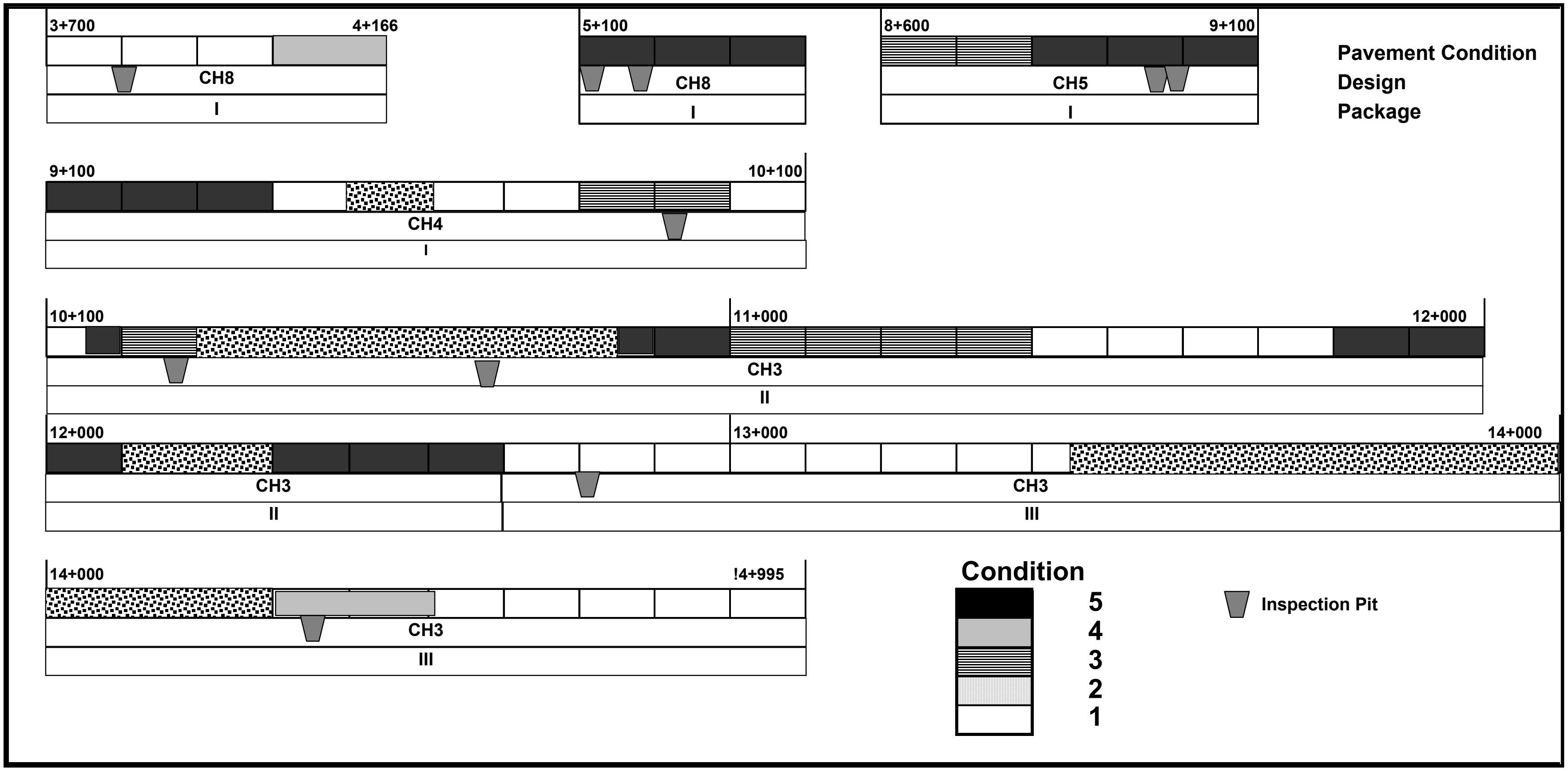
Table 5 Crushed Stone Aggregate and Bitumen Test Results from SEACAP 24 Inspection Pits

Ch. km	Pit No.	Layer	Layer Type	Bitumen kg/m2	Aggregate		Comments	Road Condition	
					%>50mm	%<5mm		At pit	Zone
3+800	BH1.01	Sub-base	WBM		19	2		2	1
5+100	BH2.01	Sub-base	WBM		11	3		3	5
5+190	BH2.02	Sub-base	WBM		6		Clay on aggregate	4	5
8+960	BH3.01	Sub-base	DBM		8	14		4	5
8+990	BH3.02	Sub-base	DBM			21		4	5
9+935	BH4.01	Sub-base	DBM		31	9		4	3
10+275	BH5.01	Base	DBM		10	58		3	3
10+620	BH5.02	Base	DBM		11	7		1	2
12+800	BH6.01	Base	DBM		17	10		1	1
14+435	BH6.02	Base	DBM		5	8		4	4
10+275	BH5.01	Surface	DBSTe	5.53	0			3	3
10+620	BH5.02	Surface	DBSTe	4.31	13		Fine aggregate segregation	1	2
12+800	BH6.01	Surface	DBSTe	4.61				1	1
14+435	BH6.02	Surface	DBSTe	5.07	9			4	4
3+800	BH1.01	Surface+base	PMac	3.83	7			2	1
5+100	BH2.01	Surface+base	PMac	4.37	19			3	5
5+190	BH2.02	Surface+base	PMac	4.08	4		Clay on aggregate	4	5
8+960	BH3.01	Surface+base	DBST+DBM	4.25	0		Fine aggregate segregation	4	5
8+990	BH3.02	Surface+base	DBST+DBM	4.76	4		Fine aggregate segregation	4	5
9+935	BH4.01	Surface+base	SSBSTe +DBM	3.80	14		Fine aggregate segregation	4	3

Table 6. Natural Gravel Test Results from SEACAP 24 Inspection Pits

Ch. km	Pit No.	Layer	Soil Class	W%			OMC%	MDD g/cm3	Lab CBR		W/OMC Ratio	DCP CBR	Road Condition	
					LL%	Ip%			95%	98%			At pit	Zone
3+800	BH1.01	Subgrade	SM	27	52	17	21	1.70	5		1.29	15-30	2	1
5+100	BH2.01	Subgrade	SM	22	61	21	19	1.80	6		1.16	34	3	5
5+190	BH2.02	Subgrade	SM	28	54	18	19	1.70	5		1.47	11	4	5
8+960	BH3.01	Subgrade	SM	22	63	20	17	1.73	5		1.29	12	4	5
8+990	BH3.02	Subgrade	SM	17	60	19	24	1.69	5		0.71	24-13	4	5
9+935	BH4.01	Subgrade	CL	22	31	11	20	1.64	5		1.10	6-13	4	3
10+275	BH5.01	Subgrade	MH	30	59	16	24	1.65	5		1.25	21-14	3	3
10+620	BH5.02	Subgrade	MH	21	51	15	23	1.71	7		0.91	25	1	2
12+800	BH6.01	Subgrade	SM	19	54	19	22	1.63	6		0.86	36	1	1
14+435	BH6.02	Subgrade	SM	21	55	16	20	1.66	5		1.05	25	4	4
10+275	BH5.01	Sub-base	SM	26	60	19	21	1.73		12	1.24	13	2	3
10+620	BH5.02	Sub-base	SM	27	63	16	21	1.73		6	1.29	25	1	2
12+800	BH6.01	Sub-base	SM	21	57	13	23	1.65		7	0.91	51	1	1
14+435	BH6.02	Sub-base	MH	27	69	22	19	1.70		6	1.42	15	4	5

Figure 9. Buon Ho Pavement Condition Summary



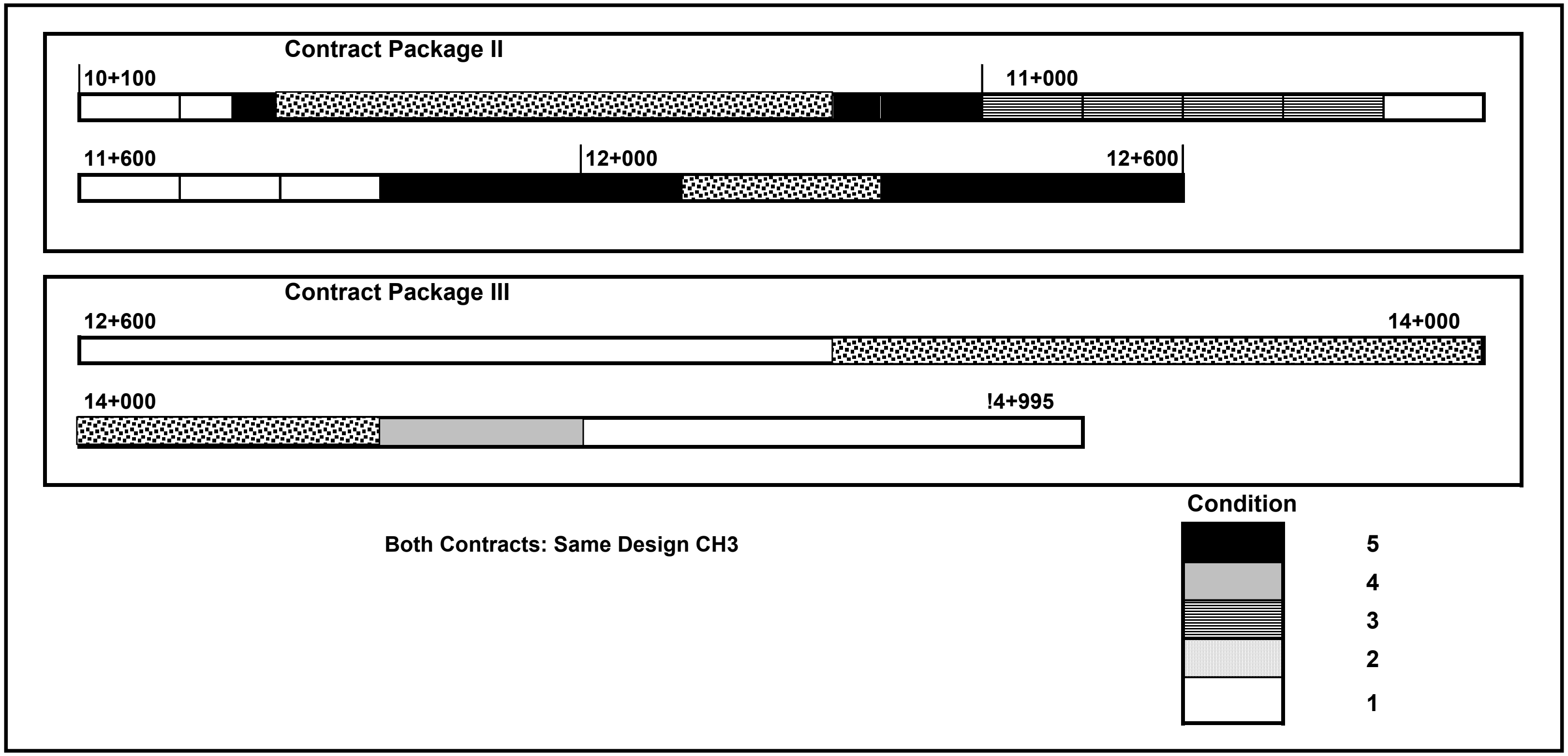
3.6 Pavement Information Review

Review of the available information gave rise to the following key points:

1. Buon Ho road has suffered significant and rapid deterioration leading in places to complete pavement failure.
2. The poor pavement condition is not uniform and there are significant lengths with only slight or moderate deterioration and other areas where no deterioration is evident.
3. Two sections BH5 and BH6 with the same design, but built by different contractors, are exhibiting markedly different performance characteristics, Figure 10.
4. Sections with the same contractor but different designs are exhibiting significantly different performance characteristics, for example compare Figure 5 and Figure 6.
5. The test results for construction materials submitted prior to construction indicated a general compliance with specification. No adverse comments were received from the local supervision team on the subsequently as-delivered materials.
6. Following a site visit during construction, Intech-TRL requested replacement of existing gravel sources with an improved material. Assessment of materials recovered from the inspection pits indicates that this request was not acted upon.
7. In situ and laboratory testing indicates low strength and out-of specification gravel sub-base within sections BH5 and BH6.
8. During the current investigations, visual and laboratory evidence indicates that the as-built Penetration Macadam, WBM and DBM pavement layers contain significant oversize material. There is also evidence in some places of segregation of the fines.
9. Re-assessment of in situ density tests undertaken at the time of construction revealed unrealistic assumptions as to the homogeneity of the density of the compacted material, leading to doubts as to the accuracy of the reported “satisfactory” in situ densities.
10. Visual evidence indicates some variability in the quality of the bitumen surfacing. Laboratory testing indicate a low bitumen content for the Penetration Macadam sections, although this may well be at least partially a result of sampling problems with this form of pavement.
11. .Assessment of the layer thickness indicated no significant thinning of the base or sub-base layers beneath carriageway ruts.

In summary, there is significant evidence to indicate that the trial road was, at least in part, constructed with materials that did not meet the specifications and, possibly, to variable compaction standards. The markedly different performance of sections BH5 and BH6, which are nominally the same design but built by different contractors, indicates that the quality of materials and the quality of construction are significant factors.

Figure 10. Sections with Same Design but Different Contractors



4 Traffic Issues

4.1 Original Traffic Survey for Design

The original traffic count was carried out on the trial road by the PDOT in July 2005 with the results shown in Table 7

Table 7 Design Traffic Count July 2005

Vehicle type	Average Daily Traffic	Equivalent ADT
Trucks > 5T	10	50
Trucks< 5T	8	20
Cars	8	6
Cong Nong	205	205
Motor cycles	391	39
Cycles	47	2
Total	-	329
Total motorized	622	-
Total 4-wheel or more	231	-

At the time of the traffic count, the road was in need of repair and therefore the traffic level was probably lower than it would normally have been. However, these figures indicate an ESA total of between 75,000 and 100,000 for a 10 year design life.

As noted previously, after the trial road was constructed, traffic increased rapidly but decreased again when the road began to deteriorate. For this investigation it is important to obtain an estimate of the traffic loading that the trial road carried during this period of heavy trafficking.

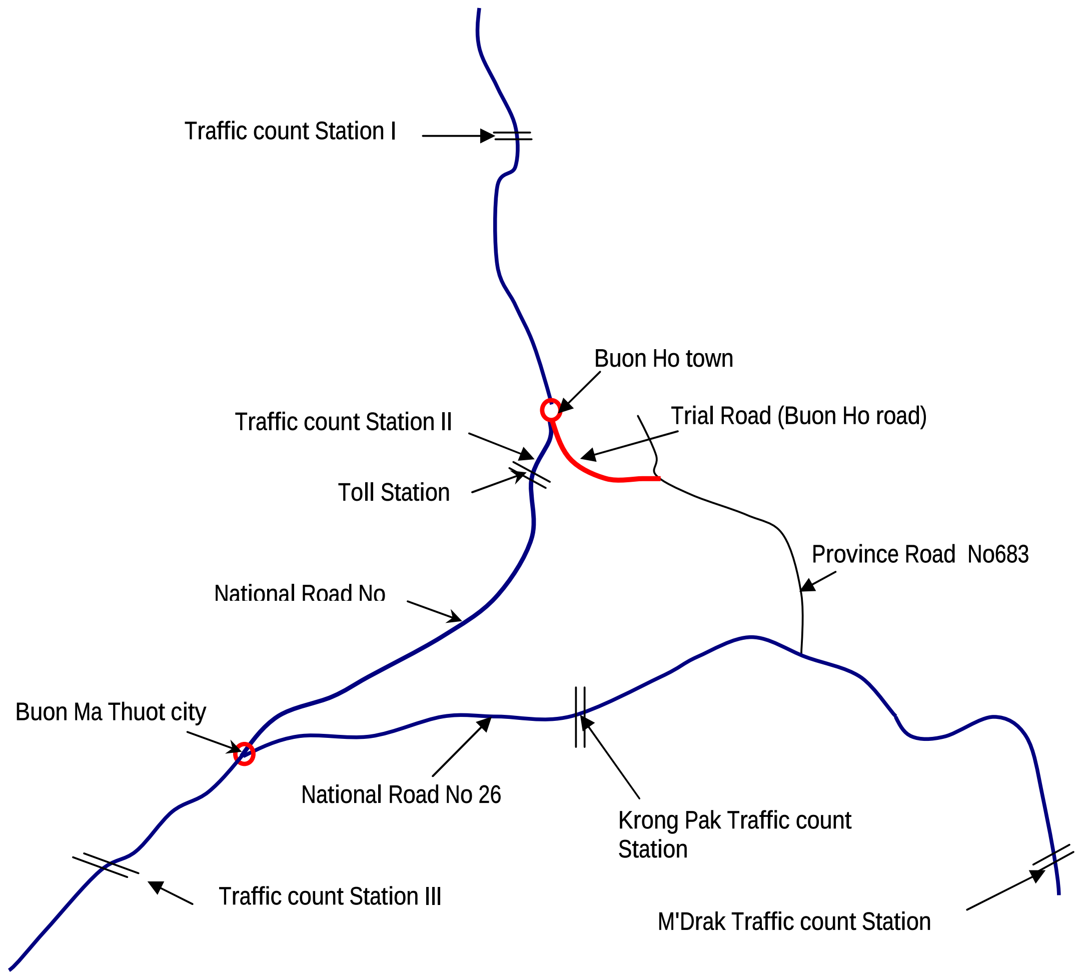
4.2 Recent Traffic Counts

Figure 11 shows the location of the road in comparison with the main towns and National Routes Number 14 and 26. Vehicles travelling from the East on RN 26 to the North on RN 14 and vice versa were able to reduce their journey distance by about 70 km by using the trial road as a short cut and this also enabled them to avoid the toll station on NR 14.

