

MINISTRY OF PUBLIC WORKS AND TRANSPORT

**PERFORMANCE MONITORING
OF
THE NEC-ADB PACKAGE I
TRIAL AND GRAVEL ROADS**

SEACAP 17.02

**FINAL REPORT
JUNE 2009**



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CONTENTS

1	Introduction	1
1.1	<i>The Overall SEACAP Context</i>	1
1.2	<i>Report Objectives</i>	1
2	Project Outline	1
2.1	<i>Background</i>	1
2.2	<i>SEACAP 17.02 Project Objectives</i>	2
2.3	<i>Contractual Arrangements</i>	2
2.4	<i>Project Mobilisation</i>	2
2.5	<i>Summary of Work Undertaken</i>	3
3	Task Groups	4
3.1	<i>Task Group 1: Trials Monitoring</i>	4
3.2	<i>Task Group 2: Gravel Assessment Survey</i>	5
3.3	<i>Task Group 3: Data Management and Analysis</i>	5
3.3.1	<i>Review and Modify Database</i>	5
3.3.2	<i>Data Analysis</i>	6
4	Trials Monitoring Discussion	10
4.1	<i>General</i>	10
4.2	<i>Unsealed gravel and natural surface trials</i>	10
4.3	<i>Sealed flexible pavements</i>	10
4.4	<i>Hand-packed Stone</i>	11
4.5	<i>Geocells</i>	12
4.6	<i>Concrete blocks</i>	13
4.7	<i>Bamboo reinforced concrete</i>	14
5	Gravel Assessment Programme Discussion	15
5.1	<i>General</i>	15
5.2	<i>Road Geometry</i>	15
5.3	<i>Gravel loss</i>	16
5.4	<i>Road shape</i>	17
5.5	<i>Erosion</i>	18
6	Conclusions	19
6.1	<i>Trials Condition Monitoring</i>	19
6.2	<i>The LGAP Survey</i>	19

Appendix A: Numeric Codes for visual assessment

ABBREVIATIONS & ACRONYMS

ADT	Average Daily Traffic
ASEAN	Association of South East Asian Nations
DBM	Dry Bound Macadam
DBST	Double Bituminous Surface Treatment
DPWT	Department of Public Works and Transport (Province Level)
DCP	Dynamic Cone Penetrometer
DfID	Department for International Development
DoR	Department of Roads
EADT	Equivalent Average Daily Traffic
ENS	Engineered Natural Surface
esa	equivalent standard axles
GSAS	Gravel Spot Assessment Survey
gTKP	global Transport Knowledge Partnership
HQ	Headquarters
ILO	International Labour Organisation
Km	kilometre
LRD	Local Roads Division (DoR)
LVRD	Low Volume Rural Road
m	metre(s)
MPWT	Ministry of Public Works and Transport
mm	Millimetre(s)
MERLIN	M achine for E valuating R oughness using L ow-cost I Nstrumentation
MoU	Memorandum of Understanding
NUOL	National University of Lao
OPWT	Office of Public Works and Transport (District Level)
ORN	Overseas Road Note
PAD	Personnel and Administration Division (MPWT)
PTD	Planning and Technical Division (DoR)
QA	Quality Assurance
Ref.	Reference
RRGAP	Rural Road Gravel Assessment Programme (Vietnam)
SCC	SEACAP Coordinating Committee
SEACAP	South East Asia Community Access Programme
SIDA	Swedish International Developments Cooperation Agency
SOE	State Owned Enterprise
TRL	Transport Research Laboratory

UK	United Kingdom
VN	Vietnam
VOCs	Vehicle Operating Costs
VPD	Vehicles per day
WBM	Water Bound Macadam
WLC	Whole Life Costs

1 Introduction

1.1 The Overall SEACAP Context

The SEACAP 17.02 project is part of the wider South East Asia Community Access Programme (SEACAP), whose strategic theme is ‘livelihoods of poor and vulnerable people in SE Asia - improved sustainability’. The core SEACAP concept relevant to infrastructure was defined at the SEACAP Practitioners Meeting (SPM) in Phnom Penh in June 2006 as “maximizing input of local resources; which are materials, labour, enterprise and ingenuity which ensures affordability”.

SEACAP builds on existing knowledge, but also provides a research resource for filling gaps in knowledge, particularly in the local environment. Mainstreaming ensures that these solutions are accepted, adopted and applied on a large scale. This involves a process of dissemination through participatory workshops, guideline documents, demonstrations, training and implementation.

SEACAP 17.02 will contribute to this overall objective through enhancing knowledge on the performance of a range of rural road pavements and surfaces. This knowledge will encourage a more sustainable approach to the provision and maintenance of rural access through selection and application of the most appropriate technology within the framework of the newly proposed LVRR Standards and Specifications.

1.2 Report Objectives

This document serves as final report on the SEACAP 17.02 programme in which the project activities are formally presented along with the recovered and analysed information. Comments are made on issues that have arisen during the project and recommendations are made as to the way forward.

2 Project Outline

2.1 Background

Rural poverty alleviation is a major objective for the Government of the Lao PDR within the next 10 years. A key element in the strategy to eliminate rural poverty is the development and upgrading of the rural infrastructure through the most cost-effective means. The Ministry of Public Works and Transport recognised that the effective application of up-to date rural road research would be of significant advantage in meeting the considerable technical and resource challenges posed by the need to significantly enhance Lao’s rural road network. High on the priorities of applied research singled out by the DoR within the Ministry was the need to identify suitable rural road pavement and surfacing solutions. To this end the SEACAP 17 project designed and constructed a series of trial sections along rural access roads being upgraded as part of the ADB funded section of the Northern Economic Corridor (NEC) within the Huay Xai district in Bokeo Province¹

¹ Roughton International, 2008. Local Resource Solutions to Problematic Rural Road Access in Lao (PDR), SEACAP 17 Rural Access Roads on Route No.3, Module 2 – Completion of Construction Report (Draft)

The construction these 12 trials sections and associated 7 gravel control sections was completed in August 2007. This was followed by an initial as-built condition survey which was also intended to provide the base-level data for a future condition monitoring programme.

