MINISTRY OF TRANSPORT VIETNAM

SOUTH EAST ASIA COMMUNITY ACCESS PROGRAMME

CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERIORATION

EA SOUP ROAD

SEACAP 24

August 2008

UNPUBLISHED PROJECT REPORT

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CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERRIORATION

EA SOUP 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**

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ABBREVIATIONS & ACRONYMS

ADT	Average Daily Traffic
CBR	California Bearing Ratio
DBM	Dry Bound Macadam
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
DST	Department of Science and Technology, Ministry of Transport
esa	equivalent standard axles
HQ	Headquarters
IRI	International Roughness Index
ITST	Institute of Transport Science and Technology
Km	kilometre
MoT	Ministry of Transport
PDoT	Provincial Department of Transport
PMU	Project Management Unit
PPC	Provincial Peoples Committee
PPMU	Provincial Project Management Unit
QA	Quality Assurance
RRGAP	Rural Road Gravel Assessment Programme
RRST	Rural Road Surfacing Trials
RTU	Rural Transport Unit
RT2	Rural Transport 2nd Project
TEDI	Transport Engineering Design Incorporated
TRL	Transport Research Laboratory
VPD	Vehicles per day
WBM	Water Bound Macadam

EXECUTIVE SUMMARY

Shortly after its completion in 2006 the Ea Soup RRSR trial road in Dak Lak Province was reported to have suffered rapid deterioration in a particular section. 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 Ea Soup road was designed based on existing Commune Class ‘A’ standards and the research guidelines developed for the RRSR programme.

The investigation showed that the Ea Soup road had suffered significant and rapid deterioration in the section km 2.7 to km 3.8 leading to complete pavement failure. Elsewhere along the road there were other lengths also exhibiting less serious deterioration. There was significant evidence to indicate that the trial road was, at least in part, constructed with materials that did not meet the specifications.

The investigation revealed a visual correlation between a recently heightened irrigation ditch; lack of side drainage and the extent of damaged pavement.

Analysis of traffic surveys indicated that traffic levels were within the anticipated design envelope, although some heavy vehicle usage had been noted.

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 primary cause of initial road failure in the section km 2.7 to km 3.9 has been the saturation and weakening of the pavement in that area caused by a combination of leakage from an adjacent elevated irrigation ditch and the lack of any side drainage.
4. If it is the intention to retain Ea Soup as a Commune Road it will be necessary to reconstruct the road pavement between km 2.7 and km 3.8 together with an adequate crown height and associated side drainage to counter the potential influence of the elevated irrigation ditch.
5. There were other smaller areas of pavement along the road that should also be repaired.
6. The nature of the traffic using this road should be monitored and if heavy vehicles are using it on a regular basis, steps should be taken either to restrict their access or strengthen the Penetration Macadam surfaced pavement with an additional structural overlay.

Other general recommendations are made as to the necessity for adequate drainage on rural roads and the need for cooperation at commune level when natural or irrigation drainage pathways are changed within a road corridor.

1 Introduction

1.1 Background

In response to the increasing recognition that gravel surfacings were 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.

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, a shown on Figure 1

Figure 1 Trials Location

The Ea Soup deterioration was confirmed during a condition monitoring survey in March 2007 and recommendations were made for a research programme to investigate the causes[1]. The Vietnam Ministry of Transport (MoT) subsequently requested SEACAP to investigate the causes of these problems as a case study.

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

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 Ea Soup 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 deterioration of the Buon Ho Road[2].

[2] SEACAP 24 Case Study of Dak Lak RRSR Pavement and Surface Deterioration: Buon Ho Road. TRL, 2008

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.

2.2 Ea Soup Design

Prior to the trials programme the Ea Soup road was primarily of unsealed gravel construction. The Ea Soup road was added to the trials programme during the design process and was not included in the Intech-TRL initial survey programme. The design of the trial pavement was undertaken by the PPMU and their local consultant following standard Vietnamese rural road guidelines for Commune A roads, with the addition of a trial section of a non-reinforced concrete at the suggestion of Intech-TRL, as shown in Table 1.

Table 1 Ea Soup Trial Pavement Designs

Section	Surface/Base	Sub-Base	Chainage
ES1	200mm Un-reinforced concrete	50mm sand on 100mm natural gravel sub-base	0.000 – 0.500
ES2	60mm of Penetration Macadam	100mm of water-bound macadam (WBM)	0.500 – 2.000
ES3	60mm of Penetration Macadam	100mm of water-bound macadam (WBM)	2.000 – 4.000

2.3 Ea Soup Construction

The RRST trial pavement designs were included within a standard RT2 contract and the road was constructed during February to May 2006 in two contract packages with different local contractors, as follows:

- Package I: Sections ES1 and ES2
- Package II Section ES3

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.

An Intech-TRL Quality Assurance team visited the completed road in June 2006 to conduct an assessment of the 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
ES1	B	B
ES2	B	B
ES3	B	B

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

In addition, the following specific points were made;

1. Crossfall in section ES3 was not satisfactory
2. Loose surface materials on ES2 and ES3
3. Oversize noted in WBM in ES2 and ES3

2.4 Ea Soup Post-Construction

In December 2006, the Dak Lak PDoT reported damage to the Buon Ho road and following site visits in March and July 2007 damage was also reported in one section of the Ea Soup road.