Five traffic count stations are shown from which traffic count data are available for the years 2005, 2006 and 2007. The traffic counting period was between 6.00 am and 6.00 pm hence traffic in the night was not counted. According to local information, a considerable volume of truck traffic travelled at night on the trial road.

Analysis of the data from these counting stations can be used to estimate the traffic that used the trial road when it was opened to traffic. The traffic counts at the Krong Pak counting station and M’Drak counting station on RN 26 are particularly useful because four counts were made in the period 2006 to 2007, spanning the period when the trial road was first opened to traffic right through to when the road had deteriorated badly and traffic levels decreased as a consequence. The other traffic counts are useful because they provide information concerning the general growth rate of traffic in the area. The traffic counts are tabulated in Appendix F.

Figure 11 Location of Trial Road and Traffic Counting Stations



A more recent traffic count was made on the trial road in January 2008, Table 8. At this time serious deterioration at one or two spots prevented heavy traffic from traversing the whole road.

Table 8 Traffic count January 2008 on trial road

Vehicle type	ADT	Equivalent ADT
Trucks > 5T	51	257
Trucks< 5T	90	224
Cars	65	52
Cong Nong	1525[1]	1525[1]
Motor cycles	2765	277
Total	-	2363
Total 4 wheel or more	206	-

Note 1 This Figure may be questionable

4.3 Estimates of diverted traffic

An estimate of the traffic that diverted from the main road to the trial road when the trial road was completed can be made by calculating the reduction in traffic observed at the counting station at Krong Pak. The increase in traffic again, at a later date when the trial road had deteriorated, also indicates how much traffic used the trial road. In carrying out these calculations, the overall steady growth in traffic has been taken into account. It has also been assumed that the diverted traffic used the trial road for six months and that it started and stopped relatively quickly. Table 9 summarises the calculation.

Table 9 Calculation of diverted traffic (vpd) on to trial road

Vehicle type	2006			2007	Growth	Diverted traffic	
	1st quarter	2nd quarter	3 /4 quarter		% per annum	Initial	Final
Car	169	173	154	199	10	34	50
Light truck 2 axle	141	136	139	145	2	N	N
Light truck 3 axle	231	245	273	396	41	17	62
Medium truck	256	312	254	315	13	129	201
Heavy truck 3-axles	93	94	77	150	35	36	56
Heavy truck ≥4-axle	29	30	20	30	2	14	17
Mini bus <20 seats	150	147	120	151	0.5	32	37
Large bus > 20 seats	123	114	126	165	20	N	N
Total buses	273	261	246	316	9	21	26
Heavy trucks	122	124	97	180	27	50	73
Total of trucks	750	817	763	1036	22	189	325

Note N = apparent negative result

It can be seen that there are some anomalies in the Table. For two classes of traffic the calculation gives negative answers and for two others the growth rate is exceptionally high. These 'errors' may simply be a result of mis-classification or real random variations during the traffic counts. The anomalous result for large buses is probably because no large buses actually diverted onto the trial road. After upgrading, the large buses continued to travel along their original routes. This is normal behaviour. The apparent diversion of small buses from the main road during the middle period may indicate the route chosen by long distance mini-buses with a more flexible route schedules but it may simply be inaccurate data from the traffic count on RN 26.

The best solution is to classify all buses together and all trucks together as shown in the last two rows of the Table. The growth rates still appear to be high, especially for the total of the two classes of heavy truck, but they are similar to the computed rates from other counting stations. Table 10 summarises the traffic growth rates counted over a 2-year period from 2005 to 2007 at each of the other counting stations. There is considerable variability within the Table but if the figures for 'all trucks' and for 'all buses' are computed, the overall growth rates for cars, trucks and buses are remarkably similar at 43%, 39% and 45%. The implication is that some of the variability within the Table has probably been caused by inaccurate classification within the vehicle classes.

Table 10 Traffic growth rates (% per annum)

Vehicle	Station I	Station II	Station III	M'Drak	Overall Average
Car	59	44	40	31	43
Light truck	-34	38	15	65	21
Medium truck	35	29	40	40	36
Heavy truck 3 axles	30	129	63	107	82
Heavy truck ≥ 4 axles	37	141	217	6	100
All trucks	8	40	41	67	39
Small bus < 20 seat	26	45	12	1	21
Large bus > 20 seat	47	81	148	60	84
All buses	36	61	53	28	45

The next step is to estimate the normal traffic that used the road in addition to the diverted traffic. The traffic counts on the trial road itself in 2005 and in 2008 use an entirely different classification of traffic, dividing trucks into those greater or smaller than 5 tonnes GVW. Reconciling the two methods is not possible except in terms of total trucks. It is the heavy trucks that contribute by far the most to the damage to the road and it is the number of these for which an estimate is needed. From Table 8 the number of trucks >5T in January 2008 was 51 per day but not all of these are really heavy. The number of heavy trucks is therefore unknown. However, from the traffic count data (see Appendix) it is found that the percentage of heavy trucks is about 29% of all trucks and this figure is fairly similar for all count stations. If we,

(a) assume that 29% of all trucks are heavy

(b) assume a growth rate of 27% (Table 9)

(c) work backwards from the January 2008 figure,

then the normal traffic of heavy trucks on the trial road during the six month period after upgrading would have been about 30 per day. The diverted traffic needs to be added to this to give the total heavy traffic. This is shown in Table 11.

Table 11 Estimates of heavy traffic on the trial road (ADT)

Vehicle type	July 2005	July 2006[1]	Dec 2006[1]	Jan 2008[2]
	Elapsed time			
	0 months	12 months	18 months	30 months
Heavy trucks	10	79	105	41

There are a number of likely errors in this calculation.

1. It has been assumed that the diverted traffic begins instantaneously and ends abruptly after six months. It is probably true that it began quickly but it probably tailed off slowly as the road deteriorated.

2. As far as normal traffic (as opposed to diverted) is concerned, the number of heavy vehicles using the south-eastern end of the road is considerably higher than that using the middle section.
3. It is also necessary to add the traffic that travels during the hours between 6.0pm and 6.0am.
4. Data concerning the axle loading of the trucks has been obtained from a comprehensive axle load survey that was carried out in March of 2008. This survey has been produced as a separate report (Appendix B).

Judgements alone must be used to estimate the likely corrections/adjustments needed to calculate the number of equivalent standard axles that contributed to the rapid deterioration of sections of the road. The adjustments that are deemed necessary are as follows.

No adjustment has been made for the ‘shape’ of the diverted traffic growth and decay.

No adjustment is made for varying normal traffic along the road since diverted traffic is dominant and is about twice as much.

Heavy traffic at night is assumed to be 50% of day-time traffic, although local hearsay evidence indicates that this may be conservative.

From the axle load survey described in Appendix B the average esa per heavy vehicle is about 8.75 esa. The level of enforcement of axle load limits is probably quite low in the provinces and so maximum values could be as high as 20 or 30 esa per vehicle, but many will be lightly loaded on a return leg.

Using the data available to date and the assumptions described above, the best estimate of the total number of esa that used the road during the six months that it deteriorated is given by,

Total esa = (Average ADT in period) x (Night correction) x (Days) x (Average esa)

Therefore,

Total esa = 92 x 1.5 x 182 x 8.75 = 220,000 (for six months)

This calculation has been entirely concentrated on the heavy vehicles. The contribution of buses and smaller vehicles, though small, must be added to this figure. It can be seen that the capacity of the road has been greatly exceeded.

5 Strength and Traffic Capacity of the Road Pavement

5.1 Key Questions

In order to satisfy the objectives of this investigation, the following key question need to be addressed;

1. Was the design suitable for Commune Road A traffic?
2. Was the road constructed as per specification?
3. Was the as-built road suitable for Commune Road A traffic ?
4. Was the design suitable for the actual traffic ?
5. Was the as-built road suitable for the actual traffic ?
6. What are the key factors that caused early deterioration ?

5.2 Identifying the Causes of Failure

For a particular type of pavement (i.e. using specific materials) its structural design consists primarily of selecting the appropriate thicknesses of each layer to allow it to carry the traffic successfully over the particular subgrades that it crosses. It is always assumed that the materials of the pavement layers meet minimum strength requirements. These are usually different for each layer depending on the function of that layer within the pavement.

Small variations (reductions) in thickness are allowed if the materials exceed these minimum strength requirements but there is no readily available method within normal design procedures for dealing with materials that do not meet these minimum requirements. Normally, extensive research involving full scale trials or, alternatively, reliance on theoretical techniques backed up with extensive laboratory testing, is required to develop ways in which such sub-standard materials can be used. This is because the design of the pavement is usually based on specific modes of anticipated behaviour and eventual failure. If substandard materials are used then the mode of failure may be different and will not be covered by the normal design method. The specifications for the materials are designed to prevent this.

Thus if a road behaves badly, there are various possible reasons based on the design, the materials and the quality of construction, or combinations of all three. In order to examine these possibilities it is necessary to estimate the likely traffic capacity assuming that the road was built properly and the materials were satisfactory. This result will then be compared with the estimated capacity based on the as-built properties but assuming that unexpected failure modes do not develop because of material failures (i.e. using actual strengths and as-built thicknesses). Finally actual behaviour will be examined to identify any failures that cannot be attributed to incorrect design or incorrect constructed thicknesses; in other words, material failures that should not occur if the materials are of adequate strength and the layers have been constructed properly.

5.3 Original Design

The original designs are shown in Table 12. Estimates of the likely ‘subgrade’ strength were made by using DCP measurements in the original old road. The results are shown in Figure 2 where it can be seen that the minimum CBR is greater than 20%, For an assessment of the design of the trial road a value of 10% CBR has been adopted. The AASHTO method was used for estimating the traffic capacity using the assumptions concerning the input variables shown in Table 13.

Thus if the road had been constructed as designed, none of the sections would have survived for more than a year or two with the traffic that was being carried after construction. However, this conclusion depends on the actual subgrade strength that may differ from the value assumed in the design.

Table 12 Original thickness designs

Section	Chainage	Surface/Base	Sub-Base	Design Structural Number SNP	Traffic Capacity esa
BH1	3.700 – 4.166	60mm of Penetration Macadam	100mm of Wet-bound Macadam (WBM)	2.37	125,000
BH2	5.100 – 5.316	60mm of Penetration Macadam	100mm of Wet-bound Macadam (WBM)	2.37	125,000
BH3	8.600 – 9.100	Double stone chip seal on 100mm DBM	100mm Dry-bound stone Macadam (DBM)	2.37	125,000
BH4	9.100 – 10.100	Sand and stone chip emulsion seals on 100mm Dry-bound stone Macadam (DBM)	100mm Dry-bound stone Macadam (DBM)	2.37	125,000
BH5	10.100 – 12.600	Double stone chip emulsion seal on 100mm Dry-bound stone Macadam (DBM)	200mm of natural gravel placed and compacted in two layers (required in situ CBR of 30%)	2.65	265,000
BH6	12.600 – 14.980	Double stone chip emulsion seal on 100mm Dry-bound stone Macadam (DBM)	200mm of natural gravel placed and compacted in two layers (required in situ CBR of 30%)	2.65	265,000

Table 13 Input values for traffic capacity estimates using the AASHTO design method

Input variable	Notes	Value
Strength coefficients .		
Chip seal		0.1
Penetration Macadam	Surface = a_1	0.25
Wet-bound Macadam	Roadbase = a_2	0.14
Dry-bound Macadam	Roadbase = a_2	0.14
Natural gravel	Sub-base = a_3	0.10
Wet-bound Macadam	Sub-base = a_3	0.13
Dry-bound Macadam	Sub-base = a_3	0.13
Standard deviation term S_o	NA. The minimum subgrade strength was used	NA
Reliability factor	For comparison with other calculations	50%
Subgrade CBR	Minimum value	10%

5.4 As Constructed Structure

The analysis of the DCP measurements made in January 2008 as part of the survey described above is shown in Appendix D. An analysis of the likely traffic carrying capacity of the road using the AASHTO pavement design model is shown in Table 15. This analysis takes no account of any weaknesses in the materials in the surfacing or base layers that were removed before the DCP tests were carried out so these traffic estimates are therefore maximum values.

It should be noted that traffic capacity is a very variable pavement attribute and subject to large errors. In this analysis a reliability level of 50% was selected. This means that there is a 50% probability that the road section will fail before the traffic levels in Table 15 have been reached, sometimes quite a lot before. The effect of climate has been assumed to be moderate and no modifications have been made to the standard 'drainage' factors in the design equation.

The axle load information in Appendix D confirms the assumptions in the traffic calculations in Chapter 3. It can be seen from Table 15 that some sections are performing as well as could be expected. These are BH1 and parts of BH 2 and BH 3 and BH 6. The sections that have not performed well are structurally weak and so this performance is also expected. These are parts of BH 2, BH 3, BH 4, BH 5 and BH 6. The only section that appears to be failing despite reasonable strength is part of BH 5. Interpreting data when a section has failed is often difficult because the layers of the pavement will have got weaker and therefore the question of which came first is raised. In this case it is useful to examine the structure more closely of sections that are nominally the same but are performing differently. This is summarised in Table 14. Perhaps the most surprising result is that the variability within sections of the same design is so large.

Table 14 Comparison of structures within each section

Section	Test Pit	SNP	Reasons
BH 2	2	3.3	The layer beneath the base is just about adequate in strength to be a sub-base and it is 250mm thick
	3	2.0	The layer underneath the base is ***not*** sub-base strength
BH 3	4	2.25	Weak layer between base and subgrade
	5	2.9	Uniform strength beneath base
BH 5	7	2.83	Thick base (300mm) on subgrade
	8	2.3 -3.2	Completely different strength profile. Thin base and strong subgrade of almost sub-base quality. Cannot analyse in traditional way
BH 6	9	4.35	Thick base and strong sub-base quality layer beneath
	10	1.8	Completely different strength structure. Thin base, no sub-base

Table 15 Buon Ho Site –traffic capacity based on subgrade protection

Section	Chainage	Surface/Base	Sub-base	Test Pit	Chainage	Condition		SNP	Mean traffic capacity (esa)	Comments
						Pit	Zone			
BH1	3.7 – 4.166	60mm of Penetration Macadam	100mm of WBM	1	3+800	2	2	2.7	330,000	Weak[1] top to subgrade. May fail early under heavy traffic
BH2	5.1 – 5.316	60mm of Penetration Macadam	100mm of WBM	2	5+070	3	5	3.3	1,350,000	Subgrade of sub-base strength for 270mm
				3	5+190	4	5	2.0	45,000	Subgrade 10%
BH3	8.6 – 9.1	Double stone chip seal on 100mm DBM	100mm DBM	4	8+960	4	5	2.25	100,000	Subgrade 12%
				5	8+990	4	5	2.9	550,000	Subgrade 13%
BH4	9.1 – 10.1	Sand and stone chip emulsion seals on 100mm DBM	100mm DBM	6	9+935	4	3	1.94	40,000	Base/sub-base 210mm Subgrade 8-10%
BH5	10.1 – 12.6	Double stone chip emulsion seal on 100mm DBM	200mm of natural gravel	7	10+275	3	3	2.83	450,000	Subgrade 13%
				8	10+620	1	2	2.3 -3.2	100,000 – 1,000,000	Outside traditional range – Poor sub-base very near surface. Could fail quickly
BH6	12.6 – 14.98	Double stone chip emulsion seal on 100mm DBM	200 mm of natural gravel	9	12+800	1	1	4.35	10,000,000	Strong subgrade
				10	14+435	4	4	1.8	25,000	Very thin and weak. Outside the normal boundaries for analysis. Subgrade 11%

6 Conclusions

Was the design suitable for Commune road A traffic? Taking into account the surveyed strength of the existing gravel road; the current local standard designs and recent SEACAP studies[4] the conclusion may be drawn that the Buon Ho pavement designs were adequate for their original intended purpose.

Was the road constructed as per specification? It is clear from investigations undertaken that some sections of the road were constructed with materials that were out-of-specification and there is a possibility that construction procedures were not fully compliant with those specified.

Was the as-built road suitable for Commune road A traffic? From assessments of as-built strength it is likely that some sections of the as-built road would have required periodic maintenance during a 10-year design life.

Was the design suitable for the actual traffic? The pavement designs were not suitable for the actual traffic and this would have inevitably resulted in early pavement failure.