2.2 SEACAP 17.02 Project Objectives

The development of new pavement or surfacing options requires that their performance be investigated within the road environment constraints within which they are designed to operate. Their deterioration characteristics need to be identified in order to establish both their general suitability and their Whole Life Costs and to define the limits of their appropriate usage. The regular monitoring of appropriately selected road sections in conjunction with assessments of the governing road environments is an essential part of this process.

The SEACAP 17.02 project was therefore a logical and necessary continuation of the main SEACAP 17 programme and was concerned primarily with the collection and analysis of pavement performance information from trial road sections. SEACAP 17 is a one-off data collection and assessment exercise that hopefully will be repeated with sufficient regularity so as to enable valuable lessons learnt to contribute to the sustainable development of the Lao PDR rural infrastructure.

In addition to the monitoring of the SEACAP 17 trials roads this project was also required to undertake a Lao Gravel Assessment Programme (LGAP) which, as a cut-down version of the successful SEACAP 4 (RRGAP) in Vietnam, sought to collect and analyse information on the performance of a number of unsealed roads within the NEC corridor.

2.3 Contractual Arrangements

In response to Requests for Proposals from Crown Agents for Overseas Governments and Administrations Ltd (acting as Contracting Agent for DfID), LTEC provided technical and financial proposals for carrying out the project and subsequently entered into a contractual arrangement with Crown Agents for SEACAP 17.02, signed on 20th January 2009.

LTEC is formally supported in its undertaking of this project by an associate organisation, OtB Engineering (International) Ltd, who are supplying technical advice through the services of Dr J R Cook.

2.4 Project Mobilisation

The project team was mobilised with the following key members:

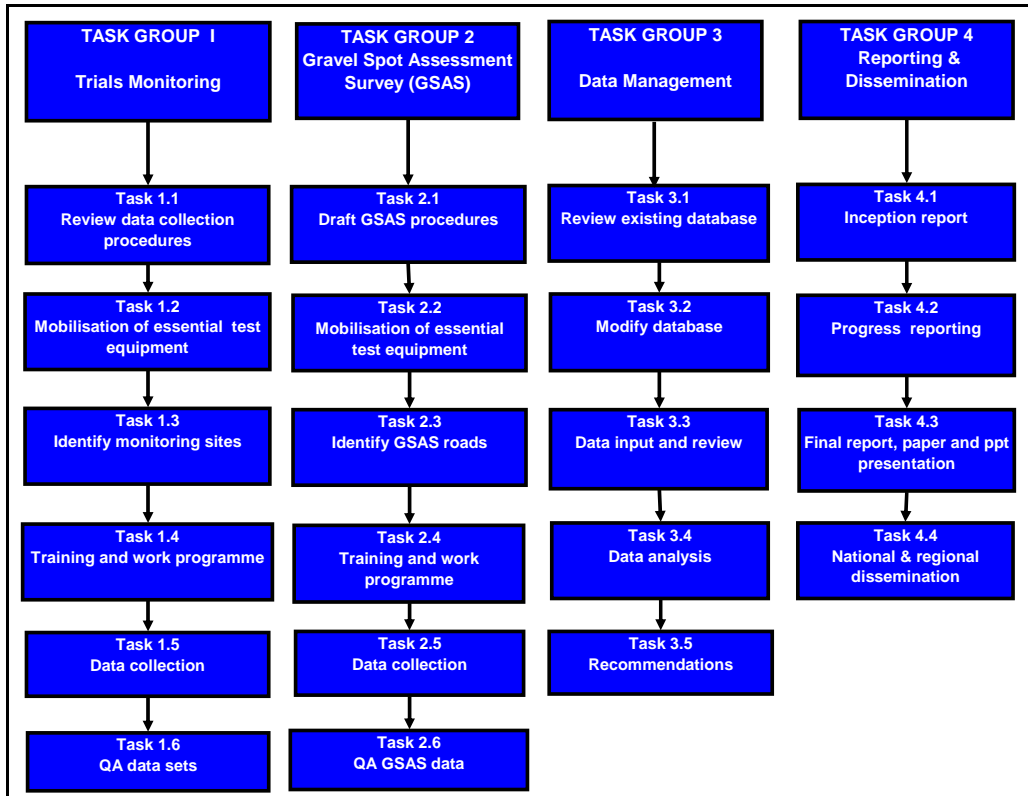
- Bounta Meksavanh (LTEC) –Team Leader
- Boupan (LTEC) – Road Engineer and Site Manager
- Kiatiphan (LTEC) – IT Specialist
- Dr J R Cook (OtB) – Technical Advisor

The programme was effectively initiated with the assembly and mobilisation of the fieldwork teams to Huay Xai on 17th February 2009, where a site office with communication and computing facilities has been established. An administration support base was also established within the LTEC offices in Vientiane.

2.5 *Summary of Work Undertaken*

The work undertaken during the SEACAP 17.02 was planned and executed within a framework of Task groups as shown in Figure 2.1

Figure 2.1, SEACAP 17.02 Task Groups



3 Task Groups

3.1 Task Group 1: Trials Monitoring

The main fieldwork for the trials monitoring was preceded by a short review and planning period.

Following a review of data collection procedures, most of the as-built survey procedures were adopted into the current survey with the exception of the Sand Patch Test and the photograph-based visual survey. This latter approach while very visual and useful as demonstration of road condition does not lend itself to scientific analysis without significant secondary interpretation. A more numeric coded system was adopted that was derived from that used on the SEACAP trial programme in Vietnam². Standard Sheets and Codes are included within the SC17.02 Project Inception report.

The trials monitoring survey followed-on from an initial training period and was completed during period 26th February to 27th March 2009. A total of 2.75km of trial section in 24 lengths on 7 trial roads were surveyed, listed in Table 2.1.