3 Road Investigation

3.1 Background Information

The following background information has been accessed for the Ea Soup road investigation

1) Pre-construction materials testing
2) In situ and laboratory testing during construction
3) ITST construction supervision notes
4) Relevant Intech-TRL technical correspondence with the PPMU and the Steering Committee
5) Intech-TRL quality assurance notes and records
6) ITST completion report
7) Relevant Intech-TRL SEACAP 1 reports
8) Post construction monitoring data.

3.2 Summary of Fieldwork

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

Table 3 Ea Soup 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

A preliminary site visit in conjunction the PPMU was undertaken to confirm general status of the Ea Soup road and to identify key areas for in situ investigation. The general locations for inspection pits were identified on site.

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.

3.3 Trial Pits and In Situ Testing

A total of 4 inspection pits were excavated and sampled along the Ea Soup road. Locations of these pits are listed in Table 4. Inspection pit records are included as Appendix A. In situ DCP testing was undertaken on sub-grade pavement layers within the inspection pits below the WBM layers. Results are summarised in Table 5.

Table 4 Inspection Pit Positions

Inspection Pit	Chainage (km)	GPS Co-ordinates
ES 2.01	1+325km	N13 04.964 E107 52.805
ES 2.02	1+980km	N13 05.238 E107 52.542
ES 3.01	3+400km	N13 05.890 E107 52.004
ES 3.02	3+875km	N13 05.978 E107 51.935

Table 5 In Situ DCP-CBR Results from within Inspection Pits

Location	Depth Below Road Surface (mm)	DCP-CBR (%)
ES 2.01	120-220	7
	220-300	25
ES 2.02	120-220	30
	220-300	7
ES 3.01	120-170	20
	170-200	40
ES 3.02	120-270	25
	270-325	60

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. Key test results are summarised in Tables 6 and 7.

3.5 Visual Inspection

A visual condition survey was undertaken of the whole of the Ea Soup 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 50m.

The summary visual survey sheets are included in Appendix B along with tabulated summary descriptions. Figures 2 and 3 present the wheel-track rut depths measured as part of the visual survey procedure.

Table 6 Sub-Grade Laboratory Test Results

Ch. km	Pit No.	Layer	Soil Class	W%			OMC%	MDD	Lab CBR	W/OMC	DCP	Road Condition	
					LL%	Ip%		g/cm3	95%	Ratio	CBR%	At pit	Zone
1+325	ES1	Subgrade	SC	8.7	37	17	11	2.13	12	0.79	7	1	1
1+980	ES2	Subgrade	CL	19	44	19	19	1.81	8	1.00	30	3	3
3+400	ES3	Subgrade	SC	25	36	14	12	2.01	8	2.08	20	1	2
3+875	ES4	Subgrade	SC	8.7	36	14	15	1.76	5	0.58	25	5	5

Table 7 Penetration Macadam Laboratory Test Results

Ch. km	Pit No.	Layer	Layer Type	Bitumen kg/m2	Penmac Aggregate		Comments
					%>50mm	%<5mm	
1+325	ES1	Surface-sub-base	Pen Mac/WBM	4.83	4	7	Oversize in sub-base up to 200mm
1+980	ES2	Surface-sub-base	Pen Mac/WBM	4.37	20	9	Oversize in sub-base up to 200mm, Clayey
3+400	ES3	Surface-sub-base	Pen Mac/WBM	5.06	6	25	
3+875	ES4	Surface-sub-base	Pen Mac/WBM	4.80	6	56	Oversize in sub-base up to 200mm

Visual assessments of the pavement are grouped into 5 general levels of condition as defined below and presented in Figure 4.

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 also includes a summary of the road-side drainage conditions as they were perceived to impact upon the pavement. These conditions were grouped as follows:

1. Good effective drainage – or none required (eg embankment)
2. No drainage – but little impact on road
3. No drainage with minimal crown height
4. Blocked drainage impacting on road
5. No drainage - water table above road level.

Appendix C provides illustrations of these drainage conditions

3.6 Pavement Information Review

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

1. Ea Soup road has suffered significant deterioration in the section km 2.7 to km 3.8; although less severe deterioration is evident in other in places.
2. The non-reinforced concrete section has suffered little or no significant deterioration.
3. During the current investigations visual and laboratory evidence indicates that the as-built Penetration Macadam, WBM pavement layers contained significant oversize material. There is also evidence in some places of contamination with clay material.
4. Visual evidence indicates variability in the quality of the bituminous surfacing. Laboratory testing indicates a low bitumen content for the Penetration Macadam sections (which is specified as between 6 and 7 kg/m2) although this may well be at least partially is a result of sampling problems with this form of pavement.
5. There is evidence of thinning of the WBM layers in one area.
6. There were clearly apparent differences in pavement drainage conditions along the length of the road.

7. An elevated irrigation ditch now exists to the left hand side of the carriageway between km 2.8 to km 3.9. This had been heightened subsequent to the trial road being completed. Local information indicated that this irrigation ditch both overtopped and leaked.
8. The road section on embankment above and adjacent to a deep irrigation channel suffered only isolated pavement deterioration, Figure 4.

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. There is also strong visual evidence to link the deterioration of the pavement between km 2.7 and km 3.9 with the lack of effective drainage and the adjacent irrigation channel.