Was the as-built road suitable for actual traffic? It follows from the above that the as-built road was totally inadequate for the actual traffic.

What are the key factors causing early deterioration? This question is dealt with further in the following Chapter but essentially; within 6-7 months the traffic carried by the road is double the 10-year design figure and hence the volume of traffic and its axle loading have far exceeded the design objectives of the road. In Consultant's opinion it is clear that this is the primary cause of road failure and that if traffic had continued at this volume the whole road is likely to have been destroyed. However, it is also clear that the rate of this deterioration was aided to some extent by marginal or poor construction in some sections.

[4] SEACAP 3 (Lao) Low Volume Rural Road Standards and Specifications: Part II, TRL Ltd, 2008

7 Recommendations

7.1 Buon Ho Road

It is understood that it is the intention of Dak Lak to upgrade the Buon Ho road to Province Standard. In this case it will be necessary to reconstruct the road to meet Province Road standards of pavement strength and geometry, taking full account of the likely heavy traffic.

If the intention is to retain the Buon Ho as a Commune Road then any rehabilitation must be accompanied by stringent measures to restrict large and overloaded trucks.

7.2 LVRR Standards and Design

Vietnam has a rapidly developing economy and this is reflected in the tasks required of Rural Infrastructure networks in different regions and provinces.

Analysis of traffic trends in Dak Lak indicates that this province is within a particularly rapidly developing region. Consequently there is a need for a re-assessment of rural road design standards based on the actual and anticipated tasks they will be asked to perform in terms of vehicles, axle loads and traffic volumes, rather than being based on an administrative classification. For example many 'Commune Roads' may indeed be 'Low Volume' but others in some regions, such as Dak lak, certainly are not.

7.3 LVRR Construction Supervision

The SEACAP 24 investigations have reinforced the conclusions reached in the SEACAP 1 Final Report that

- The role of site supervisors in controlling the contractors' procedures and material usage is not yet generally accepted.
- Supervisors had a general problem in being able to exert influence on the contractors to abide by specifications.
- There is a lack of appreciation of the importance of testing as-used materials, in situ testing and daily records.
- There is a need to introduce independent check-testing of materials because some provincial laboratories exhibit weak data management control.

7.4 LVRR Asset Management

Rural roads are valuable assets that require effective management in terms of ensuring that they are not subjected to tasks beyond their design capacity. Light or Low Volume Rural roads are designed and constructed at reduced cost to undertake specific tasks in terms of vehicle type, axle load and traffic capacity and hence a 6T Commune 'A' road cannot be expected to undertake the functions of a district or provincial road.

8 Acknowledgements

This report was produced as part of the SEACAP 24 project contracted to TRL Ltd in principal association with OtB Engineering (International) Ltd. The drafting of this report was undertaken by Dr Jasper Cook (OtB Engineering) and Dr John Rolt (TRL). Traffic surveying was managed by Mr Bach The Dzung and the Axle Load Survey reported by Mr Heng Kackada (KACE Ltd).

Invaluable support was supplied by the Dak Lak PPMU. David Salter, the SEACAP Programme Manager, provided key facilitation, guidance and programme support.

CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERRIORATION

BUON HO REPORT

Appendix A

Summary Pavement Materials Specifications

Seal Bitumen Emulsion

Cationic emulsion of Rapid Setting (RS) grade shall be used. Residual bitumen in the emulsion shall be 60 – 65% of penetration (at 25°C) 40 - 90 Pen.

Seal Bitumen

Basically, petroleum originated dense bitumen shall be used for seals. Bitumen with penetration (at 25°C) 60/70 Pen will be heated to reach 160°C for placing. Bitumen shall be from an established supplier able to provide the documentation to demonstrate compliance with the specifications. Before using, the Contractor shall provide for each source of bitumen a report on its composition, grade, and date and place of manufacture. The Engineer can approve the use of 40/60 Pen bitumen based on the climate and types of chippings. The dense bitumen to be used for seals shall comply with technical criteria within 22TCN 227-95.

Emulsion Seal Sand/Fine Aggregate

This shall be natural sand or fine aggregate that has been machine crushed or manually broken and screened material that may include, quarried rock, natural granular material such as fresh rock, gravel or boulders. Aggregate shall be clean, free from organic matter. Clay content shall be not more than 2%.The maximum particle size shall be 6mm. No more than 15% of material shall be finer than 0.15mm. Sand or fine aggregate shall be applied at the rate of 6 – 7 litres/m².

Emulsion Seal Chippings

These shall be machine crushed or manually broken fresh material that may include, quarried rock, natural granular material such as rocks, gravel or boulders. The material shall be single sized, separated by screening. After crushing/breaking, the material should be angular in shape meeting the following requirements:

Either	TCVN 1772-87:	<35%
	or	
	22TCN 57-84	<5%

Plus :

- Water absorption shall not exceed 2%.
- Los Angeles Abrasion (LAA) value not more than 35 or as directed by the Engineer.
- Adhesion between stone chipping and bitumen emulsion as per 22-TCN-63-84); Minimum Grade 3 required

Three sizes of stone chipping may be specified:- 10-14mm nominal,
6-10mm nominal,
4-6mm nominal.

The following are the recommended grading limits for the stone chippings:-

Grading Limits (mm)	Nominal size of aggregates (mm)		
	10-14	**6-10**	**4-6**
20	100	-	-
14	85 – 100	100	-
10	0 – 40	85 – 100	100
6.3	0 – 7	0 – 35	85 – 100
5	-	0 – 10	-
3.35	-	-	0 – 35
2.36	0 – 3	0 – 3	0 – 10
0.600	0 – 2	0 – 2	0 – 2
0.075	-	-	-

6-10 or 10-14 mm is normally specified for the first or only seal. 4-6mm should be used for a second seal where this is specified.

Aggregate shall be clean, free from organic matter. Clay content shall be not more than 2%. Aggregates shall be of the quality shown in the following table, only chippings complying with Classes 3 – 1 may be used:

Types of Aggregate	Class	Compression Strength (daN/cm²)
Magma (granite, syenite, gabbro…..)	1 2 3	1,200 1,000 800
Weathered stone (Gneiss, quartzite…..)	1 2 3	1,200 1,000 800
Sediment (Limestone, dolomite)	1 2 3	1,000 800 600

Hot Bitumen Chippings

Materials to be use for chippings shall be crushed or hand broken fresh material from quarried rock mass. Crushed boulders can be used provided at least 2 sides are freshly broken. The use of claystone or siltstones should not be permitted

The crushed/broken material shall comply with the following requirements:

- Compression strength shall not be less than 1,000dN/cm2 for igneous and weathered rock while it is not less than 600dN/cm2 for sedimentary rock.

- Los Angeles Abrasion (LAA) value not more than 35% for sedimentary rock and 25% with igneous and weathered rock
- Aggregate stripping value must be not less than grade 3.
- Aggregate must be clean and free from organic matter. Clay content shall be not more than 2%
- Weak and weathered content shall be ≤ 3% mass

Three sizes of stone chipping may be specified: -

16/20mm nominal,
10/16mm nominal,
05/10mm nominal.

Stone size (d/D)mm	d_{min} Nominal	D_{max} Nominal	Note
16 to 19	16	20	For convenience when naming the rounded up stone sizes
9.5 to 16	10	16	
4.75 to 9.5	5	10	

(d) is the smaller sieve size (on sieve) while (D) is larger sieve size (passing sieve). The following criteria should be secured:

- Aggregate > "D" and < "d" shall not be over 10% mass
- Aggregate > D+5mm and < 0.63d shall not be over 3% mass
- Aggregate shall be angular in shape and shark
- Flakiness content shall not be over 5% mass (The defined side is the length plus the width>6 times the thickness as per 22-TCN-57-84).

Based on the type of single seal, double seals or triple seals, appropriate stone sizes and bitumen volume will be used referring to the regulations in the chart below:

Types of seal(s)	Thickness (cm)	Bitumen		Small chippings		
		Applying procedure	Volume (kg/cm^2)	Placing procedure	Stone size (mm)	Stone volume ($litre/m^2$)
1layer	1.0	Once	1.2*	Once	5/10	10-12
	1.5	Once	1.5 (1.8)	Once	10/16	15-17
2 layer	2.5 - 3.0	1st Layer	1.5 (1.8)	1st Layer	10/16	14-16
		2nd Layer	1.2	2nd Layer	5/10	10-12
3 layer	3.5 - 4.0	1st Layer	1.7 (1.9)	1st Layer	16/20	18-20
		2nd Layer	1.5	2nd Layer	10/16	14-16
		3rd Layer	1.1	3rd Layer	5/10	9-11

Note:
- (*) Single hot bitumen seal is only applied on the existing low volume bituminous pavement.
- The value inside the brackets () is the rate for the 1st bitumen application on the newly built crushed stone layer.
- Norms for bitumen in the above chart does include prime bitumen

Gravel Sub-Base

Naturally occurring gravels shall be from sources approved by the Engineer according to the requirements of Tables 1 and 2 in 22 TCN 304-03.

The target in-situ strength of the compacted gravel layers shall be not less than CBR 30% for sub-base (at k=0.95 Modified AASHTO) and CBR 55% for base (at k=0.98 Modified AASHTO) as measured by the Dynamic Cone Penetrometer (DCP) method

The gravel material shall, on completion of compaction, be well closed, free from movement under the compaction plant and free from compaction planes, ridges, cracks or loose material. All extraneous matter, loose, segregated or otherwise defective areas shall be removed and made good with new material to the full thickness of the layer.

Dry Bound Macadam Stone

This shall be machine crushed or manually broken fresh material that may include, quarried rock, natural granular material such as rocks, gravel or boulders. The material shall be single sized, separated by screening. After crushing/breaking, the material should be angular in shape meeting the following requirements:

Either: TCVN 1772-87: <35%
or
22TCN 57-84 <10%

Plus :

Water absorption shall not exceed 2%.
Los Angeles Abrasion (LAA) value not more than 35 or as directed by the Supervising Engineer.

The crushed/broken stone materials shall conform to one of the following grading limits:

Test Sieve (mm)	Percentage by mass passing	
	M1	M2
75	100	-
50	85 – 100	100
37.5	35 – 70	85 – 100
28	0 – 15	0 – 40
20	0 - 10	0 - 5

The grading of M2 corresponds with a nominal 37.5mm single-sized aggregate and is appropriate for use with mechanically crushed aggregate. M1 is a broader nominal 50mm specification that can be used for manually-broken stone but if screens are available, M2, is preferred.

Dry Bound Macadam Blinding Fines

These should be clean, non-plastic, angular, well graded, crushed stone or natural sand passing the 5.0mm sieve:-

- Plasticity Index of binding materials shall be not more than 6.

- Fineness Modulus of sand fraction shall not be less than 1.80 and shall be free from deleterious materials.

Penetration Macadam Stone Aggregate

This shall be machine crushed or hand broken fresh material that may include, quarried rock, natural granular material such as rocks, gravel or boulders. The material shall be single sized, separated by screening. After crushing/breaking, the material should be angular in shape. Flat chippings shall not be more than 10% by weight defined as chippings with length + width more than 6 times thickness.

Three stone applications are made:-

First application: 40/60mm, or 50/70mm or 60/80mm aggregate
Second application: 10/20mm aggregate
Third application: 5/10mm aggregate

In d/D above, 'd' is the smaller (retained on sieve) and 'D' the larger (passing sieve) size for the aggregates. The following requirements shall be met:

- Chippings with size >D and <d not more than 10% by mass
- Chippings with size D+30mm not more than 3% by mass
- Chippings with size <0.63d not more than 3% by mass

Aggregate shall be clean, free from organic matter. Clay content shall be not more than 2%.

Aggregates shall be of the following quality:

Types of Aggregate	**Class**	**Quality Requirements**	
		Compression Strength (daN/cm^2)	**Deval wearing value (%)**
Magma (granite, syenite, gabbro…..)	1	1,200	< 5%
	2	1,000	< 6%
	3	800	< 8%
	4	600	< 10%
Weathered stone (Gneiss, quartzite…..)	1	1,200	< 5%
	2	1,000	< 6%
	3	800	< 8%
	4	600	< 10%
Sediment (Limestone, dolomite)	1	1,000	< 5%
	2	800	< 6%
	3	600	< 8%
	4	400	< 10%
Other sediments	1	1,000	< 5%
	2	800	< 6%
	3	600	< 8%
	4	400	< 10%

Only Class 3 – 1 may be used for second and third application chippings.

Pebble or crushed/broken stone can be used for the third application. Pebble should be good quality without being cut if tested with a knife. Soft and weathered content to be <10%.

Penetration Macadam Bitumen

Bitumen to be penetration grade 40 – 90 (at 25°C)
Ductility > 40cm at 25°C
Softening point 48°C - 60°C
Flash Point 210°C - 220°C

CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERRIORATION

BUON HO REPORT

Appendix B
Axle Load Survey

MINISTRY OF TRANSPORT VIETNAM

SOUTH EAST ASIA COMMUNITY ACCESS PROGRAMME

AXLE LOADING SURVEY IN DAK LAK PROVINCE

By Heng Kackada (KACE Ltd)

SEACAP 24

MARCH 2008

Executive summary

This report summarise axle loading survey conducted from 4th to 6th March 2008 on Buon Ho Trial Road and on Provincial Road No 683 in Dalak Province of Vietnam which is part of field investigation of “SEACAP24 - Case Study of Dak Lak RRST pavement and surface deterioration”.

In total of , 30 mini and large buses, 146 light truck 2 axles, 169 medium truck 2 axles, 61 heavy trucks 3 axles and 7 heavy truck 4 axles were weighted.

The survey has found the average conversion factors can be applied:-

- Mini bus is 0.006 esa
- Large bus is 1.64 esa
- Light truck 2 axles is 0.02 esa
- Medium truck 2 axles is 8.12 esa
- Heavy truck 3 axles is 12.26 esa

The survey has also found that

- The average axial loads of tipper trucks are generally higher that standard truck of same category. But the highest axle loads recorded were found on normal truck which is in contrary to many peoples’ perception.
- Medium trucks 2 axles (T2) were found having highest axle load. This may be explained that truck of this category can have same laden capacity of heavy truck 3 axles.
- The highest axle load recorded is up to 25.2 tons. This is more than twice of allowable axle load limit of national and provincial road networks and 4 times of the limit of Rural Road Class A.
- Medium truck 2 axles and heavy truck 3 axles continue to use the trial road despite some difficulty of its broken sections which have not yet been repaired. This means that the trial continues to suffer from extreme overloading. The level of extreme axle load can reach up to four time of beyond its allowable axle load design of 6 tons as recommend by Vietnamese road design standards.

INTRODUCTION AND OBJECTIVE

The axle load survey is part of site investigation of the SEACAP24 to understand the causes of the unexpected deterioration of the RRST roads in Dak Lak Province in order to reduce the risk of recurrence in the future.

This survey allows engineers to assess actual axle loading of different vehicle types and to calculate the conversion factor of vehicles trafficking in the surrounding area of Buon Ho Trial Road. The conversion factors and traffic data allow engineers to back-calculate the total traffic of each trial sections from the time when construction was completed and opened to traffic to time when first sign of distressed sections had been identified.

LOCATION OF SURVEY AND METHODOLOGY

Due to the current physical condition of the trial road, many of diverted traffic, especially heavy trucks which used to take this short-cut, have no longer used this trial road. To capture axle loading of different type of vehicles and especially heavy trucks which used to access and primarily contributed to the failure of some sections of the trial. Axle load survey was carried out at two different locations. One station located on the trial road where another station located on Provincial Road No 683. Figure 1 shows locations of axle loading stations.

Traffic weighting were conducted during the day (from 8:00 am to 5:00 pm) for a period of 3 days consecutive (one day on Buon Ho Trial Road and 2 days on Road No 683) bus and trucks from both directions were weighted and recorded.