Table 2.1 Extent of Condition Monitoring

Roads				Monitored Lengths			
New Ref	Old Ref	From	To	Pavement Type	Start (km)	End (km)	Length (m)
1011	1-1	B.Phi Mon Sine	B.Chom Keo	Gravel	0+600	0+700	100
1013	1-3	B.Chan Sa Vang	B.Si Pho Sai	Gravel	1+270	1+370	100
102	2	B.Nam Phou Kang	B.Nam Sa Mok Neua	Gravel	0+450	0+550	100
				Packed Stone	0+700	0+800	100
				Packed Stone	0+940	1+040	100
1032	3-2	B.Bolek	B.Nam Tong Neua	Single Otta Seal	0+150	0+250	100
				Double Otta Seal	0+415	0+515	100
				Engineered Nat. Surface	0+800	0+900	100
				Mortared Stone	1+200	1+300	100
				Mortared Stone	1+300	1+400	100
				Gravel	1+520	1+720	200
1033	3-3	B.Nam Tin	B.Phou Vane Kao	Gravel	1+650	1+750	100
105	5	Gam Mining	B.Houay Sala	Paving Blocks	0+950	1+050	100
				Paving Blocks	1+250	1+350	100
				Bamboo Concrete (125mm)	2+000	2+100	100
				Bamboo Concrete (150mm)	2+350	2+450	100
				Geocells (75mm)	2+800	2+900	100
				Geocells (100mm)	2+950	3+050	100
				Geocells	3+050	3+125	75
				Gravel	3+175	3+275	100
				Gravel	4+550	4+650	100
				108	8	B.Chom Chouk	B.Nam Kham Neua
Sand Seal	2+000	2+100	100				
Gravel	2+225	2+325	100				
						Total	2,475

The following data sets were collected.

- Visual survey

² Intech-TRL, 2007. Rural Road Pavement Construction and Supervision Guidelines. SEACAP 1 report for the MoT, Vietnam

- Cross sections
- DCP
- Roughness (MERLIN)
- Mini FWD
- Rut depth

3.2 *Task Group 2: Gravel Assessment Survey*

The contract called for a survey of the condition of NEC gravel access roads by means of “spot” assessments. This was taken to mean a survey similar in nature to SEACAP 4 carried out in Vietnam as the Rural Road Gravel Assessment Programme (RRGAP). The ToR called for a survey of a minimum of 100 sites.

The data collection procedures and forms and associated codes were derived from the SEACAP 4 project and the subsequent modification used on the recent SEACAP 19 Engineered Natural Surface roads survey in Cambodia.

The LGAP survey was completed during the period 26th March – 8th April 2009. Table 2.2 lists the extent of this survey.

Table 2.2 Gravel Spot Assessment Programme

Roads			Length (km)	Number of GSA Sites
Ref	From	To		
Package I SC17 Trial Roads				
1011	0+000	2+183	2,183	8
1013	0+600	3+487	2,887	8
102	0+000	5+350	5,350	10
1032	0+000	6+880	6,880	13
1033	0+000	2+000	2,000	4
105	0+000	6+093	6,093	11
108	0+000	2+770	2,770	7
			Sub-Total	61
Bokeo Non-Trial				
1013A	0+000	0+600	600	3
102A	0+000	0+800	800	3
105A	0+000	3+000	3,000	8
108A	0+000	0+500	500	2
			Sub-Total	16
Package II				
201	0+000	12+600	12,600	25
202	0+000	4+126	4,126	10
			Sub-Total	35
			Overall Total	112

The survey of 16 non-NEC unsealed road sites was included for control and comparison purposes.

3.3 *Task Group 3: Data Management and Analysis*

3.3.1 *Review and Modify Database*

The ToR called for recovered data to be entered into the existing SEACAP 17 database, a current version of which was held by LTEC as the local consultants involved in that project.

An initial review showed that the existing database in ACCESS format contains two principal data files; one relating to the trial roads and the second relating to the trial sections. Additional files

contain definitions used in these two principal files. Most of the monitoring data are contained in linked external files.

The review however has raised a number of issues.

1. The majority of the links to monitoring data sets were either inactive or missing:
2. The version of the database held by LTEC had the much of the monitoring information held in pdf files which were not amenable to analysis. (Files in XLS format were subsequently made available).
3. There are no visual condition data sets in numeric standard format.
4. A new files structure would be required to accommodate the LGAP data sets.

As a consequence of the above and the limited time available the following data holding structure has been set up:

1. All SC17-related data has been collected into a single folder (db-Lao-2009) on the LTEC server. This main folder contains two main sub-folders; LGAP holding all gravel assessment data files and TRIAL which holds all trial monitoring data files.
2. The LGAP folder comprises a central ACCESS file with all principal data and associated pdf or jpg files holding summarized DCP data for easy access. This DCP information is also held on DCP-specific software files (UKDCP).
3. The TRIALS folder currently holds the as-built and SDC17.02 data in separate sub-folders (SC 17.10 and SC17.02) the linkage between the data sets is shown within the SC17.02 ACCESS file. Principal data sets are held on mainly XLS files, although as with the LGAP folder the DCP data is held as pdf or jpg files.

3.3.2 Data Analysis

The ToR calls for a “*updated performance and cost models for the trials and for gravel surfaced LVRR in Northern Laos*”. There are a two significant issues impacting on the full compliance with this requirement.

1. The SEACAP 17.02 trials data collection will be only the second set of data collected within 18 months and consequently it will very difficult to identify trends
2. As noted previously there is no easily analysable base-line data for visual condition assessment

As a consequence the SEACAP 17.02 data was collated and assessed and analysed for any immediate issues that may be of significance to the development of a Lao LVRR cost model and comments made on the existing condition of each trial pavement type.

The LGAP analysis is a one-off assessment of the recovered data in which significant issues are highlighted and commented on.

The Trials data analysis and comment is largely based on interpretation of the visual survey data sets supported by MERLIN roughness and DCP-CBR information. For each pavement group a number of key factors have been identified that may be reasonably be able to represent road performance. These are listed in Table 2.3. These factors can then be analysed using the associated numeric codes to ascertain relative pavement deterioration. Appendix A contains a listing of all the key factor codes and related descriptions.

A total deterioration index is calculated by combining the deterioration of the key factors as percentage of total deterioration (ie all numeric codes at their maximum defect values). These indices are a percentage of the maximum deterioration possible for a single factor in trial section. As an example; a maximum deterioration for potholes is code "3" (>3 potholes in a 5 m block)– if every 5m block on a 100m trial section had this maximum deterioration this would equal $3 \times 20 = 100\%$ index. Note that 100% does not indicate a complete disintegration of the road, but rather an extremely serious pot-holed condition.