Figure 2 Carriageway Rut Depths km 0.000- 2.000

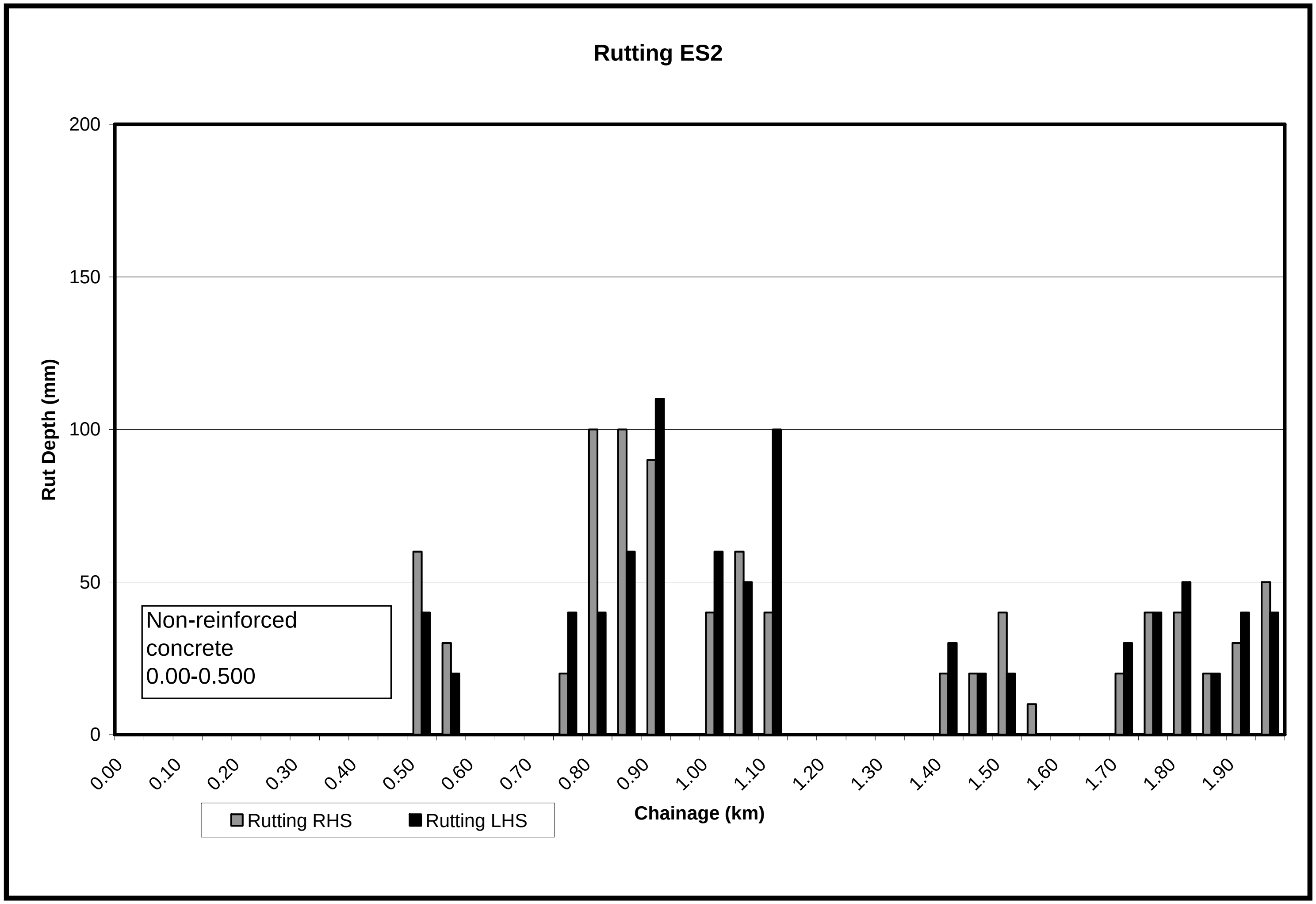


Figure 3 Carriageway