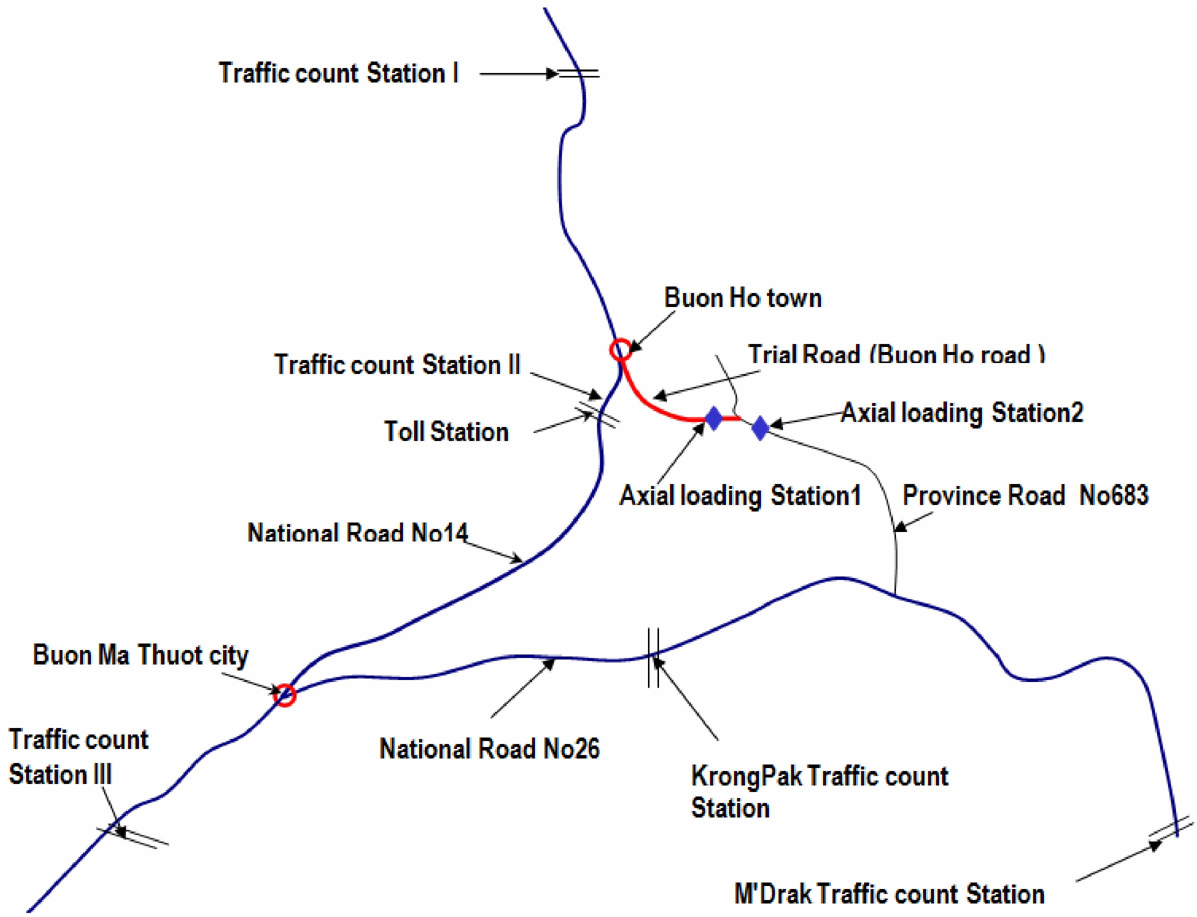


Figure 1: Location of Axle Loading Station

CLASSIFICATION OF VEHICLES

It was in our intention to classify vehicles type according to classification used in traffic survey (Table 3.4 of Study's Main Report). However, a simplified classification as given in Table 1 below which reflects the actual composition of traffic and axle loading pattern found from this survey. These were associated to number reasons:-

- **Light truck 2 axles:** It was found that trucks with 2 axles should be classified into two different categories in regard to the maximum loading capacity. Thus trucks with two axles are classified into Light Truck 2 Axles and Medium Truck 2 Axles.

- **Light Truck 3 axles:** there are military vehicles with 3 single axles (usually with axle configuration of 1.11). This type of truck normally has small loading capacity in cubic metre thus low axle loading. This truck should be classified as medium truck 2 axles in term of it effect to damage of pavement. However there was no vehicle of that type been recorded during the 3 days-survey. It was also observed that this kind of truck is rarely found on the road network. Therefore light truck 3 axles was omitted from table 1 below.

- **Medium truck 3 axles**: it is not easy to distinguish between medium and heavy truck with 3 axles. It can be done if axle load survey was coupled with detail questionnaire for which we would have to stop all truck to ask driver questions. Moreover, it was observed there were trucks which have smaller loading capacity carried more load than truck with bigger body. Therefore it would be better accurate and much simple for designer to use these axle load information and conversion factors to design other roads if truck with 3 axles be classified into one category as **Heavy Truck 3 axles**.

- **Standard and Tipper Trucks**: the survey also identified there were big differences of axle loading between tipper-truck and standard truck of same type and therefore it is important to differentiate between the two vehicle types.

- **Heavy truck ≥ 4 axles**: traffic count report classifies heavy truck of 4 or more axles into one category. But the survey has captured data of trucks with 4 axles only. Therefore the conversion factor calculated from data of this survey should cover **Heavy truck with 4 axles** only.

Table 1 below provides detail classification of vehicle and codes used in this axle load survey report where Figure 2 summarises axle load configuration according to ORN40[5].

[5] Overseas Road Notes 40 "A Guide to the Measurement of Axle Loads in Developing Countries using a Portable Weighbridge",

Table 1: Vehicle types and classification

Vehicle	common axles configuration	Code (*)
Car	1.1	C1
Mini bus < 20 seats	1.1	C2
Large bus >20 seats	1.1 or 1.2	C3
Light truck 2 axle	1.1 or 1.2	T1: for normal truck
		T1+: for tipper truck
Medium truck 2 axle	1.1 or 1.2	T2: normal truck
		T2+: tipper truck
Heavy truck 3 axles	11.2 or 1.22	T3: normal truck
		T3+: tipper truck
Heavy Truck 4 axles	1.222 or 11.22	T4

(*): used in this axle load report

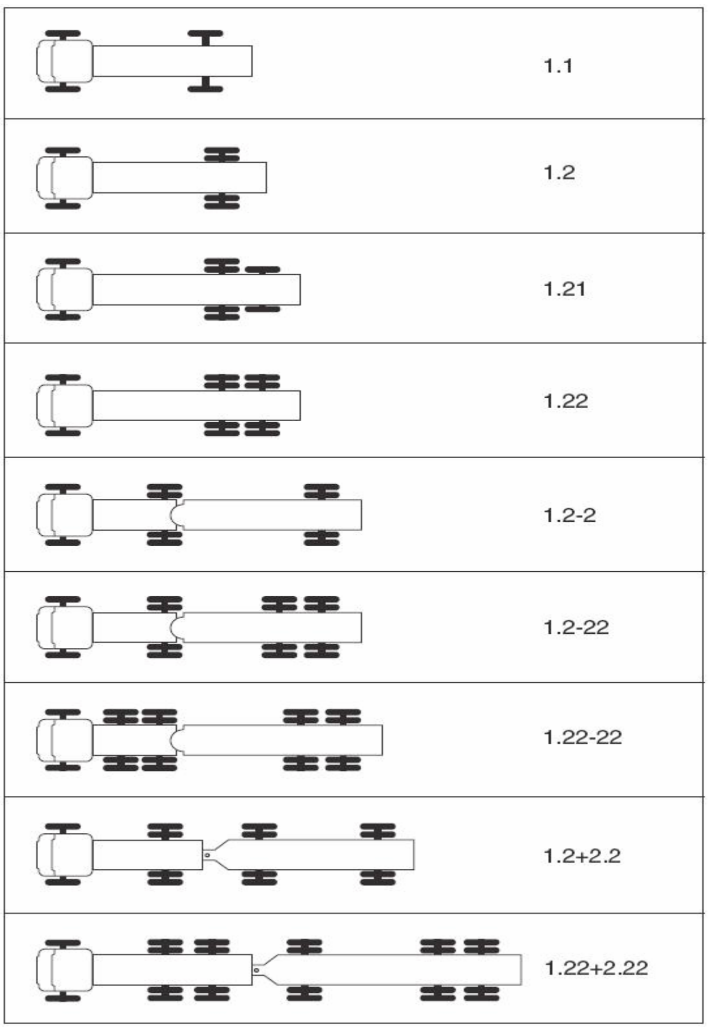


Figure 2: Axle Configuration (Extracted from ONR40)

CALCULATION OF CONVERSION FACTOR FOR EACH VIHICLE TYPE

Data from all three days survey were put together for the calculation of an average conversion factor of each vehicle type without making a distinction between traffic directions. This is because the objective of conducting this axle survey is to get reliable data on axle loading of various vehicle types being used in the area based for the calculation of average conversion factors of each vehicle class. Therefore the greater number of vehicle samples the smaller the error..

It should also noted that cars were not weighed during this survey because:- (i) the effect from very light vehicle such as car on the pavement structure is negligible; (ii) there were reliable data of axle loading conducted in October 2006 under the Rural Road Surfacing Research Phase II Project (RRST-II). Data from RRST-II survey was used for the calculation of equivalent factor for car.

The equivalence factors for each of the wheel loads on are determined from the following formula:-

$$EF = [\text{Axle Load (kg)} \div 8160]^{4.55}$$

The factors for the axles are totalled to give the equivalence factor for each of the vehicles.

The mean equivalence factor for all vehicles of same class travelling in both directions can then be determined by adding up the equivalence factors and dividing by the numbers of vehicles.

Table 2 below gives summary on total number of vehicle weighted, estimation on loading status noted by field surveyors and the conversion factors for each vehicle type calculated from data of the survey.

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Table 2: Mean conversion factors for each vehicle type in ESA[6]

Description	Code	Total vehicles weighted	Estimated loading status		Mean conversion
			Empty	Partial, fully and over loaded	
Car	C1	17			0.0002
Mini bus < 20 seats	C2	21	29%	71%	0.006
Large bus >20 seats	C3	9	11%	89%	1.64
Light truck 2 axle	T1: for normal truck	135	54%	46%	0.015
	T1+: for tipper truck	11	27%	73%	0.074
	T1 & T1+ mixed	146	52%	48%	0.02
Medium truck 2 axle	T2: normal truck	136	62%	38%	7.19
	T2+: tipper truck	33	45%	55%	11.97
	T2 & T2+ mixed	169	59%	41%	8.12
Heavy truck 3 axles	T3: normal truck	26	69%	31%	7.96
	T3+: tipper truck	35	23%	77%	15.46
	T3 & T3+ mixed	61	43%	57%	12.26
Heavy Truck 4 axles	T4	7	43%	57%	45.11(*)

(*) It should note that only 7 trucks of T4 type were weighted and they were all rigid chassis. Although the data is well distributed between laden and un-laden which should provide an acceptable average conversion, there is big different between the conversion factor of laden truck of this type which varies from 5 esa to 150 esa. This T4's factor shown in above table should be considered as an indication only.

ALLOWABLE LIMIT AND ACTUAL AXLE LOADS

According to Vietnamese road design standards (22 TCN 211-2006) and (22TCN 210-92) axle loading limits for each category of roads is summarised in Table 3 below.

Table 3: Axle Loading Limits

Road Category	Axle load limit	Standard References
National trunk highway, Arterial road, industrial zones etc.	12 tons	22 TCN 211-2006
General road network, highway, urban, streets and other lower level roads.	10 tons	22 TCN 211-2006
Rural road class A	6 tons	22TCN 210-92
Rural road class B	2.5 tons	22TCN 210-92

Table 4 below summarises average and maximum axle loads of fully load trucks. This table also shows that:

[6] Equivalent Standard Axle Load

- The average axial of tipper truck is higher that standard truck same category. But, except for light truck, the highest axle loads recorded were found on normal truck which is contrary to many peoples' perception.
- Medium trucks 2 axles (T2) were found having highest axle load. Because there are trucks of this category have same laden capacity of heavy truck 3 axles.
- The highest axle load recorded is more than twice of allowable axle load limit of national and provincial road networks and 4 times of the limit of Rural Road Class A.

Table 4: Average and Maximum Axle Load of Fully Load Trucks in Tones

Vehicle type		Average axle load		Maximum axle load		Total weight	
		Front	Rear	Front	Rear	Average	Maximum
Light truck 2 axle	T1	2.1	3.1	**4.3**	**5.3**	5.3	8.2
	T1+	2.7	4.0	**3.9**	**11.1**	6.7	11.1
Medium truck 2 axle	T2	5.1	11.5	**11.1**	**25.2**	16.6	36.3
	T2+	6.6	14.5	**8.9**	**19.6**	21.1	26.5
Heavy truck 3 axles	T3	7.1	10.9	**11.8**	**21.5**	17.4	52.1
	T3+	6.8	14.2	**9.2**	**18.8**	35.3	43.5
Heavy Truck 4 axles	T4	9.5	13.8	**11.4**	**22.5**	50.8	62.8

CURRENT TRAFFIC COMPOSITION ON BUON HO TRIAL ROAD

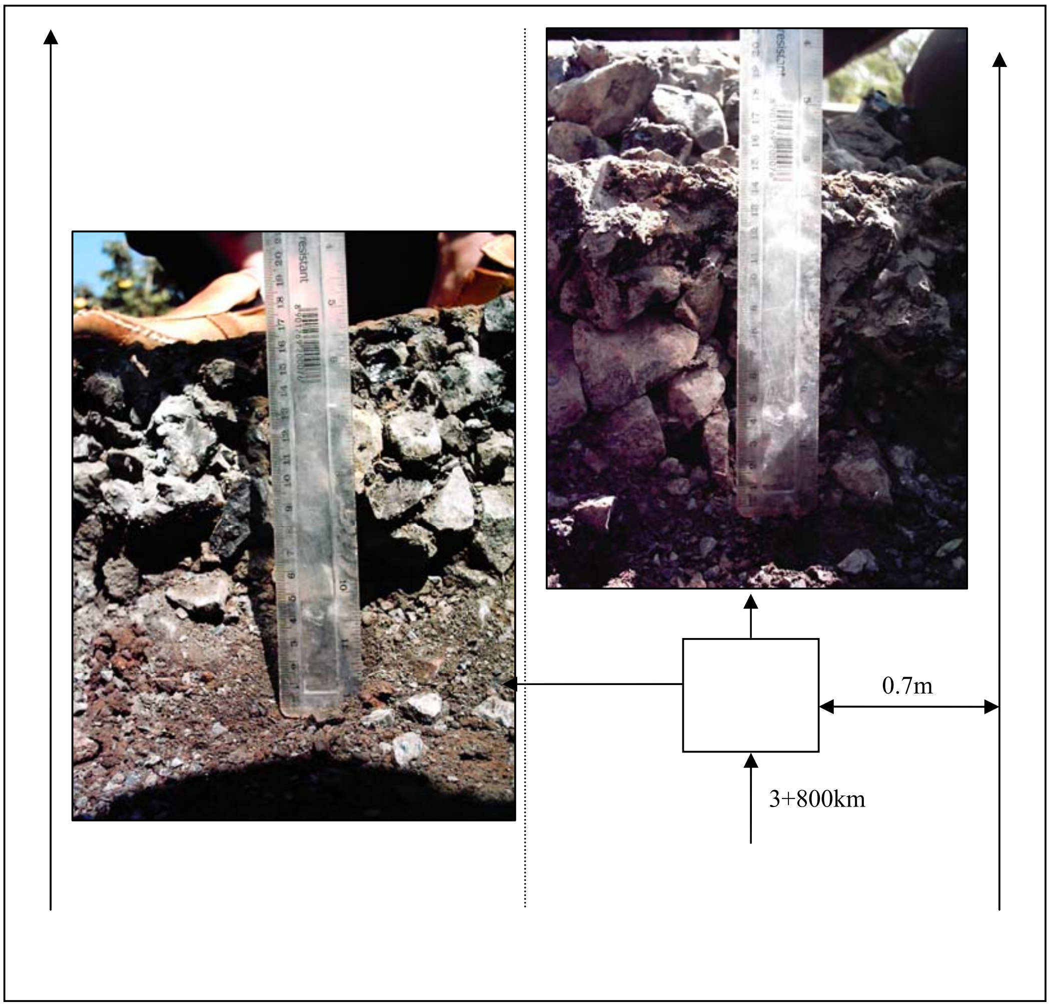
The data of survey conducted on Buon Ho trial road show that medium truck 2 axles and heavy truck 3 axles continues to use the trial road despite some difficulty form its broken sections which have not yet been repaired. This means that the trial continues to suffer from extreme overloading. The level of extreme axle load can reach up to four time of beyond its allowable axle load design of 6 tons as recommend by Vietnamese road design standards.

CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERRIORATION

BUON HO REPORT

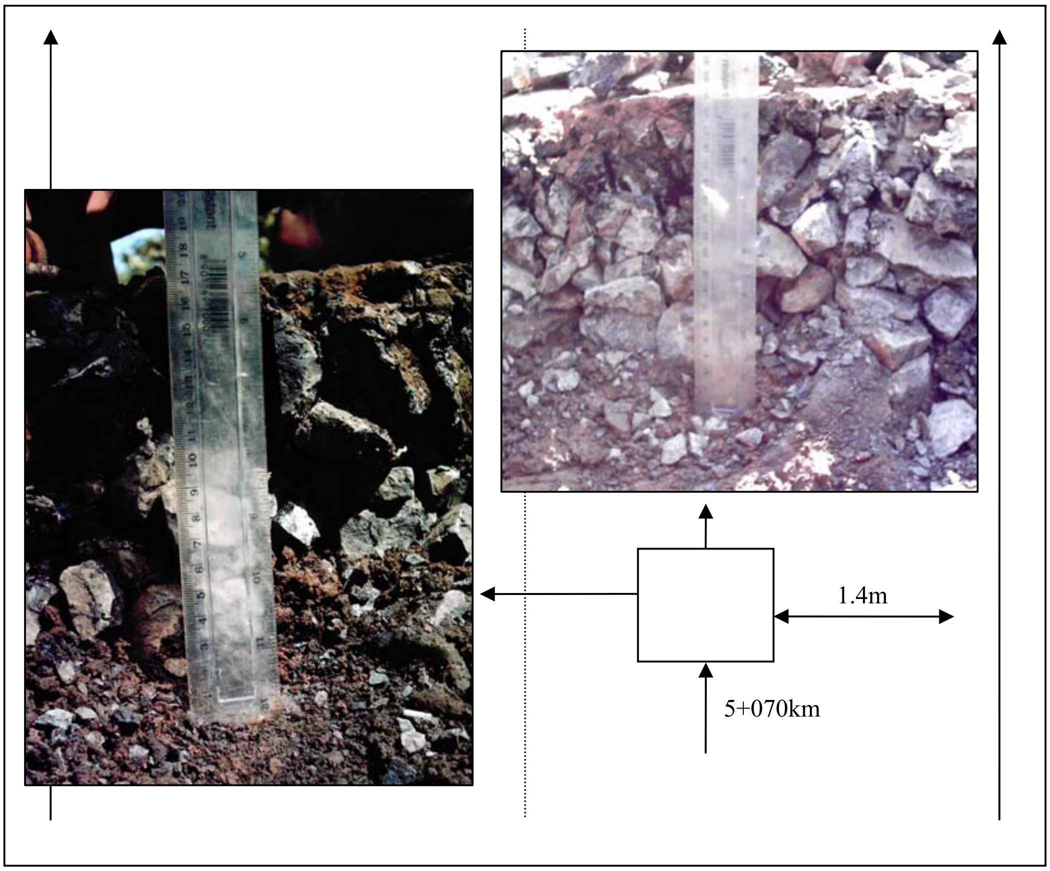
Appendix C
Inspection Pit Logs

BH1.01 Chainage 3+800km; right side	
Description	**Layer**
60mm penetration macadam, angular clean gravel-cobble, some as large as 80mm	Surface-Base
100mm thick as per design, angular aggregate, well graded WBM, with largest dimension up to 100mm.	Sub-Base
Dark brown stiff clay with some organic material.	Sub-Grade



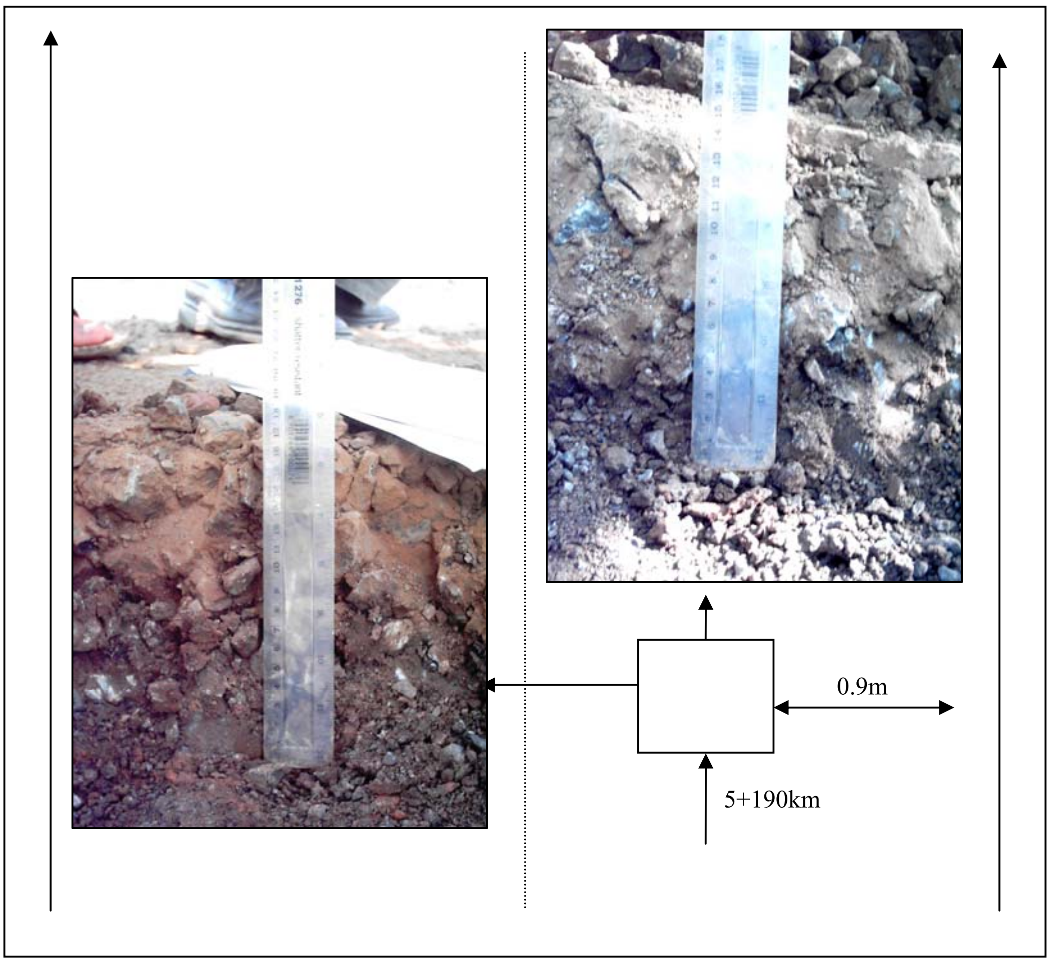
Buon Ho Test Pit 2

BH 2.01 Chainage 5+070 km; right side	
Description	**Layer**
60mm penetration macadam angular clean gravel sized aggregate	Surface/Base
100-120mm, angular aggregate, well graded WBM, largest dimension up to 90-100mm.	Sub-Base
Mottled dark brown and orange stiff clay, some fine gravel. No depression in sub-grade	Sub-Grade



Buon Ho Test Pit 3

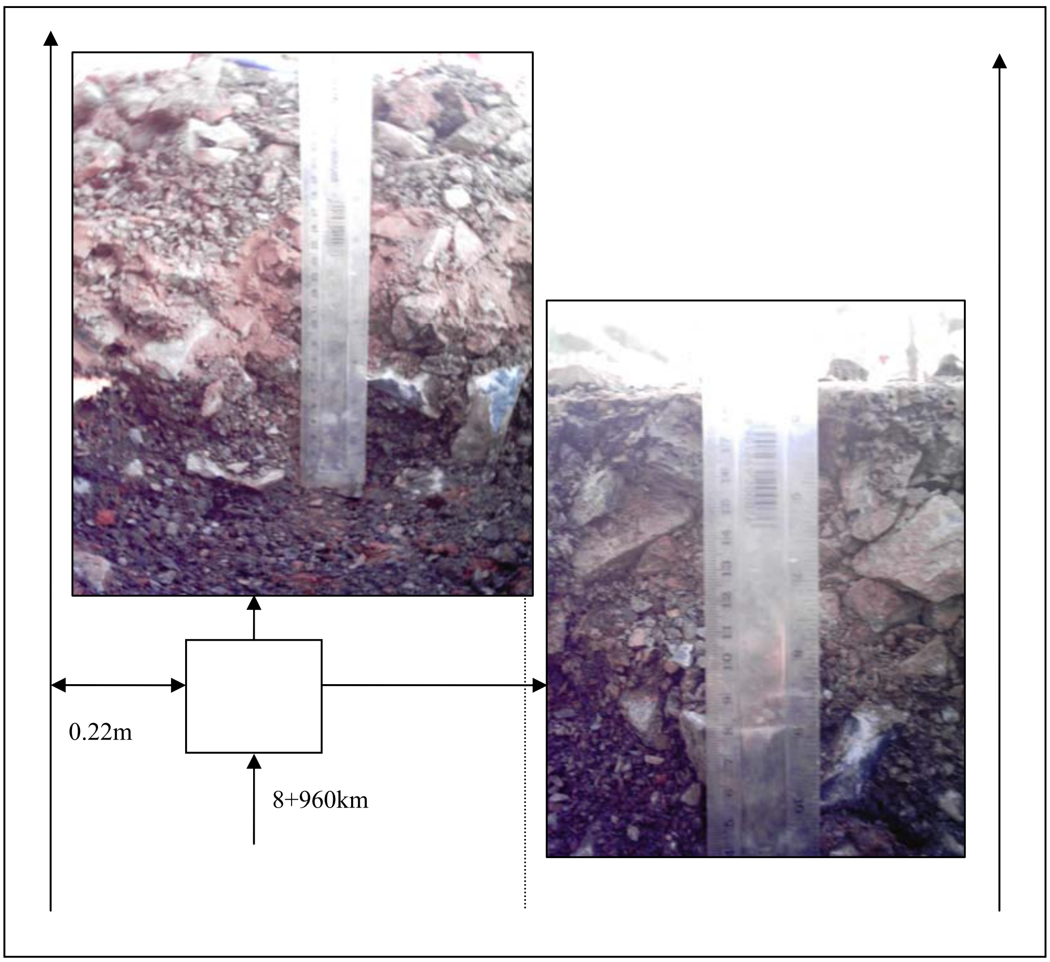
BH 2 02 Chainage 5+190 KM	
Description	**Layer**
60mm penetration macadam, angular aggregate though some clay adhered to particles.	Surface/Base
100mm angular aggregate, well graded WBM, largest dimension less than 100mm. Has clay adhered to particles.	Sub-Base
Dark brown firm clay, uneven interface with sub-base with coarse aggregate punched into top layer.	Sub-Grade



Pit was sunk in a heavily rutted section, the base materially contained significantly more clay than the previous trial pit.

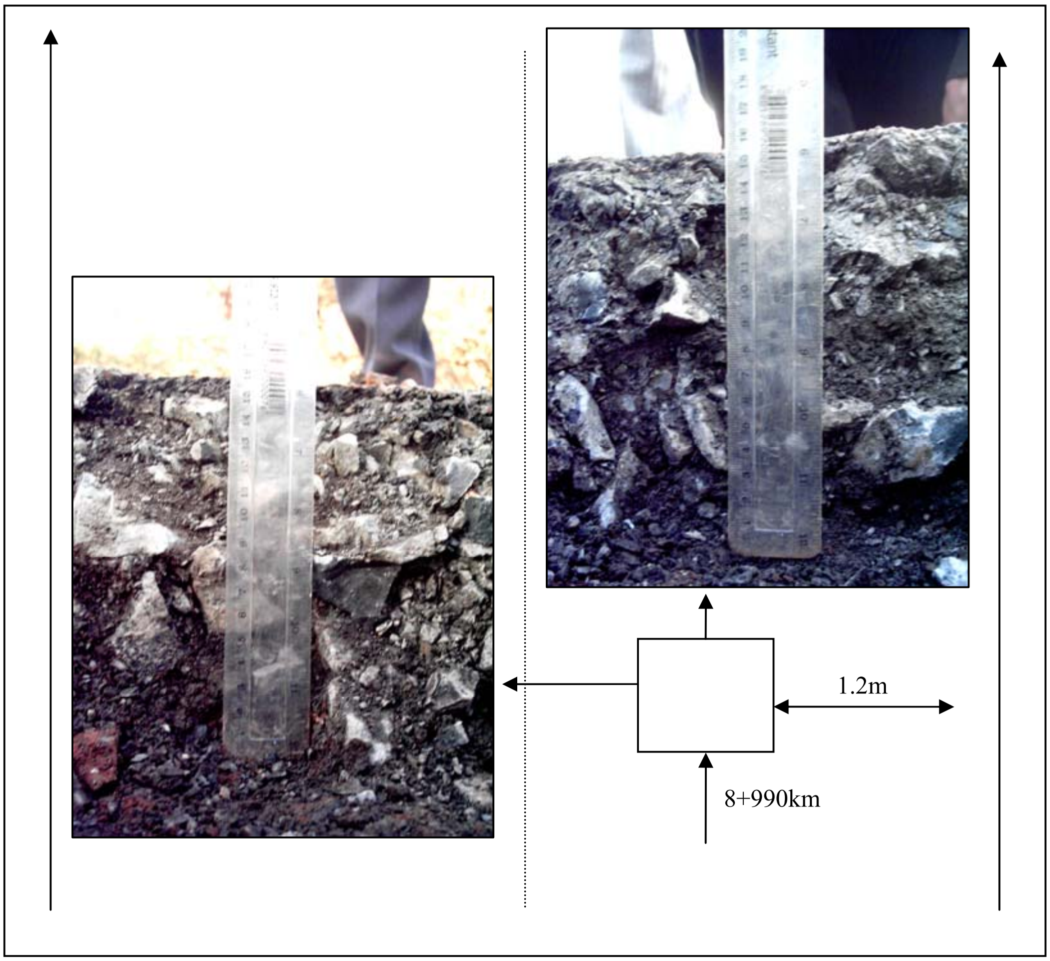
Buon Ho Test Pit 4

BH 3.01 Chainage 8+960 km, Left hand side	
Description	**Layer**
10-20mm surfacing good. 100mm base contains clay adhered to aggregate. Aggregate largest dimension up to 70mm. Distinct thin 5mm chip between layers.	Surface/Base
100mm layer of angular intact aggregate no bigger that 60-70mm	Sub-Base
Red brown clay soil	Sub-Grade



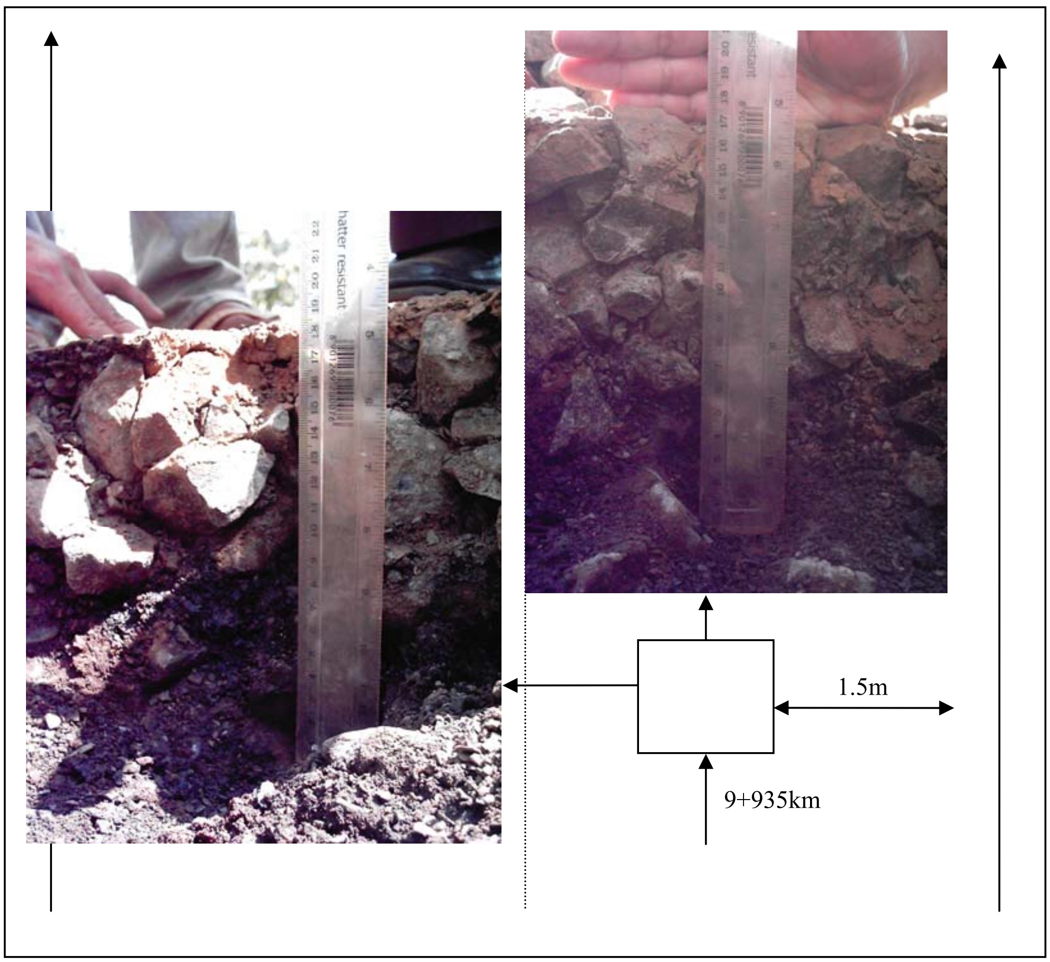
Buon Ho Test Pit 5

BH 3.02 Chainage 8+990km Right hand side	
Description	**Layer**
10mm surfacing, base 80-90mm good intact angular aggregate on average 60-70mm, overlying then fine chipping layer	Surface/Base
80-90mm clean angular aggregate, 60-70mm, not punched into sub-grade.	Sub-Base
Red brown clay firm, some fine gravel 2-3mm.	Sub-Grade