Table 2.3 Key Performance Indicators

Trial Group	Indicative Factors
Concrete	Joint condition Crack extent Surface condition Potholes
Geocells	Structural crack extent Cell condition Joint condition
Sealed Flexible	Crack extent Ruts Potholes
Blocks e	Block condition Joint Condition Ruts Potholes
Hand Packed Stone	Block condition Joint Condition Depressions Potholes
Unsealed	Erosion Ruts Potholes

The Road Condition Deterioration Index (RCDI) can be calculated for series of condition surveys over a number of years and the comparative deterioration of pavements can be plotted versus time or traffic (esa). Individual Condition Deterioration Indices (CDIs) for separate factors can be examined to identify the most significant deterioration modes.

The RCDI gives a measure of defect occurrence within a section but does not indicate whether this is an isolated or extensive problem. The associated Defect Extent Index (DEI) is a simple measure of the percentage of the road affected by any deterioration. This is done by simply noting how many of the 5m visual assessment blocks have a key defect. The combination of RCDI and DEI allows a rapid assessment for maintenance of deterioration seriousness and extent; for example

- A high RCDI and high DEI indicates a widespread serious defect problem
- High RCDI but low DEI indicates a isolated serious defect
- Low RCDI and high DEI indicates a minor widespread defect

The LGAP survey data has been analysed using key factors identified as important during the SEACAP 4 programme, such as gravel loss and erosion. Within the time constraints some assumptions have had to be made regarding the exact age of the gravel roads.

Three-day traffic counts were undertaken during the trials monitoring survey and the results of these have been analysed using the following conversion factors for esa.

Car/pick-up	0.1
Small bus	0.1
Large bus	1.5
Truck<5t	0.1
Truck>5t	3.0

Table 2.4 presents estimated traffic loading to date for the trial roads, all of which fall well within the LVRR envelope, with only road 102 showing significant traffic loading

Table 2.4 Trials Traffic

Road	24 hr esa	Age (Months)	esa to date
1011	0.72	20	432
1013	0.24	20	144
102	26.28	20	15768
1032	7.2	20	4320
1033	1.44	20	864
105	7.68	20	4608
108	1.68	20	1008

Materials information for the unsealed roads was obtained from the construction records held by the Consultant (Table 2.5). Some logical assumptions had to be made as to which borrow pits were used for particular road sections. It understood that the a mixed material (mix 108+) was used on roads 108 and 102 .

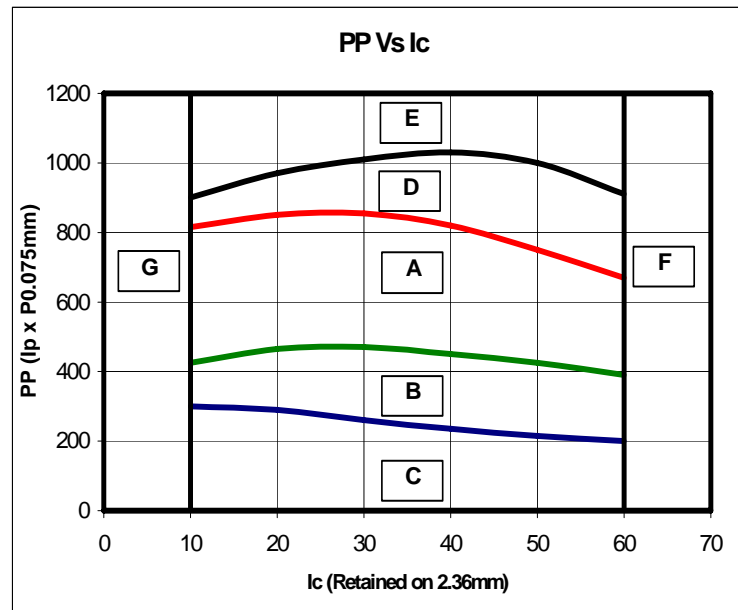
Table 2.5 Summary Gravel Borrow Pit Information

Road	lp	P.075	R 2.00	PP	PP v IC	CBR(95%)	Chain
201	10	23	43	230	B	29	
202	13	38	43	494	A	29	
1022	18	29	46	522	A	28	
1013	11	25	63	275	F	28	3.000
1013	10	27	62	270	F	27	1.900
1013	10	22	51	220	B	28	0.800
1032	16	17	63	272	F	30	3.450
1032	18	11	71	198	F	26	5.500
1032	19	15	70	285	F	27	4.320
1032	18	29	64	522	F	27	2.250
1032	17	16	67	272	F	27	6.435
105	9	14	53	126	C	36	3.500
105	10	54	40	540	A	40	4.500
105	9	12	53	108	C	31	5.500
105	8	11	51	88	C	40	0.700
105	9	12	57	108	C	37	2.600
105	8	13	54	104	C	33	0.900
1011	9	18	59	162	C	38	2.050
1011	9	23	57	207	B	32	0.500
1033	9	11	62	99	F	35	1.750
1033	9	12	62	108	F	33	0.800
Mix (108)+	9	10	56	90	C	32	

- Notes : (1) I_p = Plasticity; (2) $P_{0.075}$ = % material passing the 0.075mm sieve
- (3) $R_{2.00}$ = % material retained on the 2.00mm sieve = I_c
- (4) PP = Plasticity Product (1) x (2)

The value of PP v I_c is an empirical figure used as standard assessment of gravel suitability, as shown in Figure 3.1

Figure 3.1 Gravel Suitability Assessment



- A: Good performance under wet and dry conditions
- B: Good performance under wet conditions; corrugates in dry conditions
- C: Lacks cohesion: rapid deterioration with traffic
- D: Good in dry conditions; slippery in wet; potholes/erosion
- E: Poor in both wet and dry conditions
- F: Too coarse: erodes badly; difficult to maintain
- G: Too fine; traffickability problems in wet and very dusty when dry

The above plot indicates that only 6 out of the 22 approved materials sources fell into “good performance categories” and that the remaining materials could be described as being susceptible to rapid erosion. It should be noted however that figure 3.1 was originally derived for Southern African road environment conditions and may require some re-calibration for the higher and more intense rainfall environments of S E Asia. It nevertheless provides valuable relative comparison for gravel source assessment.