Rut Depths km 2.000- 4.000

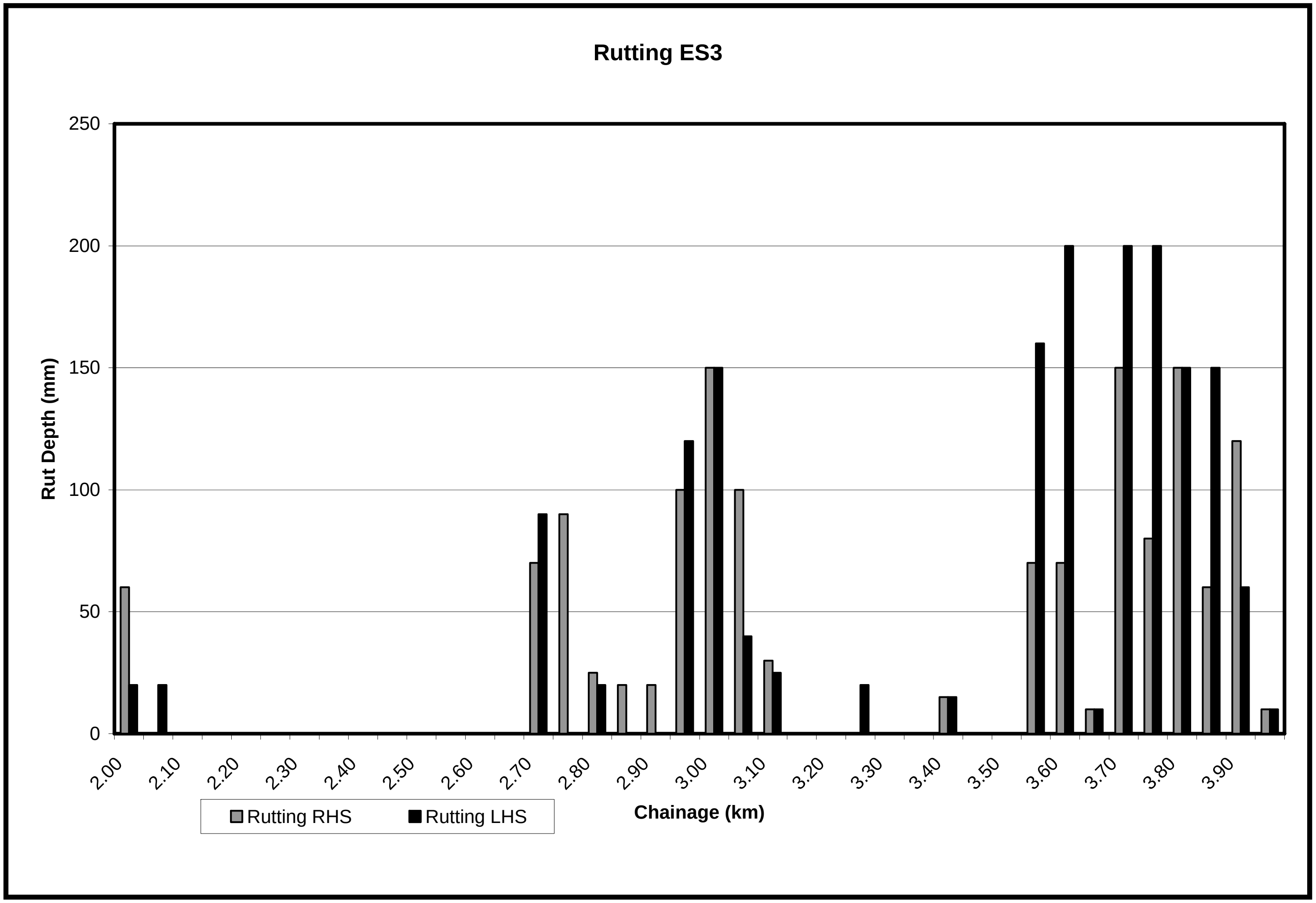
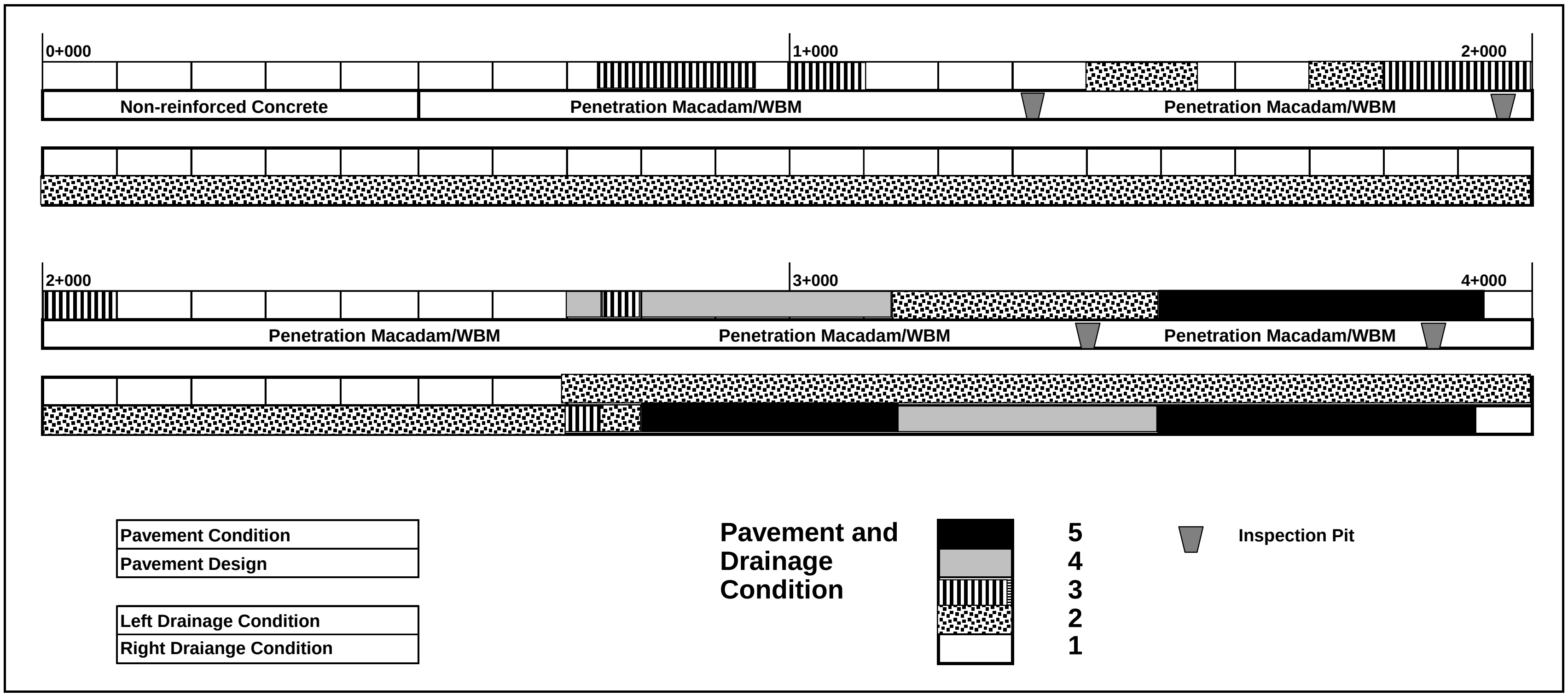