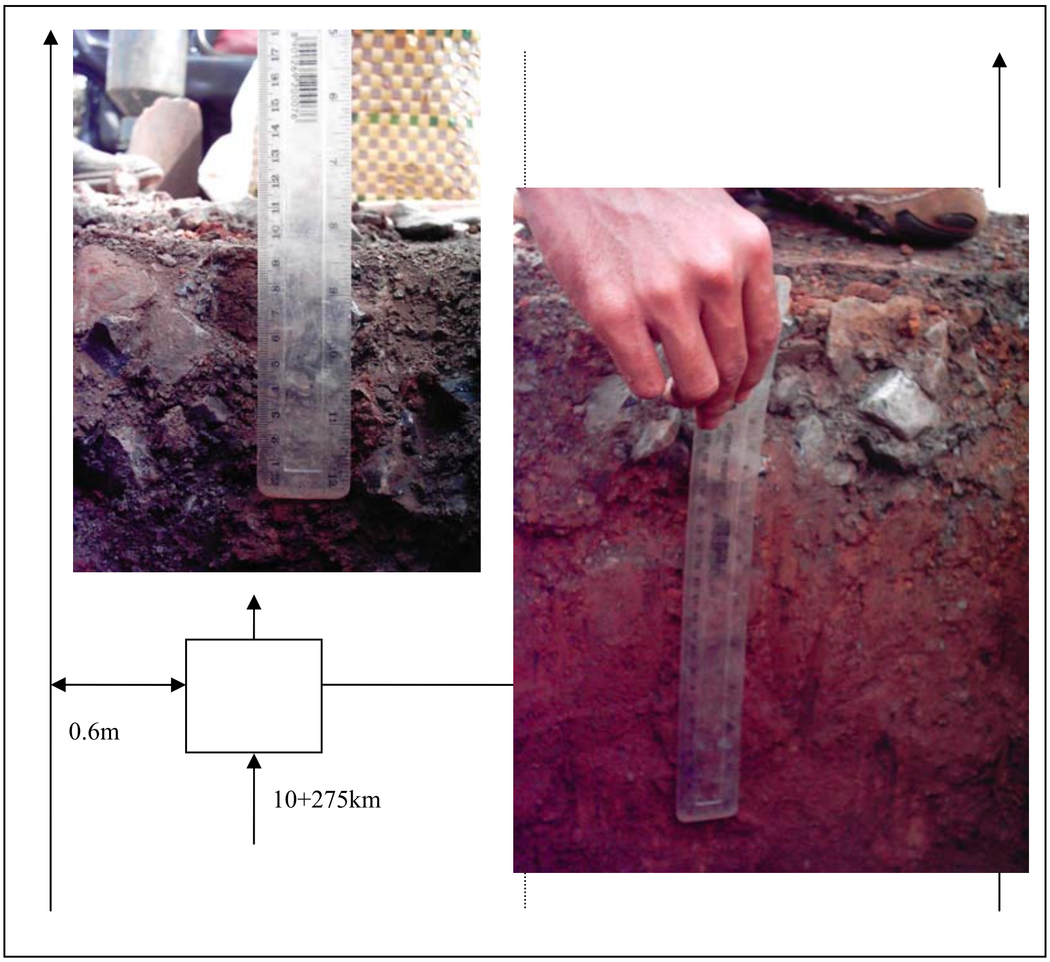
Buon Ho Test Pit 6

BH 4.01 Chainage 9+935km; Right hand side	
Description	**Layer**
5-10mm surfacing. 100mm base angular intact aggregate average 50-60mm, largest dimension less than 80mm. Slight clay content. Fine chippings layer at bottom.	Surface/Base
100mm of 40-60mm intact aggregate layer, slightly damp,	Sub-Base
Dark brown clay sub grade punctured by sub base approx 40-60mm.	Sub-Grade)



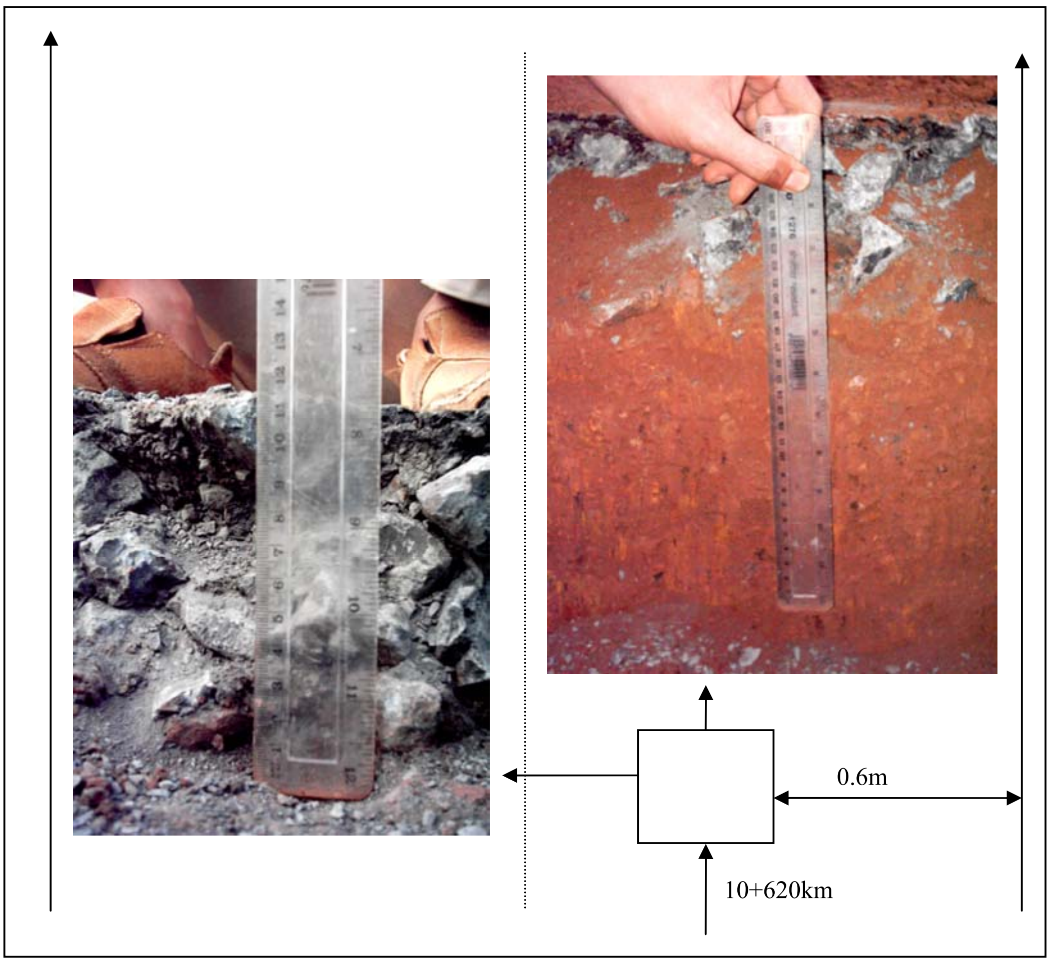
Buon Ho Test Pit 7

BH 5.01 Chainage 10+275km; Left hand side	
Description	**Layer**
5-10mm surface seal 10omm clean intact aggregate average 50-60mm, uneven interface with sub-base.	Surface/Base
200mm of light brown slightly gravelly clay with discernable layer break at 100mm. Very similar to underlying sub-grade, no clear interface.	Sub-Base
Light brown clay with fine gravel (5mm) , appears the same material as above.	Sub-Grade



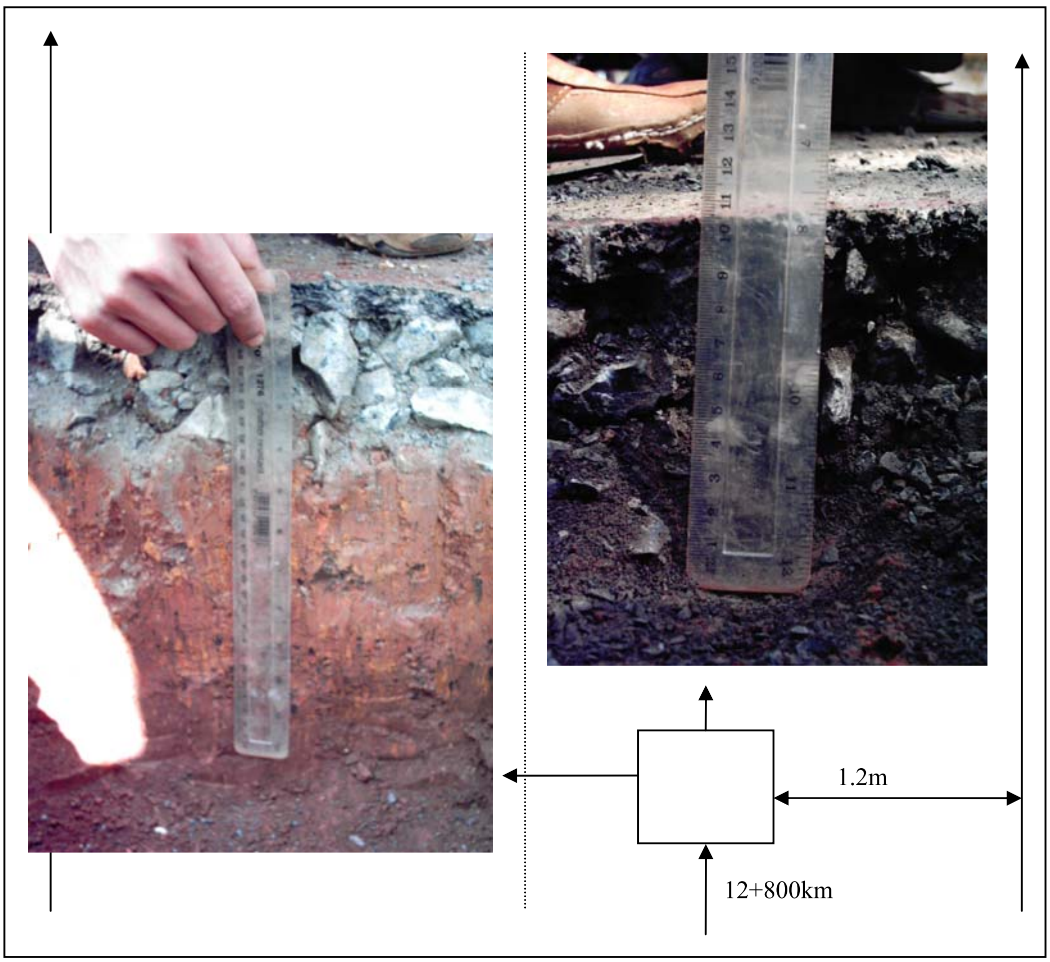
Buon Ho Test Pit 8

BH 5.02 Chainage 10+620km; Right hand side	
Description	**Layer**
10mm strong surfacing, breaks in large pieces. 100mm good angular clean aggregate, no bigger than 70mm and 50-70mm on average. Followed by thin layer of 5mm fine chippings.	Surface/Base
200mm Brown clay with fine gravel (5mm); no layering at 100mm and no apparent change to sub-grade	Sub-Base
Brown clay with some yellow flecks, no small gravel	Sub-Grade



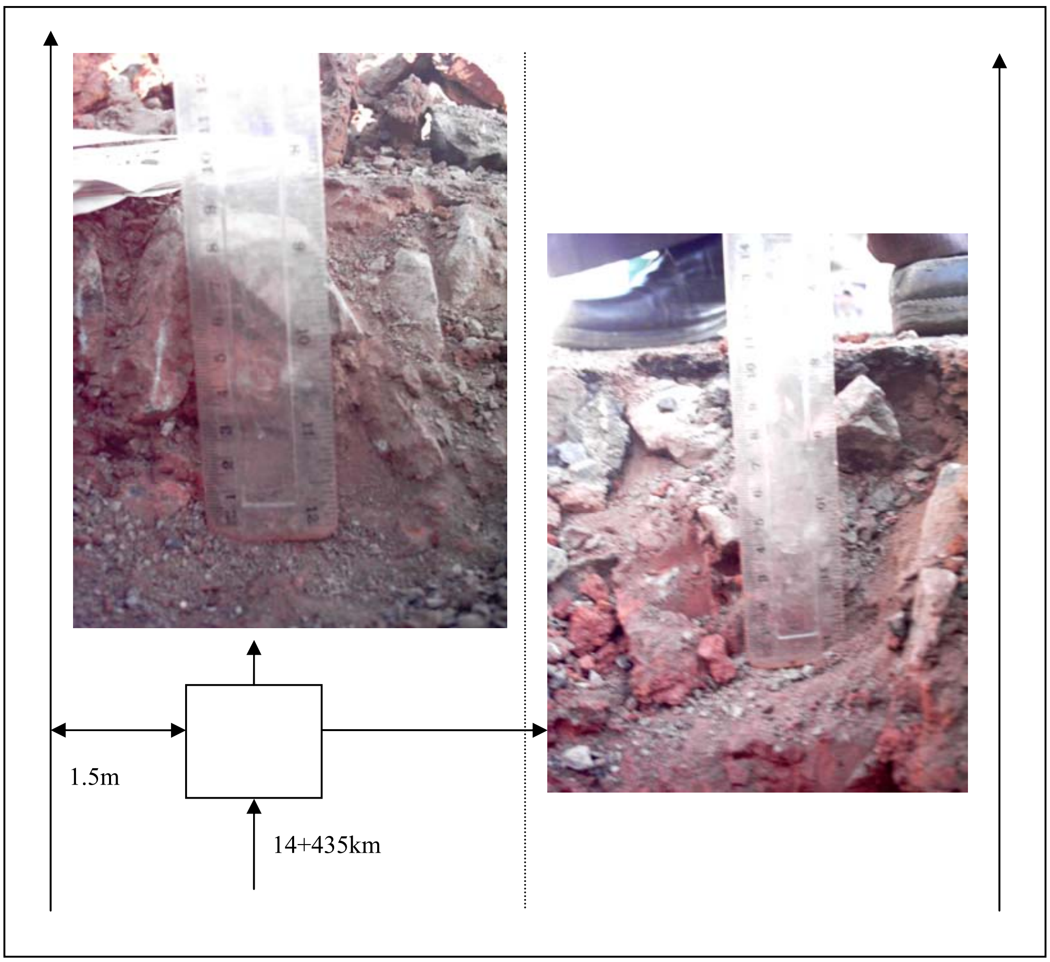
Buon Ho Test Pit 9

BH 6.01 Chainage 12+800km; Right hand side	
Description	**Layer**
10-15m dense stone surface seal, hard to break with crow-bar. 100mm- well graded angular intact aggregate; average 50-80mm	Surface/Base
200mm mottled orange-brown clay, firm-stiff with layer of gravel-cobble approximately 90-100mm at the bottom. Layer change not discernable	Sub-Base
Layer of black aggregate then brown firm clay with fine gravel.	Sub-Grade



Buon Ho Test Pit 10

BH 6 02 Chainage 14+435km; Left hand side	
Description	**Layer**
5 to 10 mm surfacing, poor quality, thin in places. 50 to 80mmof intact clean, aggregate on average 50-60mm.	Surface/Base
200mm of brown firm clay with fine gravel (5mm). Interface not deformed. Layers not discernable	Sub-Base
Brown firm clay with fine gravel (5mm), same as sub base, No discernable change to sub base.	Sub-Grade



CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERRIORATION

BUON HO REPORT

Appendix D

DCP Summaries

Appendix A.

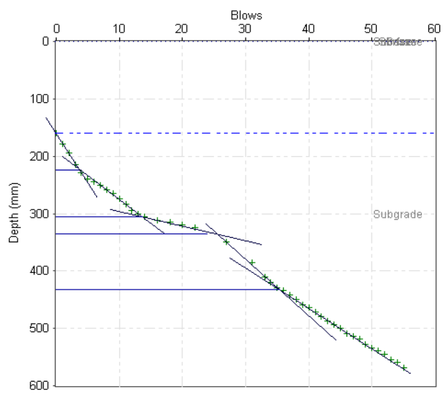
BH 1 Test Pit 1

UK DCP V2.2

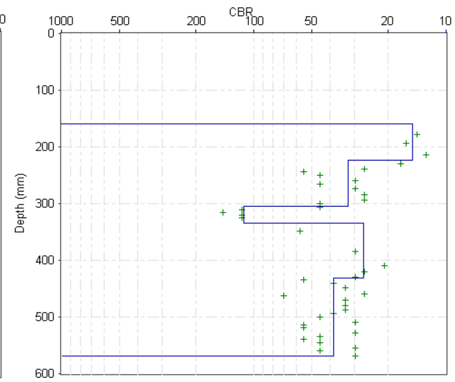
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	3.800	Surface Type:	Other
Direction:		Thickness (mm):	60
Location/Offset:	Carriageway	Strength Coeff.:	0.20
Cone Angle:	60 degrees	Base Type:	Coarse granular
Zero Error (mm):	0	Thickness (mm):	100
Test Date:	11/01/2008	Strength Coeff.:	0.13



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	17.27	15	64	224	Subgrade	0.00
2	8.27	32	81	305	Subgrade	0.00
3	2.54	113	30	335	Subgrade	0.00
4	9.82	27	97	432	Subgrade	0.00
5	7.03	38	137	569	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.47	0.47	0.47
Base	0.51	0.51	0.51
Sub-Base	--	--	--
Subgrade	--	1.72	1.72
Pavement Strength	0.98	2.70	2.70

CBR Relationship:

TRL equation: $\log_{10}(CBR) = 2.48 - 1.057 \times \log_{10}(\text{penetration rate})$

Report produced by ....