4 Trials Monitoring Discussion

4.1 General

The condition of the selected trial lengths is discussed in the following sections mainly with respect to the visual and MERLIN roughness surveys. The trial lengths are grouped under the principal pavement or surfacing types.

The RCD and DE indices are used to illustrate comparative deterioration. Individual deterioration indices are also given where appropriate to highlight key modes of deterioration.

4.2 Unsealed gravel and natural surface trials

A total of 9 unsealed sections were surveyed; 8 gravel and one Engineered Natural Surface. Key condition summaries are shown on Table 4.1

Table 4.2 Unsealed Road Summary

Road Ref.	esa to date	Gradient	DEI%	RCDI	IRI (17.01)	IRI (17.02)	Material Assessment as per Figure 3.1
1011.01	400	11	100	41	8.28	9.07	C
1013.01	150	0	100	30	7.46	10.93	F
102.01	15,700	0	100	31	9.51	10.57	C
1032.06	4,300	4	100	15	9.01	7.82	F
1033.01	900	0	100	19	7.46	6.08	F
105.08	4,600	2	100	22	7.92	6.08	C
105.09	4,600	8	100	23	7.92	6.97	A
108.03	1,000	5	100	29	7.79	6.08	C
1032.03	4,300	0	100	16	6.02	6.32	

Key points discussion points are:

1. The three worst performing gravel roads are those where the IRI roughness is also deteriorating. In the other 5 gravel roads the surface is apparently becoming smoother. This is likely to be at least part due to material characteristics.
2. All the unsealed roads show some deterioration over all the trial length (DEI=100%).

The performance of the unsealed roads is discussed further in Chapter 5.

4.3 Sealed flexible pavements

The four sealed flexible trial sections comprised 120mm sub-base of NEC gravel overlain by 150mm of crushed stone aggregate. Summary details are listed in Table 4.2.

Table 4.2 Flexible Pavement Summary

Road Ref.	Seal	esa to date	DEI%	RCDI	IRI (17.01)	IRI (17.02)	Comment
1032.01	Single Otta seal	4,300	63	6	7.19	5.44	Steep gradient
1032.02	Double Otta seal	4,300	83	9	7.31	5.28	
108.01	Sand seal	1,000	95	23	6.80	5.03	
108.02	Sand seal	1,000	80	30	6.80	5.48	

Key points discussion points are:

1. The principal deterioration mode in the Otta seals is minor widespread rutting (<20mm).
2. There was some evident localised damage to the surface of the Otta seals. It is not clear however whether this is construction defect. Figure 4.1
3. The significant decrease in roughness for the Otta Seals can be logically accounted for by the “bedding –in” of the sealing aggregate with use. Some of the aggregate appeared significantly oversize which also enhance initial roughness.
4. The principal deterioration on the sand seal sections is the occurrence of shallow potholes associated with localise stripping of the seal (CDI 40-50%). Figure 4.2
5. Secondary deterioration forms are minor rutting (CDI<10%) and seal cracking (CDI<30%).
6. The defects for this group are a consequence of surface deterioration rather than structural problems.



Figure 4.1 Seal erosion and shallow potholes. Road 1032.01



Figure 4.1 Defects in Otta Seal – possibly construction related

4.4 *Hand-packed Stone*

Two hand-packed stone options were constructed one mortared and one non-mortared, over a gravel sub-base, Table 4.3-

Table 4.3 Hand-Packed Stone Summary

Road Ref.	Description	esa to date	DEI%	RCDI	IRI (17.01)	IRI (17.02)	Comment
102.02	Non-mortared	15,700	100	20	6.59	9.96	
102.03	Non-mortared	15,700	100	30	6.59	10.56	
1032.04	Mortared	4,300	100	15	14.28	15.65	
1032.05	Mortared	4,300	98	22	11.82	13.36	Steep Gradient

Key points discussion points are:

1. The visual appearance of both these option is poor and the evident roughness of surface is reflected in the high IRI figures. In the case of the non-mortared option the surface has evidently deteriorated significantly since construction. Figure 4.3
2. The non-mortared option shows a significant DCI of 40% surface condition with stone and inter-stone matrix conditions between 20-30% DCI.
3. The mortared option shows a similar figure for surface condition and matrix but a much better figure for stone condition (10% DCI), which may either reflect better selection of stone or that the mortared matrix is giving better support to the larger stones.
4. It was evident that because of the roughness of these options the local two-wheeled traffic was using the gravel shoulder rather than the carriageway. The result is a significant deterioration of the shoulder and an undercutting of the carriageway edge. Figure 4.4



Figure 4.4 Traffic using shoulder rather than rough carriageway



Figure 4.3 Rough stone surface

4.5 Geocells

Three thickness of geocell were constructed over a 125mm thickness of gravel sub-base, (Table 4.4)

Table 4.4 Geocell Summary

Road Ref.	Description	esa to date	DEI%	RCDI	IRI (17.01)	IRI (17.02)	Comment
105.05	75mm	4,600	98	16	8.12	5.68	
105.06	100mm	4,600	100	22	8.12	5.03	
105.07	150mm	4,600	100	23	8.12	5.68	Steep gradient

Key points discussion points are:

1. These options were in generally good condition and the high DEI figure is largely a reflection of the widespread deterioration of the thin surface screed. It is likely that in future analyses the importance of this factor will be down-graded.
2. There is some possible evidence of deterioration at the concrete-membrane joints (DCI 20-30%). It is unclear yet whether this is significant issue or not. Figure 4.5
3. There was no evidence of structural cracking through cells. Figure 4.6



Figure 4.5 Erosion adjacent to cell boundaries



Figure 4.6 Cracks in surface screed following cell boundaries

4.6 Concrete blocks

This option comprised an unsealed surface of unsealed sand jointed blocks over a gravel sub-base. sub-base, Table 4.5

Table 4.5

Road Ref.	Description	esa to date	DEI%	RCDI	IRI (17.01)	IRI (17.02)	Comment
105.01	Non-mortared	4,600	100	15	9.05	6.97	Gravel sub-base
105.02	Non-mortared	4,600	98	13	9.05	5.03	Gravel sub-base

Key points discussion points are:

1. The principal deterioration issue is erosion of the unsealed sand joints - with an individual DCI of 30%, Figures 4.7 and 4.8
2. There is however a surprisingly high figure for cracked or broken blocks (DCI 15-20%). This is high in comparison with similar pavements in Vietnam which would suggest that the Bokeo concrete blocks could be below specification as regards strength.
3. The decrease in roughness probably reflects a bedding-down effect on the blocks in the sand bedding layer.