Figure 4. Ea Soup Pavement Condition Summary



4 Discussion

4.1 General

In order to satisfy the objectives of this investigation, the following key questions were 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 its purpose?
4. Were there any external factors impacting on the road performance?
5. What are the key factors that caused early deterioration?

4.2 Traffic

Traffic counts undertaken as part of the RRST monitoring programmes are summarised in Table 8.

Table 8 Traffic Counts

Vehicle type	Average Daily Traffic	
	Sept. 2006	**Jan 2008**
Bus	0	0
Truck.>5t GWT	8	8
Truck/Pickup<5t GWT	19	12
Car	8	12
Cong Nong	17	24
Motor Cycle	1235	867
Cycle	1100	236
Total ADT (24hrs)	**361**	**246**
Total Motorised	**1287**	**923**
Total 4-wheel or more	**52**	**56**

The very low percentage of trucks within the overall ADT[3] indicates an equivalent standard axle (esa) total of between 50,000 and 75,000 for a 10-year design life. The pavement was designed to comply with Commune Class A Standards and as such has a 6t axle load limit. There is anecdotal evidence however of at least some overloading by large trucks and during the investigation heavily laden trucks were noted as using the road on an intermittent basis (Figure 5).

Figure 5 Overloading of the Ea Soup Road

[3] ADT calculated on basis of guidance in ORN 20

4.3 Pavement Strength

The SEACAP Buon Ho report summarises key issues on pavement strength relating the early failure of road pavements to various possible reasons based on the design, the materials and the quality of construction, or combinations of all three. As regards the Ea Soup road the relevant points of note are as follows:

1. The Ea Soup road section of interest is of Penetration Macadam design and similar Buon Ho pavements were assessed as having an as-designed esa capacity of 125,000.
2. Investigated DCP-CBRs in the damaged areas indicated adequate sub-grade strengths.
3. Although some large trucks have been observed on the Ea Soup road, there is no evidence of consistent overloading on anything approaching the scale of the Buon Ho traffic.

4.4 Drainage

A design that is successful with regard to pavement strength may fail due to other road environmental processes and it is commonly acknowledged that extensive damage to both rigid and flexible pavements can be caused by water trapped within the pavement.

The effect of water on road pavements and the need to maintain adequate drainage at all times is summarised by Rolt (2002)[4]. as contributing to either 'gradual',' incremental', or 'catastrophic' road failure. It is clear that the Ea Soup failure falls into the 'catastrophic' category where a problem appears to have been 'switched on' suddenly and affected the road in the area from km 2.7 to km 3.8.

The likely impacts of saturation of road pavements include:

1. Loss of effective mass strength due to imposed water pressures
2. Loss of material strength due to saturation
3. Pumping of fines within pavement layers
4. Internal erosion

Once deterioration begins due to such impacts, the traffic may accelerate the process, although the original cause is not necessarily accumulated traffic induced distress. The passing of even occasional heavy vehicles could be significant in this regard. The arrival of a heavy lorry acts like a hydraulic pump to compress the surface and to pressurise the water to such an extent that areas of surfacing that do not have sufficient adhesion to the roadbase will lift, crack and develop numerous pot-holes.

The walkover survey of the Ea Soup road has shown that little or no attention had been given to the construction of effective side drainage.

4.5 External Factors

The construction of an elevated irrigation ditch immediately after the completion of the road in July 2006 constitutes a significant external factor. However the presence of this ditch, even though it is reported as over-topping and leaking from time to time, would not in itself constitute a risk to pavement performance provided there was adequate drainage protection to the road carriageway, as required by the RT2 Standard Specifications:

> *"The level of the water table beneath the carriageway is a major influence on the strength of the subgrade. The bottom level of side drains should be maintained well*

[4] J Rolt , 2001. Rational Road Drainage Design. TRL Report for DFID KaR project R6990

below formation level (the underside of the first pavement course)." RT2 Technical Guidelines, January 2003.

The investigation has shown that no side drainage was constructed and hence the combination of this with the leaking irrigation ditch constituted a significant risk to adequate pavement performance by providing what is in effect a reservoir of water to keep the pavement in a saturated condition between km 2.7 and km 3.9, (Figure 6).