Report Date: 06-Feb-2008

Page 1 of 1

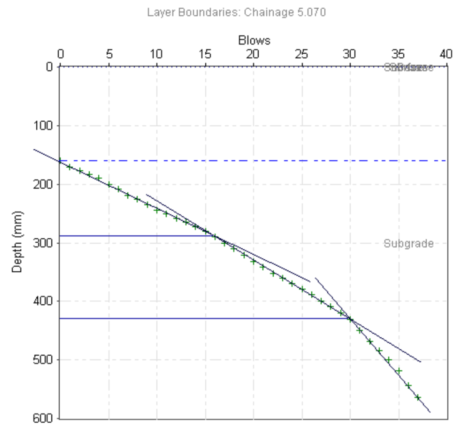
BH 2 Test Pit 1

UK DCP V2.2

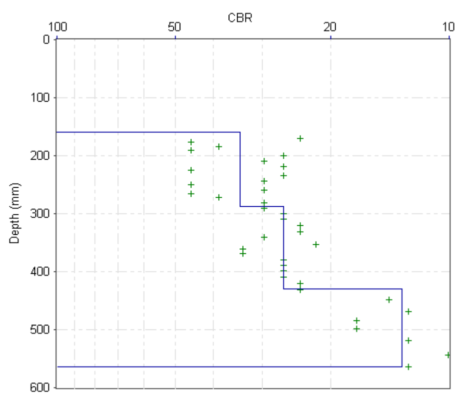
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	5.070	Surface Type:	Other
Direction:		Thickness (mm):	60
Location/Offset:	Carriageway	Strength Coeff.:	0.20
Cone Angle:	60 degrees	Base Type:	Coarse granular
Zero Error (mm):	0	Thickness (mm):	100
Test Date:	11/01/2008	Strength Coeff.:	0.13



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	7.89	34	128	288	Sub-Base	0.10
2	10.00	26	141	429	Sub-Base	0.10
3	19.35	13	135	564	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.47	0.47	0.47
Base	0.51	0.51	0.51
Sub-Base	1.06	1.06	1.08
Subgrade	--	1.43	1.26
Pavement Strength	2.04	3.47	3.32

CBR Relationship:

TRL equation: $\log_{10}(CBR) = 2.48 - 1.057 \times \log_{10}(\text{penetration rate})$

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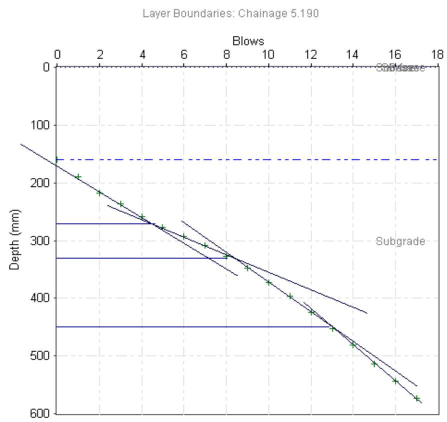
BH 2 Test Pit 2

UK DCP V2.2

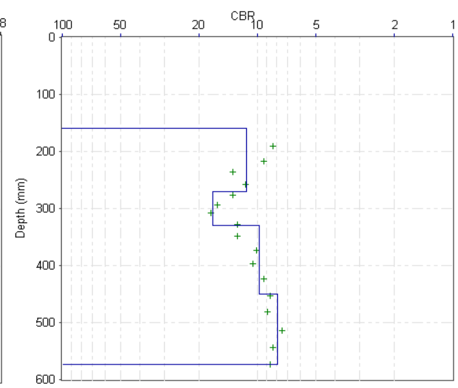
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	5.190	Surface Type:	Other
Direction:		Thickness (mm):	60
Location/Offset:	Carriageway	Strength Coeff.:	0.20
Cone Angle:	60 degrees	Base Type:	Coarse granular
Zero Error (mm):	0	Thickness (mm):	100
Test Date:	11/01/2008	Strength Coeff.:	0.13



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	22.28	11	111	271	Subgrade	0.00
2	15.26	17	59	330	Subgrade	0.00
3	25.70	10	120	450	Subgrade	0.00
4	31.40	8	123	573	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.47	0.47	0.47
Base	0.51	0.51	0.51
Sub-Base	--	--	--
Subgrade	--	1.04	1.04
Pavement Strength	0.98	2.02	2.02

CBR Relationship:

TRL equation: $\log_{10}(CBR) = 2.48 - 1.057 \times \log_{10}(\text{penetration rate})$

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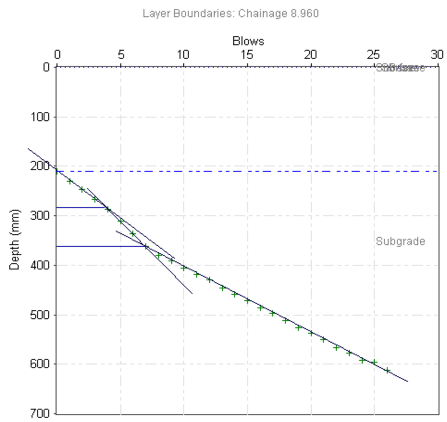
BH 3 TP 1

UK DCP V2.2

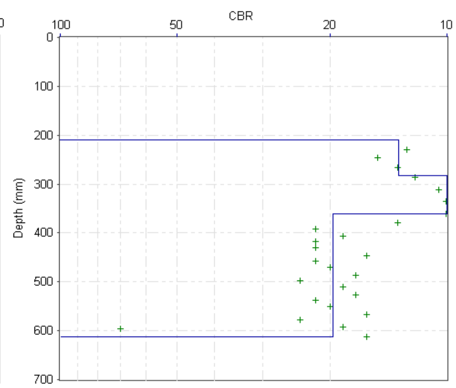
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	8.960	Surface Type:	Other
Direction:		Thickness (mm):	110
Location/Offset:	Carriageway	Strength Coeff.:	0.10
Cone Angle:	60 degrees	Base Type:	Coarse granular
Zero Error (mm):	0	Thickness (mm):	100
Test Date:	11/01/2008	Strength Coeff.:	0.13



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	19.17	13	73	283	Subgrade	0.00
2	25.97	10	78	361	Subgrade	0.00
3	13.24	20	251	612	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.43	0.43	0.43
Base	0.51	0.51	0.51
Sub-Base	--	--	--
Subgrade	--	1.30	1.30
Pavement Strength	0.94	2.24	2.24

CBR Relationship:

TRL equation: $\log_{10}(CBR) = 2.48 - 1.057 \times \log_{10}(\text{penetration rate})$

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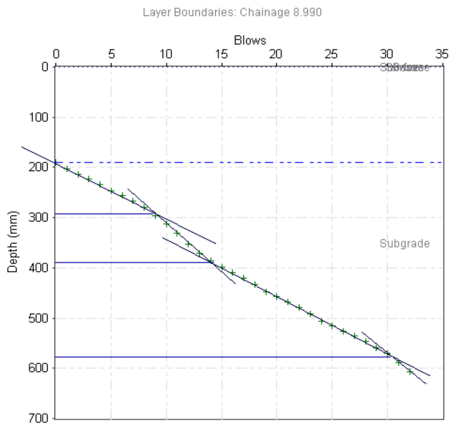
BH 3 TP 2

UK DCP V2.2

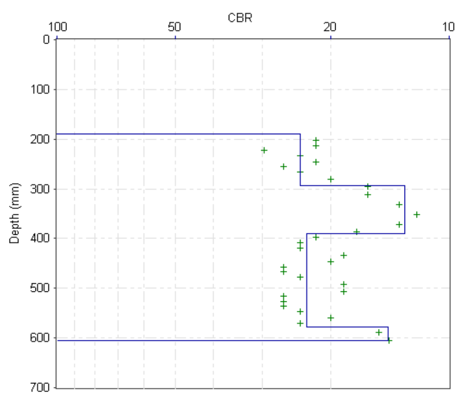
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	8.990	Surface Type:	Other
Direction:		Thickness (mm):	100
Location/Offset:	Carriageway	Strength Coeff.:	0.13
Cone Angle:	60 degrees	Base Type:	Coarse granular
Zero Error (mm):	0	Thickness (mm):	90
Test Date:	11/01/2008	Strength Coeff.:	0.13



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	10.98	24	103	293	Sub-Base	0.09
2	19.62	13	97	390	Subgrade	0.00
3	11.38	23	187	577	Subgrade	0.00
4	17.94	14	29	606	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.51	0.51	0.51
Base	0.46	0.46	0.46
Sub-Base	0.38	0.38	0.41
Subgrade	--	1.42	1.54
Pavement Strength	1.35	2.77	2.92

CBR Relationship:

TRL equation: $\log_{10}(CBR) = 2.48 - 1.057 \times \log_{10}(\text{penetration rate})$

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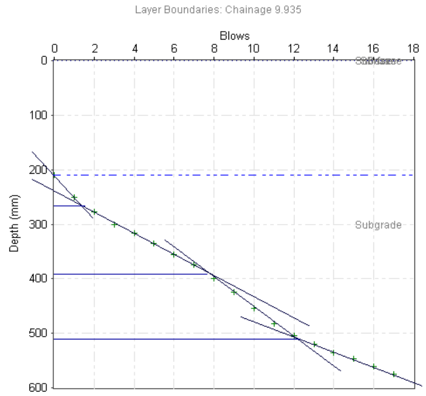
BH 4 TP 1

UK DCP V2.2

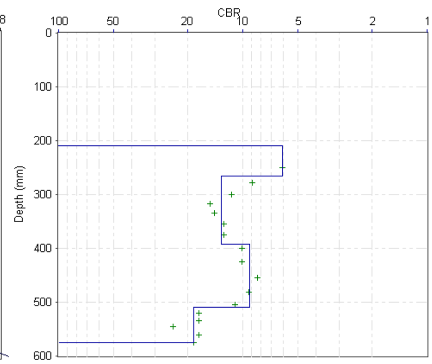
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	9.935	Surface Type:	Other
Direction:		Thickness (mm):	110
Location/Offset:	Carriageway	Strength Coeff.:	0.10
Cone Angle:	60 degrees	Base Type:	Coarse granular
Zero Error (mm):	0	Thickness (mm):	100
Test Date:	13/01/2008	Strength Coeff.:	0.13



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	40.03	6	56	266	Subgrade	0.00
2	19.39	13	126	392	Subgrade	0.00
3	27.19	9	118	510	Subgrade	0.00
4	14.07	18	65	575	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.43	0.43	0.43
Base	0.51	0.51	0.51
Sub-Base	--	--	--
Subgrade	--	1.00	1.00
Pavement Strength	0.94	1.94	1.94

CBR Relationship:

TRL equation: $\log_{10}(CBR) = 2.48 - 1.057 \times \log_{10}(\text{penetration rate})$

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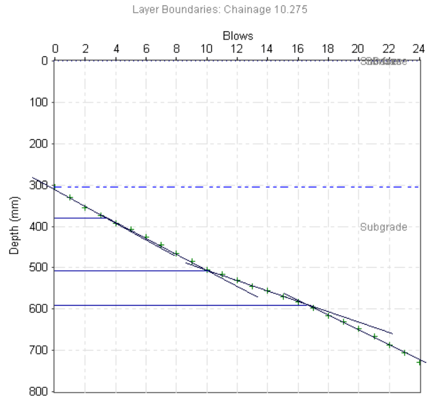
BH 5 TP 1

UK DCP V2.2

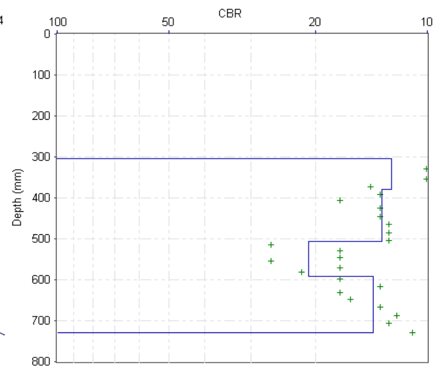
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	10.275	Surface Type:	Other
Direction:		Thickness (mm):	105
Location/Offset:	Carriageway	Strength Coeff.:	0.13
Cone Angle:	60 degrees	Base Type:	Coarse granular
Zero Error (mm):	0	Thickness (mm):	200
Test Date:	13/01/2008	Strength Coeff.:	0.11



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	20.34	13	75	380	Subgrade	0.00
2	19.21	13	127	507	Subgrade	0.00
3	12.48	21	84	591	Subgrade	0.00
4	18.25	14	139	730	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.54	0.54	0.54
Base	0.87	0.87	0.87
Sub-Base	--	--	--
Subgrade	--	1.42	1.42
Pavement Strength	1.41	2.83	2.83

CBR Relationship:

TRL equation: $\log_{10}(CBR) = 2.48 - 1.057 \times \log_{10}(\text{penetration rate})$

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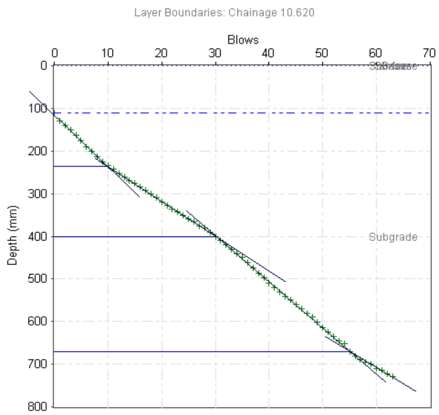
BH 5 TP 2

UK DCP V2.2

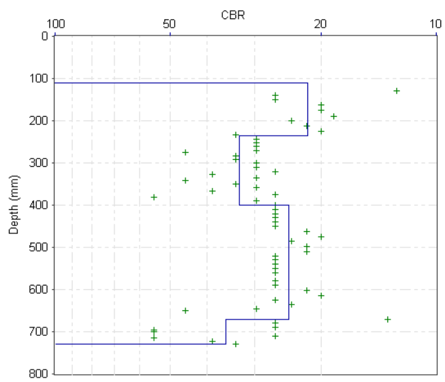
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	10.620	Surface Type:	Other
Direction:		Thickness (mm):	20
Location/Offset:	Carriageway	Strength Coeff.:	0.13
Cone Angle:	60 degrees	Base Type:	Coarse granular
Zero Error (mm):	0	Thickness (mm):	90
Test Date:	13/01/2008	Strength Coeff.:	0.13



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	12.08	22	125	235	Sub-Base	0.09
2	8.15	33	166	401	Sub-Base	0.10
3	10.84	24	270	671	Subgrade	0.00
4	7.56	36	59	730	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.10	0.10	0.10
Base	0.46	0.46	0.46
Sub-Base	1.12	1.12	1.12
Subgrade	--	1.80	1.52
Pavement Strength	1.68	3.48	3.20

CBR Relationship:

TRL equation: $\log_{10}(CBR) = 2.48 - 1.057 \times \log_{10}(\text{penetration rate})$

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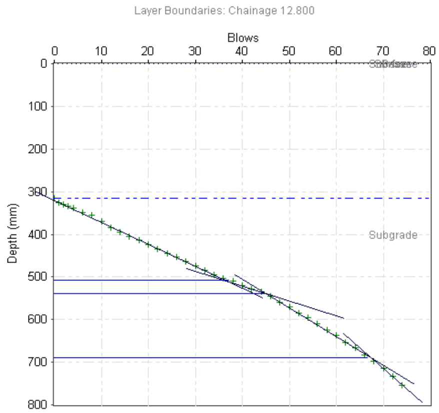
BH 6 TP 1

UK DCP V2.2

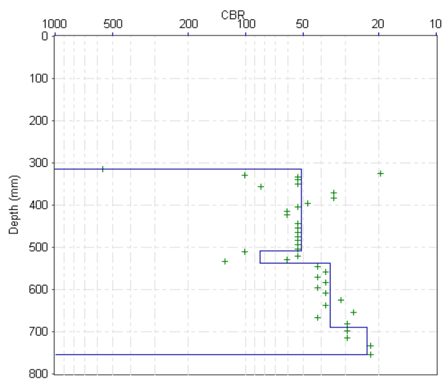
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	12.800	Surface Type:	Other
Direction:		Thickness (mm):	115
Location/Offset:	Carriageway	Strength Coeff.:	0.13
Cone Angle:	60 degrees	Base Type:	Coarse granular
Zero Error (mm):	0	Thickness (mm):	200
Test Date:	13/01/2008	Strength Coeff.:	0.11