Figure 4.7 Grass growing within joints may loosen blocks



Figure 4.6 Eroded badly spaced joints. One cracked block

4.7 Bamboo reinforced concrete

Two thickness of bamboo reinforced concrete were constructed over a 125mm thick gravel sub-base, Table 4.6

Table 4.6 Concrete Summary

Road Ref.	Description	esa to date	DEI%	RCDI	Seals CDI	IRI (17.01)	IRI (17.02)	Comment
105.03	125mm	4,600	10	2	40	11.67	9.07	
105.04	150mm	4,600	5	4	41	11.67	7.62	

Key points discussion points are:

1. The pavement blocks are performing satisfactorily with only isolated cracks – typically at the edge of blocks. Experience from elsewhere indicates that erosion or soaking of the gravel sub-base can sometimes lead to cracking under load. Figure 4.8
2. The inter-block seal condition is shown separately as a significant deterioration factor that should be dealt with easily by routine maintenance.



Figure 4.8 Typical corner edge crack in concrete slab

5 Gravel Assessment Programme Discussion

5.1 General

The Lao Gravel Assessment Programme (LGAP) survey, although much smaller size and extent than the RRGAP in Vietnam, does give an opportunity to analyse unsealed road data within reasonably uniform general environment. This analysis has concentrated on key issues raised by the RRGAP, namely gravel loss and erosion, but also has focussed on how these recently constructed roads relate to the proposed LVRR Standards and Specifications.

5.2 Road Geometry

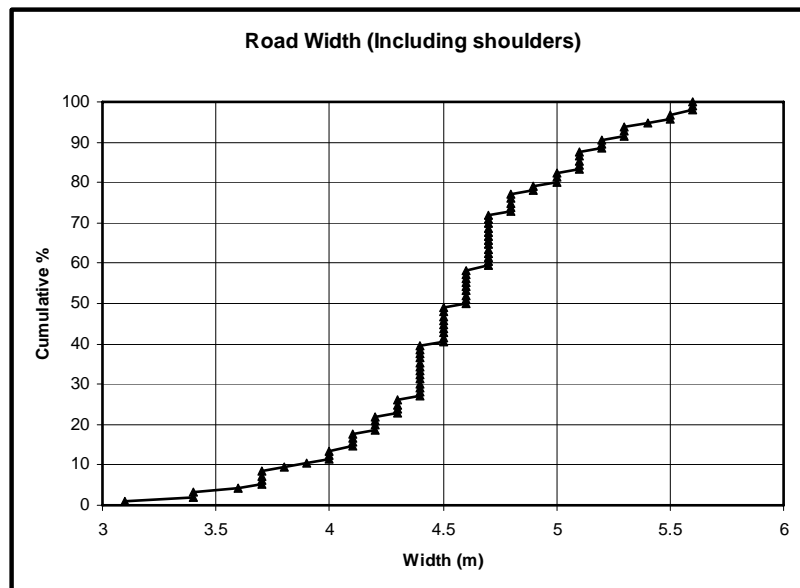
The new LVRR Geometric standards require a minimum road width (carriageway + shoulders) of 4.5m for a 2.5m wide carriageway and 5.5m for a 3.5m wide carriageway. The latter is recommended where vehicles larger than a Kao Lao are likely to use the road. A minimum shoulder with of 1.0m is recommended unless significant amounts mixed traffic require a wider 1.5m shoulder on safety grounds.

The survey indicated a significant variation in road width even with this one group of roads. The carriageway varied from 2.3m to 4.0m, with shoulders mainly from 0.5 to 0.7m. The roads were constructed at gradients from 0-15%.

It is likely that with, one possible exception, all the surveyed roads could fall within the lower category of road allowing minimum 4.5m road width. Compared to the proposed standards the carriageway widths were largely compliant with the standards provided the smaller vehicle option was used.

The overall road widths were however below standard at about 40% of the sites, largely due to the narrow shoulders, Figure 5.1. Shoulders below 1.0m are not permitted in the proposed LVRR standards.

Figure 5.1 Surveyed Road Widths



5.3 Gravel loss

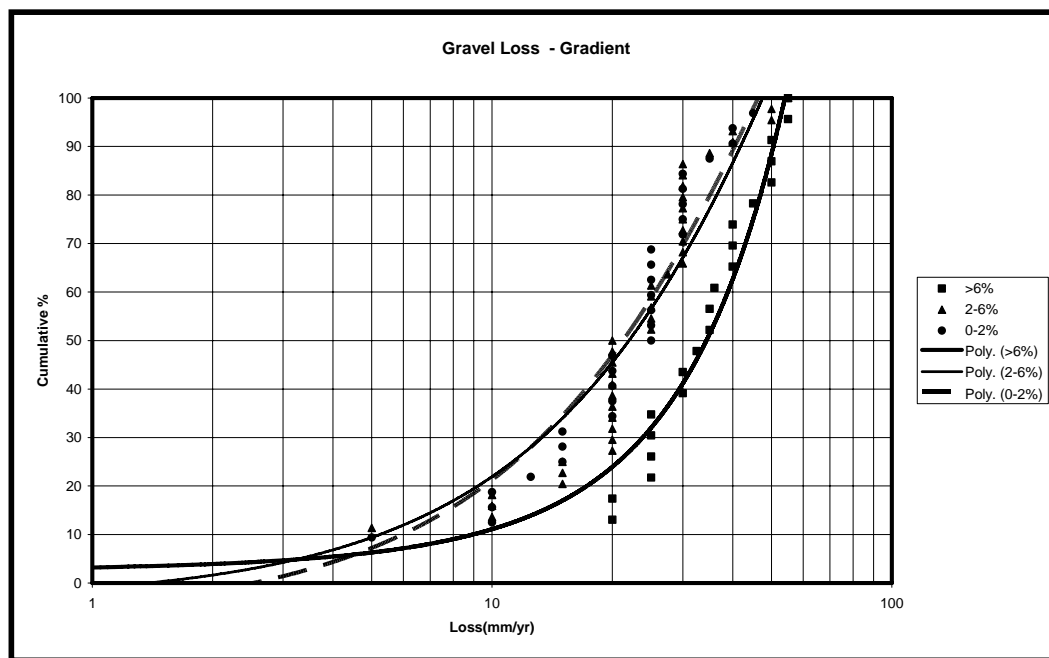
The RRGAP study in Vietnam indicated that gravel losses in excess of 20mm/yr is unsustainable in an environment where periodic grading and re-gravelling were not established activities. It is clear from observation and from the survey data that little or no effective maintenance is being undertaken on the LGAP roads. Hence the 20mm/yr figure is reasonable to assume as a boundary of unsustainability for these roads.