Figure 6 Elevated Irrigation Ditch with no Pavement Side Drainage

5 Conclusions

Was the design suitable for Commune road A traffic? Taking into account the data recovered from the investigations; the current local standard designs and recent SEACAP studies[5] the conclusion may be drawn that the Ea Soup 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 its purpose? 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. It is also clear that significant lengths of the road were constructed with inadequate side drainage.

Were there any external factors impacting on the road performance? An irrigation ditch, subject to both overtopping and leakage, had been heightened to a level above the road pavement subsequent to the construction of the trial road

What are the key factors that caused early deterioration? In the Consultant's opinion the primary cause of the initial road failure in the Ea Soup section from km2.7 to km 3.9 was the saturation and weakening of the pavement in that area caused by a combination of leakage from an adjacent elevated irrigation ditch and the lack of any side drainage. However, it is also likely that the rate of this deterioration was aided to some extent by marginal or poor construction. The passage of occasional heavy trucks will also have tended to increase this rate of deterioration.

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

6 Recommendations

6.1 Ea Soup Road

If it is the intention to retain Ea Soup as a Commune Road it will be necessary to reconstruct the road pavement between km 2.7 and km 3.8 together with an adequate crown height and associated side drainage to counter the potential influence of the elevated irrigation ditch.

There are other smaller areas of pavement along the road, as shown on Figure 4, that should also be repaired.

The nature of the traffic using this road should be monitored and if heavy vehicles are using it on a regular basis, steps should be taken either to restrict their access or strengthen the Penetration Macadam surfaced pavement with an additional structural overlay.

6.2 Other Recommendations

The damage to the Ea Soup has high-lighted two key issues;

1. Construction of roads without the required side drainage will most likely lead to early deterioration and additional maintenance and repair costs
2. Changes in natural or irrigation drainage pathways within a road corridor need to be assessed as to their likely impacts on the road. This requires effective coordination at local authority or commune level.

In addition, the general recommendations made in the Buon Ho report with respect to LVRR Standards and Designs, Asset Management, and improved quality control of construction, are equally valid in the context of this report.

7 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.

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

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Appendix A

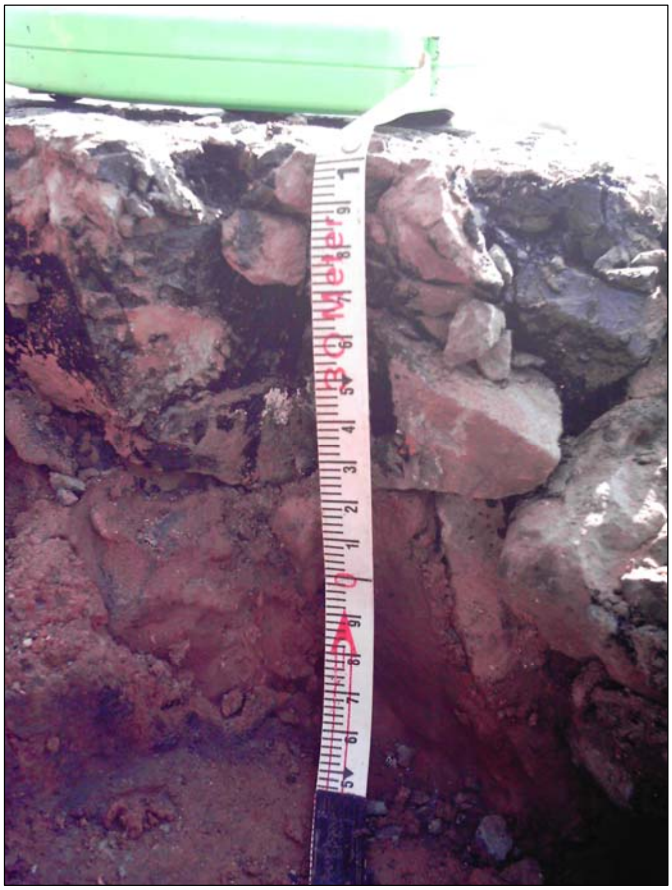
Inspection Pits

Ea Soup Pit No 1

ES 2.01 Chainage 1+325km	
Description	**Layer**
60mm Penetration macadam surface Materials size is close to standard. Penmac in fair condition. Bitumen content looks sufficient	Surface/Base
100-120mm of WBM sub-base; 50% of material is oversize, with largest dimension 100 to 200mm	Sub-Base
Natural gravel. Brown sandy clay with gravel. Particle size distribution is fairly good. Strong subgrade	Subgrade