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	5.16	51	193	508	Sub-Base	0.11
2	3.49	84	30	538	Sub-Base	0.11
3	6.76	36	151	689	Sub-Base	0.10
4	9.63	23	65	754	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.59	0.59	0.59
Base	0.87	0.87	0.87
Sub-Base	1.59	1.59	1.53
Subgrade	--	1.78	1.29
Pavement Strength	3.05	4.83	4.28

CBR Relationship:

Kleyn equation: [Strength > 2] CBR = 410 x Strength$^{(-1.27)}$; [Else] 66.66 x Strength^2 - 330 x Strength + 563.33

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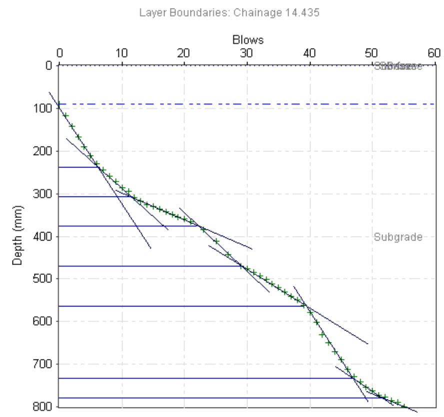
BH 6 TP 2

UK DCP V2.2

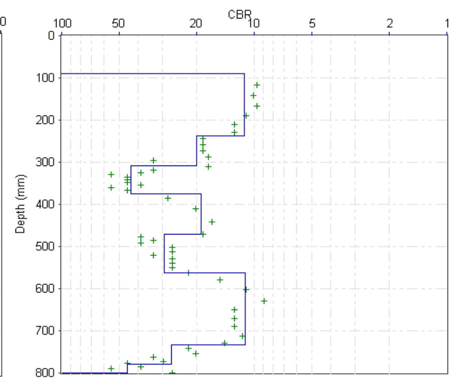
DCP Layer Strength Analysis Report

Project Name: daklak - Buon ho

Chainage (km):	14.435	Surface Type:	Other
Direction:		Thickness (mm):	90
Location/Offset:	Carriageway/1.50m	Strength Coeff.:	0.13
Cone Angle:	60 degrees	Base Type:	
Zero Error (mm):	0	Thickness (mm):	
Test Date:	13/01/2008	Strength Coeff.:	



Layer Boundaries Chart



CBR Chart

Layer Properties

No.	Penetration Rate (mm/blow)	CBR (%)	Thickness (mm)	Depth (mm)	Position	Strength Coefficient
1	22.51	11	148	238	Subgrade	0.00
2	13.16	20	70	308	Subgrade	0.00
3	6.25	43	67	375	Subgrade	0.00
4	13.73	19	96	471	Subgrade	0.00
5	9.10	29	92	563	Subgrade	0.00
6	22.59	11	170	733	Subgrade	0.00
7	9.89	27	46	779	Subgrade	0.00
8	5.98	46	21	800	Subgrade	0.00

Pavement Strength

	Layer Contribution		
Layer	**SN**	**SNC**	**SNP**
Surface	0.46	0.46	0.46
Base	--	--	--
Sub-Base	--	--	--
Subgrade	--	1.32	1.32
Pavement Strength	0.46	1.78	1.78

CBR Relationship:

TRL equation: $\log_{10}(CBR) = 2.48 - 1.057 \times \log_{10}(\text{penetration rate})$

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CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERRIORATION

BUON HO REPORT

APPENDIX E

Visual Survey Summaries

Summary of the Buon Ho Visual Condition Survey

Section	From(km)	To (Km)	Pavement Condition	Shoulder Condition	Surface drainage	Side drainage	Water-table
1	**3.700**	**4.166**	**Option CH8b**				
1.1	3.700	4.000	In general in good condition, almost no cracking or rutting. Isolated cracking and rutting in one sub -section (small isolated, not connected cracking <10 % and rut of 10 to 20 mm.	Sealed WBM in good condition. Slight loss of fine aggregate	Adequate pavement and shoulder cross-fall, good run-off	Left side drain with grass infill but still functional Right side: missing in some sub-sections and with grass in the remaining but still functional.	Not definable
1.2	4.000	4.166	Pavement very bad, severe crocodile cracking and rutting, badly damaged in some sub-sections. Significant shallow potholes in the last 50 m, average rut depth 100 mm on the left and 200 mm on the right.	Sealed WBM in good condition. Slight loss of fine aggregate	Poor pavement and shoulder cross-fall impeding run-off	Left side: grass filled but still functioning Right side severe defects at the last 100m, the remaining still functioning well.	Not definable
2	**5.100**	**5.316**	**Option CH8b**				
2.1	5.100	5.316	Very bad condition. Severe crocodile cracking and separation making the pavement rough, pavement structure badly damaged in some sub-sections. Cracking >50% in majority of sub-sections, elsewhere 10-50%. Significant shallow potholes; average rut depth 150mm	Severe defects in WBM shoulders with ruts and related shoving, some areas.	Surface run-off severely impeded by pavement and shoulder shape and ruts .	No drainage at the last 100m – the remaining grass filled but still functional	Not definable
3	**8.600**	**9.100**	**Option CH5**				
3.1	8.600	8.800	LHS condition is moderately bad; crocodile cracking in small area (<10%) crack width <3mm; few potholes, average rut depth 50mm. RHS is in better condition with some isolated longitudinal cracks in the ruts in some sub-sections. Area of small cracks <10% no potholes, rut depth about 20mm	Sealed DBM in good condition. Slight loss of fine aggregate	.Drainage largely unimpeded.	LHS no drainage over 50% of section- remaining with grass infill but functioning. RHS – grass filled but functioning	Not definable

Section	From(km)	To (Km)	Pavement Condition	Shoulder Condition	Surface drainage	Side drainage	Water-table
3.2	8.800	9.100	Pavement in poor condition. Rough due to stripping of seals, crocodile cracks >50%, crack width>3mm. Significant spalling of seal. Significant potholes and pavement settlement. Rut depth up to 200mm. In some sub-sections pavement structure is essentially destroyed.	DBM – severe defects, rutting and shoving in some spots.	Pavement run-off severely hampered by loss of shape.	Grass in LHS and RHS – still functioning.	Not definable
4	**9.100**	**10.100**	**Option CH4**				
4.1	9.100	9.300	Pavement in bad condition. Rough due to large stripping of seals, crocodile cracks >50%, crack width>3mm. Significant spalling of seal. Significant potholes and pavement settlement. Rut depth up to 200mm. In some sub-sections pavement structure is essentially destroyed.	DBM – severe defects, rutting and shoving in some spots.	Pavement run-off severely hampered by loss of shape.	LHS – grass but still functioning. RHS – almost no drainage after first 50m	Not definable
4.2	9.300	9.400	In general in good condition; slight stripping of seal, isolated longitudinal cracks in ruts on RHS. Cracked <10%, width <3mm. No potholes, rut depth 10mm.	DBM – good condition, slight loss of fine aggregate	Good run-off unimpeded by pavement and shoulder shape.	No drainage	Not definable
4.3	9.400	9.550	In general in fair condition, crocodile cracks in small areas <10%- surface fairly rough; some shallow potholes, average rut depth 20mm.	DBM – good condition, slight loss of fine aggregate	Good run-off unimpeded by pavement and shoulder shape	No drainage.	Not definable
4.4	9.550	9.800	In general in good condition, no cracks, only fairly rough due to slight loss of seal aggregate. Some shallow No ruts	DBM – good condition, slight loss of fine aggregate	Good run-off unimpeded by pavement and shoulder shape	No drainage	Not definable

Section	From(km)	To (Km)	Pavement Condition	Shoulder Condition	Surface drainage	Side drainage	Water-table
4.5	9.800	10.000	LHS cracks in alternate sub-sections on RHS more cracked sections – majority of crocodile cracks with area of 10-50% and sometimes more than 50%. Rough chipping surface. Significant shallow potholes, average rut depth 30mm – occasionally 150mm .	DBM – good condition, slight loss of fine aggregate	Surface run-off impeded slightly by pavement shape	LHS – none at last 50m – remaining grass-filled but functioning No right side drainage	Not definable
4.6	10.000	10.100	In good condition, with slight lost of seal surface, no cracking and slight rutting, average depth 20 mm.	Sealed DBM in good condition. Slight loss of fine aggregate	Surface run-off impeded slightly by pavement shape	No drainage	Not definable
5	**10.100**	**12.600**	**Option CH3**				
5.1	10.100	10.150	In good condition, with slight lost of seal surface, no cracking and slight rutting, average depth 20 mm	Sealed DBM in good condition. Slight loss of fine aggregate	Surface run-off impeded slightly by pavement shap	LHS – none. RHS functioning well	Not definable
5.2	10.150	10.200	Pavement in very poor condition, severe crocodile cracking and rutting – pavement structure is essentially destroyed in some sub-sections. Many shallow potholes. Rut depth up to 300mm on LHS, 250mm on RHS.	DBM with severe defects – rutting and shoving and cracking in many locations	Run-off severely impeded by pavement and shoulder shape	None	Not definable
5.3	10.200	10.600	LHS fairly good, almost no cracking apart from Km10+450 - Km10+500 where crocodile cracking <10%. Almost no potholes, but rutting about 15mm deep. RHS mainly interconnected crocodile cracking average 10-50%, significant potholes, rut depth about 40mm.	DBM in fairly good condition –only first 50m of LHS with cracking	Good run-off unhindered by pavement and shoulder shape.	LHS none on a 100m section, remaining drain functioning well. LHS similar apart from 150m	Not definable
5.4	10.600	10.850	Pavement in fairly good condition – slightly rough due to slight stripping of seal, almost no cracking or rutting.	Gravel shoulder slightly eroded	Run-off slightly hindered by high vegetation on LHS.	Drainage functioning well.	Not definable

Section	From(km)	To (Km)	Pavement Condition	Shoulder Condition	Surface drainage	Side drainage	Water-table
5.5	10.850	11.000	Pavement in bad condition, crocodile and large scale longitudinal cracking especially at the last 100 m. The cracks are wide and separated making pavement rough; in some sub-sections pavement structure is destroyed. Significant potholes, average depth of rut 50 mm.	Gravel shoulder is slightly to moderately eroded.	Run-off badly impeded by to poor pavement shape	Drainage is functioning fairly well	Not definable
5.6	11.000	11.400	LHS is fairly good, only isolated cracking at sub-section Km1+200 - Km1+250, cracking area <10 %, however significant potholes, rut depth of about 20 mm. RHS with crocodile cracking in some sub-sections. Cracking area from 0 – 50 % occasionally 50 %. Significant potholes, average rut depth 20 mm occasionally 80 mm.	Gravel shoulder is slightly eroded on the left side. On the right hand side many sub-sections eroded severely with rutting and related shoving.	Slightly hindered by shoulder and pavement shape apart from sub-section Km11+200 - Km11+250.	Left drains: operating well. Right: 50 % of sub-section no drainage. The remaining functioning well	Not definable
5.7	11.400	11.800	Pavement in good condition, seal layer is slightly rough, no cracking and negligible rutting.	Gravel shoulder is slightly to moderately eroded	. Good unimpeded run-off	Drainage still functioning well	Not definable
5.8	11.800	12.100	Pavement is in very bad condition, severe crocodile cracking especially at the right hand side. Cracks are wide and separated; in some sub-sections pavement structure is essentially destroyed. Many potholes, average rut depth 100 mm.	Gravel shoulder is moderately to severely eroded.	Pavement run-off is impeded by pavement shape at 150 m at the edge of left shoulder, and by shoulder shape	Drainage still functioning well	Not definable
5.9	12.100	12.300	Pavement is moderately good, almost no cracking apart from occasional longitudinal cracking within the last 50 m of the subsection. No potholes, average rut depth 10 mm.	Gravel shoulder is slightly eroded.	Pavement drainage is fairly good, only slightly hindered by high vegetation	Drainage still functioning well	Not definable

Section	From(km)	To (Km)	Pavement Condition	Shoulder Condition	Surface drainage	Side drainage	Water-table
5.10	12.300	12.600	Pavement is in bad condition, severe crocodile cracking especially at last half of the subsection. Cracks are wide and separated; pavement structure is essentially destroyed in some sub-sections. Cracking intensity in the majority of sub-sections >50 %. Many potholes, with average rut depth at the beginning is 30 mm and up to 250 mm at the end of the sub-sections.	Gravel shoulder is severely eroded, and totally destroyed is some sub-sections.	Pavement drainage is severely hindered by pavement and shoulder shape.	Drainage still functioning well, no left drainage at Km12+500 - Km12+600.	Not definable
6	**12.600**	**14.980**	**Option CH3**				
6.1	12.600	14.300	Pavement is in good condition, seal layer is slightly rough, almost no cracking and rutting. Almost no potholes apart from isolated potholes at Km13+350 - Km14+450.	Hill gravel shoulder is in good condition, slightly eroded only.	Pavement drainage is fairly good, unhindered by pavement and shoulder shape, only slightly impeded by high vegetation	Grass filled drainage but still functioning well. No drainage at Km14+00 - Km14+300	Not definable
6.2	14.300	14.550	Pavement in bad condition, crocodile cracking over large area. Average cracking intensity from 10 - 50 %. Pavement is rough in some spots, lot of potholes especially at the left hand side, average rut depth 40 mm.	Hill gravel shoulder is in good condition, slightly eroded only.	Pavement drainage is bad, impeded by shoulder shape.	Left: functioning well Right: no drainage	Not definable
6.3	14.550	14.980	Pavement is in good condition, seal is smooth, undamaged. No cracking or rutting. Isolated shallow potholes.	Hill gravel shoulder is in good condition, slightly eroded only.	Drainage is in good condition, unhindered by pavement and shoulder shape.	Drainage still functioning well.	Not definable

CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERRIORATION

BUON HO REPORT

Appendix F
Traffic Data

Table F.1 Traffic counts at KrongPak station, NR 26

Vehicle type	2006			2007
	1st quarter	2nd quarter	3/4 quarter	
	ADT	ADT	ADT	ADT
Car	169	173	154	199
Light truck 2-axle	141	136	139	145
Light truck 3-axle	231	245	273	396
Medium truck 3-axle	256	312	254	315
Heavy truck 3-axles	93	94	77	150
Heavy truck ≥ 4-axles	29	30	20	30
Mini bus <20 seats (2-axle)	150	147	120	151
Large bus >20 seats (3-axle)	123	114	126	165
Cong Nong	145	156	158	162
Motor cycle & 3-wheelers	4819	4573	3431	4598
Total of truck, car and bus	**1192**	**1251**	**1163**	**1551**
Total motorized	6156	5980	4752	6311

Table F.2 Traffic counts at M'Drak station, NR 26

Vehicle type	2006		2007
	2nd quarter	3/4 quarter	
	ADT	ADT	ADT
Car	85	75	92
Light truck 2-axle	53	39	30
Light truck 3-axle	77	72	113
Medium truck 3-axle	212	169	248
Heavy truck 3-axles	90	82	103
Heavy truck ≥ 4-axles	22	12	28
Mini bus <20 seats (2-axle)	116	109	118
Large bus >20 seats (3-axle)	23	18	32
Cong Nong	81	78	56
Motor cycle & 3-wheelers	683	-	717
Total of truck, car and bus	**678**	**576**	**764**
Total motorized	1442	-	1537

Table F.3 Traffic count on NR 14 at Station I

Vehicle type	2005 ADT	2006 ADT	2007 ADT	Annual Growth (%)
Car	114	157	284	59
Light truck	180	156	71	-34
Medium truck	144	155	252	35
Heavy truck 3-axles	81	87	132	30
Heavy truck ≥ 4-axles	32	26	50	37
Mini bus < 20 seats (2-axle)	176	187	271	26
Large bus > 20 seats (3-axle)	164	181	334	47
Cong Nong	149	186	233	25
Motor cycle & 3-wheelers	2036	5190	6351	89
Total of truck, car and bus	**891**	**949**	**1394**	

Table F.4 Traffic count on NR 14 at Station II

Vehicle type	2005 ADT	2006 ADT	2007 ADT	Annual Growth (%)
Car	328	326	615	44
Light truck	267	296	488	38
Medium truck	204	215	327	29
Heavy truck 3-axles	80	315	204	129
Heavy truck ≥ 4-axles	24	27	100	141
Mini bus < 20 seats (2-axle)	218	232	426	45
Large bus > 20 seats (3-axle)	164	175	448	81
Cong Nong	121	100	268	75
Motor cycle & 3-wheelers	2677	3484	6250	55
Total of truck, car and bus	**1285**	**1586**	**2608**	

Table F.5 Traffic count on NR 14 at Station III

Vehicle type	2005 ADT	2006 ADT	2007 ADT	Annual Growth Rate (%)
Car	278	321	525	40
Light truck	292	314	382	15
Medium truck	329	298	565	40
Heavy truck 3-axles	160	171	375	63
Heavy truck ≥ 4-axles	18	30	140	217
Mini bus < 20 seats (2-axle)	301	311	378	12
Large bus > 20 seats (3-axle)	102	135	490	148
Cong Nong	49	51	178	127
Motor cycle & 3-wheelers	1736	2567	*3479*	42
Total of truck, car and bus	**1480**	**1580**	**2855**	