The gravel loss figure for the LGAP roads were assessed with particular attention focussed on the 6% limit imposed by the LVRR Standards. The analysis was based on the following assumptions

- The road were constructed to a 200mm gravel thickness
- The roads have an average age of 20 months
- The rainfall is reasonable uniform over the area of 1500-2000m/yr

The gravel losses were calculated for 3 different gradient ranges 0-2%; 2.1-6%; and >6%, as shown in Figure 2.2.

Figure 5.2 LGAP Gravel Loss



The following key points arise out of this analysis:

1. The gravel loss figures for 0-2 and 2-6% are reasonably similar, with just over 50% having an unsustainable loss of greater than 20mm/yr.
2. However, 70% of roads with less than 6% gradient show gravel losses less than 30mm/yr which would indicate that with at least some effective shape maintenance these roads could be sustainable.
3. Roads with greater than 6% gradient show a significant increase in gravel loss, with around 75% having a loss of greater than 20mm/yr and 60% greater than 30mm/yr. These sections would not be considered sustainable.

5.4 Road shape

A related analysis looked at the existing shape and loss of camber on the LGAP roads. Table 5.1 summarises actual camber measurements for all the NEC roads and Table 5.2 shows loss of shape in relation to gradient, including the non NEC roads.

Table 5.1 Measured Crossfall

Measured Crossfall	Percentage of roads within this group
0-2%	41%
2.1-4%	34%
4.1-7%	25%

Table 5.2 Cross-sectional Shape

Code		NEC Sections (%)	Non NEC (%)	Gradient : NEC Sections		
				>6%	2-6%	0-2%
1	As built	0	0	0	0	0
2	Slight deterioration of camber	91	25	70	95	100
3	Flat	0	25	0	0	0
4	Uneven	9	31	30	5	0
5	Dished - Bowl shaped	0	19	0	0	0

Key points to note are:

1. On the assumption that the roads were constructed to the specified 6-7% camber, then after just under 2 years all road sections are now below the required shape requirements.
2. On high gradients 30% of the NEC roads are significantly below shape, Figure 5.3
3. 75% of the non-NEC road sites were recorded as having a cross sectional shape incapable of effectively shedding surface water. The implication is that there is no effective maintenance procedure in place to maintain shape



Figure 5.3 Eroded gravel on steep section of NEC package II road 201. Shape prevents run-off into well constructed drain

5.5 *Erosion*

The visual assessments of surface erosion of the carriageway and shoulders (Table 5.3) confirm the impact of gradient on unsealed surface condition. It is worth noting that even on very low gradient section there are very few sections showing no evidence of erosion.

Table 5.3 Carriageway and Shoulder Erosion

Code	Erosion Effect	Gradient Carriageway			Gradient Shoulders		
		>6%	2-6%	0-2%	>6%	2-6%	0-2%
1	None	0	2	3	13	9	9
2	Rills <15mm deep	43	91	97	65	82	91
3	Rills 15-50 mm deep	57	7	0	22	9	0

6 Conclusions

6.1 *Trials Condition Monitoring*

The interim survey of trials road condition has raised some important issues regarding the selection and maintenance of LVRR pavement and surfacing options in Lao, namely

1. The unsealed block option with sand joints is not likely to be a sustainable option unless regular maintenance is undertaken on the joints. Mortared joints or some form of resistant bitumen-sand mix are likely to be more sustainable options. More stringent compliance with block strength requirements may be required in future use of this option.
2. The hand packed stone and mortared stone options have not been successful. Indications are that problems during construction may have contributed to their current deteriorating condition.
3. The sand sealed option is showing signs of serious deterioration and without immediate maintenance this could escalate rapidly.
4. The geocell options are performing well, although the deterioration of the surface screed and joint areas should be monitored for indication of any more serious consequential defects.
5. The concrete options require ongoing maintenance to the inter-slab seals, otherwise only occasion localised cracking is evident.

The SC17.02 survey has confirmed the need for ongoing regular monitoring of these sites if any meaningful outcomes are to be achieved from the initial outlay on this programme. Much more time needs to be given to combining the SC17.01 and SC17.02 data sets into a comprehensive working database capable of effective analysis.