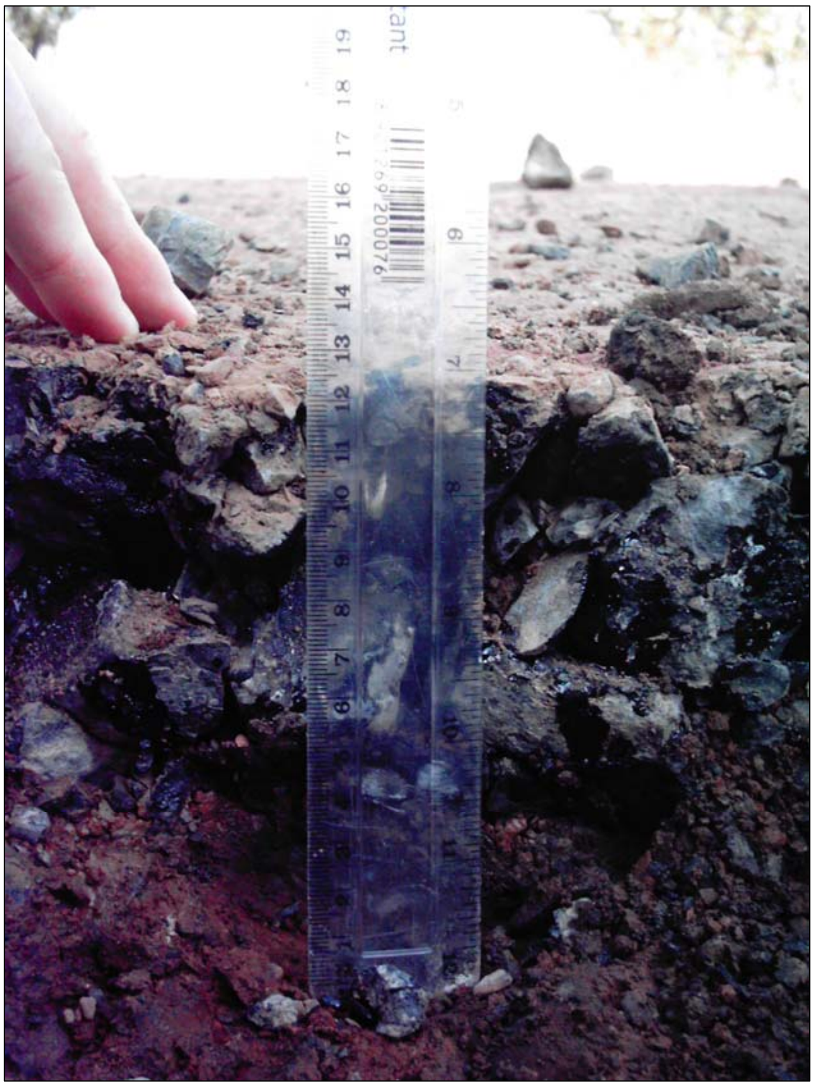
Ea Soup Pit No 2

ES 2 02 Chainage 1+980km	
Description	**Layer**
60mm of Penetration macadam surface Materials size is close to standard. Penmac in fair condition. Bitumen content looks sufficient	Surface/Base
100mm WBM with significant percentage of oversize materials. Also large amount of clay material present in sub base. Oversize particles from 100 to 200mm.	Sub-Base
Hill gravel. Brown sandy clay with a little gravel. Low subgrade strength	Subgrade



Ea Soup Pit No 3

ES 3 01 Chainage 3+400km	
Description	**Layer**
60mm Penetration macadam. Materials size is close to standard and in fair condition. Bitumen content looks adequate.	Surface/Base
70-80mm WBM. Materials size is close to standard.	Sub-Base
Grey brown sandy clay, wet. High subgrade strength.	Subgrade



Ea Soup Pit No 4

ES 3.02 Chainage 3+875km	
Description	**Layer**
60mm Penetration macadam surface. Materials size is close to standard. Layer in bad condition. Bitumen content looks insufficient.	Surface/Base
100mm WBM, with a lot of oversize materials. Oversize materials from 100mm to 200mm.	Sub-Base
Grey sandy clay with a little gravel, wet condition. Subgrade strength is poor.	Subgrade

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APPENDIX B

Visual Survey Summaries

Summary of Ea Soup Visual Condition Survey

Section	From (km)	To (Km)	Pavement Condition	Shoulder Condition	Surface drainage	Side drainage	Water-table
1	**0.000**	**0.500**	Pavement is in good condition apart from occasional cracks in concrete slabs. The bituminous joint seals have settled with a significant loss of seal.	Gravel in good condition, adequate strength, and stable.	Embankment. Pavement and shoulder cross-fall is adequate. Unimpeded run-off	Irrigation channel forms the good left side-drainage. No right side drainage.	Left: -2.0m Right: -1.5m
2	**0.500**	**2.000**					
2.1	0.500	0.750	Pavement is in good condition, no cracks or potholes. Slight loss of aggregate from seal.	Sealed WBM in good condition. Some loss of aggregate.	Embankment, Pavement and shoulder cross-fall is adequate. Unimpeded run-off	Irrigation channel forms good left side-drainage. No right side drainage.	Left: -2.0m
2.2	0.750	0.950	Severe crocodile cracking in general 10-50% and separated. With >50% in some sub-sections. No potholes. Average rut depth on left 50mm, on right 80mm.	Sealed WBM in good condition. Some loss of seal aggregate.	Surface drainage is largely unimpeded except where ponding occurs in the ruts	Irrigation channel forms good left side-drainage. No right side drainage.	Left: -2.0m
2.3	0.950	1.000	Good surface condition, no potholes, or cracking, slight loss of aggregate from seal.	Sealed WBM in good condition Some loss of seal aggregate.	Good unimpeded cross-fall drainage	Irrigation channel forms good left side-drainage. No right side drainage	Not definable
2.4	1.000	1.100	Crocodile cracking in some areas of pavement (0-10%), Significant shallow potholes. Average rut depth is 50mm.	Sealed WBM in good condition. Some loss of seal aggregate.	Good unimpeded cross-fall drainage	Irrigation channel forms good left side-drainage. No right side drainage.	Not definable
2.5	1.100	1.400	Some slight fine aggregate loss. Generally good condition. No ruts, cracks or potholes.	Sealed WBM in good condition. Some loss of seal aggregate.	Good unimpeded cross-fall drainage	Irrigation channel forms left side-drainage. Right side drainage – suitable shape and level. A little silting.	Left: -2.0m Right: -0.2m
2.6	1.400	1.550	Crocodile cracks in some areas (0-10%). Average rut depth is 20mm, isolated shallow potholes.	Sealed WBM in good condition. Some loss of seal aggregate.	Good unimpeded cross-fall drainage	Irrigation channel forms the good left side-drainage. No right side drainage.	Left: -2.0m

Section	From (km)	To (Km)	Pavement Condition	Shoulder Condition	Surface drainage	Side drainage	Water-table
2.7	1.550	1.700	Good surface condition, no ruts, cracking or potholes. Some stripping of fine aggregate.	Sealed WBM in good condition. Slight loss of fine aggregate	Embankment, Pavement and shoulder cross-fall is adequate. Good drainage	Irrigation channel forms good left side-drainage. No right side drainage.	Left: -2.0m Right: -2.0m
2.8	1.700	1.800	Crocodile cracks in some areas <10%. Significant potholes; average rut depth is 30mm.	Sealed WBM in good condition. Slight loss of fine aggregate	Embankment, Pavement and shoulder cross-fall is adequate. Good drainage	Irrigation channel forms good left side-drainage. No right side drainage.	Left: -2.0m Right: -2.0m
2.9	1.800	2.000	Severe crocodile cracking in some areas and separated, cracking areas – from 10-50%. With >50% in some sections. Significant shallow potholes; average rut depth is 30mm.	Sealed WBM in good condition. Slight loss of aggregate	Embankment, Pavement and shoulder cross-fall is adequate. Good run-off	Irrigation channel forms the good left side-drainage. No right side drainage.	Not definable
3	**2.000**	**4.000**					
3.1	2.000	2.100	Some crocodile cracks in some areas <10%. Significant potholes, average rut depth is 30mm.	Sealed WBM in good condition. Slight loss of aggregate	High embankment, Pavement and shoulder cross-fall is adequate. Good run-off	Irrigation channel forms good left side-drainage. No right side drainage.	Right: -1.2m
3.2	2.100	2.700	Some slight aggregate loss. Generally good condition. No rut. Occasional shallow potholes in some sub-sections.	Sealed WBM in good condition. Slight loss of aggregate.	Good unimpeded cross-fall drainage	Irrigation channel forms good left side-drainage. No right side drainage.	Not definable
3.3	2.700	2.750	Bad pavement, severe crocodile cracking in some areas, with >50% in some sub-sections. Significant potholes. Average rut depth 80mm.	Sealed WBM. Crocodile cracking, Slight loss of fine aggregate.	Surface drainage is hindered by pavement shape. Some ponding occurs in the ruts.	Severe defect on right -side drainage, silting but still operating. No left side drainage	Right: -0.8m
3.4	2.750	2.800	No cracking in pavement, however significant shallow potholes. Average rut depth on right is 90 mm, but no rut on left	Sealed WBM in good condition. Slight loss of aggregate	Good unimpeded cross-fall drainage	No left or right side drainage .	Right: -0.3m

Section	From (km)	To (Km)	Pavement Condition	Shoulder Condition	Surface drainage	Side drainage	Water-table
3.5	2.800	3.150	Severe crocodile cracking in some areas (10-50%) with separation. The majority of sub-sections have crocodile cracking is >50%. Significant large shallow potholes. Average rut depth from 100 to 120 mm.	In general left shoulder in good condition, crocodile cracking in the right shoulder, erosion and settling hinder the drainage.	Left side run-off moderately good, only some ponding on ruts. Bad right side run-off impeded by lack of pavement and shoulder cross-fall.	No left or right side drainage.	Right: + 0.1 - +0.2m (surface water higher than pavement)
3.6	3.150	3.550	Some slight seal aggregate loss. Generally good pavement condition. No rut or potholes. Slight crocodile cracking (0 to 10 %) at Km3+400 to Km3+450.	In general in good condition with loss of fine aggregate	Good unimpeded cross-fall drainage.	No left or right side drainage.	Right: -0.4m Left: - 1.2m
3.7	3.550	3.950	Pavement almost totally damaged. Severe crocodile cracking in the remaining sections >50 %. Significant potholes, average rut depth up to 150 mm or more.	In general badly damaged with ruts and related shoving, and aggregate loss	Ponding caused by severe defects of shoulder and pavement. Drainage badly impeded, especially on left side.	No left or right side drainage.	Left: - 1.0m Right: +0.15m (surface water higher than pavement)
3.8	3.950	4.000	Good surface condition, no ruts, cracking or potholes. Some stripping of seal aggregate.	Sealed WBM in good condition. Slight loss of fine aggregate	Adequate pavement and shoulder cross-fall, good run-off.	Irrigation channel forms the good left side-drainage. No right side drainage.	

CASE STUDY OF DAK LAK RRST PAVEMENT AND SURFACE DETERRIORATION

EA SOUP REPORT

APPENDIX C

Illustration of Drainage Conditions

Road-side Drainage Conditions