6.2 *The LGAP Survey*

Even the limited analysis undertaken on this data set has been able to highlight some important issues:

1. The 6% gradient cut-off for gravel use in the LVRR Standards and Specifications has been shown to be logical.
2. Current unsealed road designs are below LVRR Standard as regards roadway width.
3. Unsealed gravel roads built with suitable materials can be a sustainable option if combined with some minimum road shape maintenance.
4. The combination of unsealed roads at gradients less than 6% and Spot Improvements on sections >6% can provide a Lao with major tool to address their poverty alleviation aims through improved access

**PERFORMANCE MONITORING
OF
THE NEC-ADB PACKAGE I
TRIAL AND GRAVEL ROADS**

SEACAP 17.02

**APPENDIX A
NUMERIC CODES FOR VISUAL ASSESSMENT**

Concrete Pavements

Defect	Database scale	Notes
Joint Seal	0 Sound 1 0-5% cracked or missing 2 5-10% cracked or missing 3 10-25% cracked or missing 4 25-50% cracked or missing 5 >50% cracked or missing	This factor calculated as a separate CDI
Crack Extent	0 No cracks 1 0-10% length or total area < 1m ² 2 10 – 50% length or total area 1-5m ² 3 >50% length or total area > 5m ²	A score of 100 means more than 100m ² of pavement is cracked along the section. This represents about 30% of every 5m subsection.
Surface Condition	0 Good 1 Crazed cracking 2 Surface stripping- aggregate exposed	
Potholes	0 None 1 1 pothole in 5 metre block 2 2 – 3 potholes 3 >3 potholes	A score of 15 is a warning level. One pothole every 5 metres is serious therefore a score >33is serious

Geocells

Defect	Database scale	Notes
Structural Crack Extent	0 No cracks 1 0-10% length or total area < 1m ² 2 10 – 50% length or total area 1-5m ² 3 >50% length or total area > 5m ²	This excludes cracking in surface screed
Cell Condition	0 Solid – no deterioration 1 Minor erosion at joint edges 2 General erosion at joints Maximum 3 0-10% aggregate exposed 4 10-50% aggregate exposed 5 >50% aggregate exposed	These codes may require adjustment as deterioration patterns emerge with time
Joint Condition	0 Solid – no deterioration 1 0-5% Cracked or missing k 2 5-10% Cracked or missing >3 3 10-25% Cracked or missing 4 25-50% Cracked or missing 5 >50% Cracked or missing	A score of 15 is a warning level. One pothole every 5 metres is serious therefore score of 33 or more is serious

Sealed Flexible

Defect	Database scale	Notes
Crack Extent	0 No cracks	A score of 100 means more than one crack along the whole 100m or crocodile cracking along at least 50m
	1 <1m	
	2 1-5m	
	3 >5m	
Ruts	0 <10	A score of >20 indicates the beginning of failures. Ruts of 50-100mm usually indicate base and surfacing failure thus 60/100 is a serious condition
	1 Maximum rut= 10-20mm	
	2 Maximum rut= 20-50mm	
	3 Maximum rut= 50-100mm	
	4 Maximum rut= 100-200mm	
5 Maximum rut >200mm		
Potholes	0 None	A score of 15 is a warning level. One pothole every 5 metres is serious therefore score of 33 or more is serious
	1 1 pothole in 5 metre block	
	2 2 – 3 potholes	
	3 >3 potholes	

Block Pavements

Defect	Database scale	Notes
Block condition	1 Sound	A score of 100 means that more than 50% of blocks in every 5m are loose or broken – a very serious condition indeed.
	2 0-5% loose or broken	
	3 5-10% loose or broken	
	4 10-25% loose or broken	
	5 25-50% loose or broken	
	6 >50% loose or broken	
Joint condition	1 Sound	. A score of 100 means that more than 50% of joints in every 5m are cracked or missing.
	2 0-5% cracked or missing	
	3 5-10% cracked or missing	
	4 10-25% cracked or missing	
	5 25-50% cracked or missing	
	6 >50% cracked or missing	
Ruts	0 <10	A score of >20 indicates the beginning of failures. Ruts of 50-100mm usually indicate base and surfacing failure thus 60/100 is a serious condition
	1 Maximum rut= 10-20mm	
	2 Maximum rut= 20-50mm	
	3 Maximum rut= 50-100mm	
	4 Maximum rut= 100-200mm	
5 Maximum rut >200mm		
Potholes	0 None	A score of 15 is a warning level. One pothole every 5 metres is serious therefore a score >33 is serious
	1 1 pothole in 5 metre block	
	2 2 – 3 potholes	
	3 >3 potholes	

Hand-Packed Stone

Defect	Database scale	Notes
Surface Condition	0 Compact tight as built condition 1 0-5% loose or missing stone 2 5-10% loose or missing stone 3 0-25% Loose or missing stone 4 25-50% Loose or missing stone 5 >50% loose or missing stone	A score of 100 means that more than 50% of stone blocks in every 5m are loose or missing– a very serious condition indeed.
Block condition	0 Sound 1 0-5% loose or broken 2 5-10% loose or broken 3 10-25% loose or broken 4 25-50% loose or broken 5 >50% loose or broken	A score of 100 means that more than 50% of stone blocks in every 5m are loose or broken – a very serious condition indeed.
Matrix/Joint condition	0 Sound 1 0-5% cracked or missing 2 5-10% cracked or missing 3 10-25% cracked or missing 4 25-50% cracked or missing 5 >50% cracked or missing	A score of 100 means that more than 50% of the matrix or joints in every 5m are cracked or missing.
Depressions	0 None 1 1 pothole in 5 metre block 2 2 – 3 potholes 3 >3 potholes	A score of 15 is a warning level. One pothole every 5 metres is serious therefore a score >33is serious
Potholes	0 None 1 1 pothole in 5 metre block 2 2 – 3 potholes 3 >3 potholes	A score of 15 is a warning level. One pothole every 5 metres is serious therefore a score >33is serious

Unsealed

Defect		Database scale	Notes
Erosion	1	Negligible	A score of >100 means that significant gravel loss has occurred over more that 50% of the section
	2	Slight (loss 5-20mm, <10% of area)	
	3	Moderate (loss 5-20mm, 10-50% of area)	
	4	Severe (material loss >20mm, area >10%	
	5	Very severe (material loss >20mm, area >50%	
Ruts	0	<10	A score of >20 indicates the beginning of failures. Ruts of 50-100mm usually indicate base and surfacing failure thus 60/100 is a serious condition
	1	Maximum rut= 10-20mm	
	2	Maximum rut= 20-50mm	
	3	Maximum rut= 50-100mm	
	4	Maximum rut= 100-200mm	
Potholes	0	None	A score of 15 is a warning level. One pothole every 5 metres is serious therefore score of 33 or more is serious
	1	1 pothole in 5 metre block	
	2	2 – 3 potholes	
	3	>3 potholes	

