PERFORMANCE MONITORING OF LOW VOLUME RURAL ROADS

IN NORTHWEST LAOS PDR (SEACAP 17-002)[1]

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1 Background

Rural poverty alleviation is a major objective for the Government of the Lao PDR (GoL) within the next 10 years. A key element in the poverty reduction strategy is the development and upgrading of the rural infrastructure through the most cost-effective means. The Ministry of Public Works and Transport (MPWT) 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 develop Lao's rural road network. High on the priorities of applied research singled out by the DoR within the MPWT was the need to identify appropraite rural road pavement and surfacing options. To this end the South East Asian Community Access Programme (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 Province[2].

Figure 1: Map indicating location of SEACAP 17 trials.

The pavement and surfacing trial options were as follows:

[1] http://www.seacap-info.org/?mod=home&act=pdesc&pid=44
[2] http://www.seacap-info.org/?mod=home&act=pdesc&pid=19

- **Standard NEC Gravel.** This construction comprises 200mm of gravel wearing course with a bearing capacity of CBR[3]≥25%;

- **Bamboo Reinforced Concrete.** Consists of a concrete slab, reinforced with strips of bamboo, and laid upon a compacted base;

- **Geocell**. A manufactured plastic formwork is used to construct in-situ concrete paving. The plastic formwork is sacrificial and remains embedded in the concrete creating a form of block paving;

- **Mortared Stone.** This pavement consists of a layer of large stones, placed closely together to form a tight surface. The voids are filled with mortar to form an impervious layer;

- **Hand Packed Stone.** This consists of a layer of large stones into which smaller chips are packed. Remaining voids are filled with sand or gravel to form a strong and semi-impervious matrix;

- **Concrete Paving Blocks.** The blocks are precast in moulds and then laid side by side on a prepared sub-base. Gaps between blocks are filled with fine material to form a strong and semi-impervious layer;

- **Sand Seal.** This seal consists of a machine applied film of bitumen followed by the application of excess sand which is lightly rolled into the bitumen;

- **Otta Seal**. This surface comprises a layer of binder followed by a layer of aggregate that is rolled into the binder using a roller or loaded trucks. It is different to surface dressing in that an 'all in' graded gravel or crushed aggregate is used instead of single sized chippings. The layer is thicker and more bitumen is used; and,

- **Engineered Natural Surface**. This construction is used where the existing subgrade material comprises natural gravel with the same engineering characteristics as the pavement layer.

The construction 12 trials sections and associated seven 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 Project Objectives

The development of recommendations on suitable pavement or surfacing options requires that their performance is 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 selected road sections in conjunction with assessments of the governing road environments is an essential part of this process.

The performance monitoring was a logical and necessary continuation of the main SEACAP 17 trial programme and was concerned primarily with the collection and analysis

[3] CBR = California Bearing Ratio

of pavement performance information from trial road sections. This project (termed SEACAP 17.02) was a one-off data collection and assessment exercise that should be repeated with sufficient regularity so as to enable valuable lessons to contribute to the sustainable development of the Lao PDR rural infrastructure.

In addition to the monitoring of the trial roads, this project undertook a Lao Gravel Assessment Programme (LGAP) with the objective of analysing information on the performance of a number of unsealed gravel roads within the NEC corridor.

3 Work Undertaken

Trials Monitoring

A more numeric coded system was adopted that was derived from that used on the SEACAP trial programme[4] in Vietnam. The trials monitoring survey which followed-on from an initial training period, was completed during February and March 2009. A total of 2.75km of trial sections in 24 lengths on seven trial roads were surveyed. They are listed in Table 1.

Table 1, Trial roads, characteristics and lengths.

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	1+800	1+900	100
				Sand Seal	2+000	2+100	100
				Gravel	2+225	2+325	100
						Total	2,475

The following data sets were collected.

- Visual survey - using standard numeric based coded sheets;
- Cross sections – using standard levelling techniques;
- In Situ pavement layer strength – using Dynamic Cone Penetrometer (DCP);
- IRI Roughness - MERLIN;
- Pavement structure stiffness - Mini Falling Weight Deflectometer (FWD); and,
- Rut depth – using dipped measurements from a straight edge.

[4] http://www.seacap-info.org/?mod=home&act=pdesc&pid=4 & http://www.seacap-info.org/?mod=home&act=pdesc&pid=25

Gravel Assessment Survey

A survey of the condition of NEC gravel access roads by means of "spot" assessments was carried out. This survey was similar in nature to a previous larger SEACAP 4 project[5] carried out in Vietnam. The data collection procedures and forms and associated codes were derived from the SEACAP 4 project.

The LGAP survey was completed during March and April 2009. Table 2 lists the extent of this survey.

Table 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**

Data Analysis

The trials data analysis and associated comments are 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 were identified that may reasonably be able to represent road performance (Table 3). These factors were analysed using the associated numeric codes to ascertain relative pavement deterioration.

A total deterioration index is calculated by combining the deterioration of the key factors as percentage of total deterioration (i.e. 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" (i.e. >3 potholes in a 5 m block). If every 5m block on a 100m trial section had this maximum deterioration this would be equal to 100% index. Note that 100% index does not indicate a complete disintegration of the road, but rather an extremely serious pot-holed condition

[5] http://www.seacap-info.org/?mod=home&act=pdesc&pid=7

Table 3, Key Performance Indicators.

Trial Group	Indicative Factors	Trial Group	Indicative Factors
Concrete	Joint condition Crack extent Surface condition Potholes	Blocks	Block condition Joint Condition Ruts Potholes
Geocells	Structural crack extent Cell condition Joint condition	Hand Packed Stone	Block condition Joint Condition Depressions Potholes
Sealed Flexible	Crack extent Ruts 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[6]).

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 Indicator (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 of deterioration seriousness and extent.

For example:

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

The LGAP survey data was analysed using key factors, such as gravel loss and erosion. Within the time constraints some assumptions were 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 4 presents estimated traffic loading to date for the trial roads, all of which fall well within the Low Volume Rural Road (LVRR) envelope, with only road 102 showing significant traffic loading.

[6] esa = Equivalent Standard Axle

Table 4, Trials Traffic Loading

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 (Table 5).

Table 5, Summary Gravel Borrow Pit Information.

Road	Ip	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	

Where: (1) Ip = Plasticity;

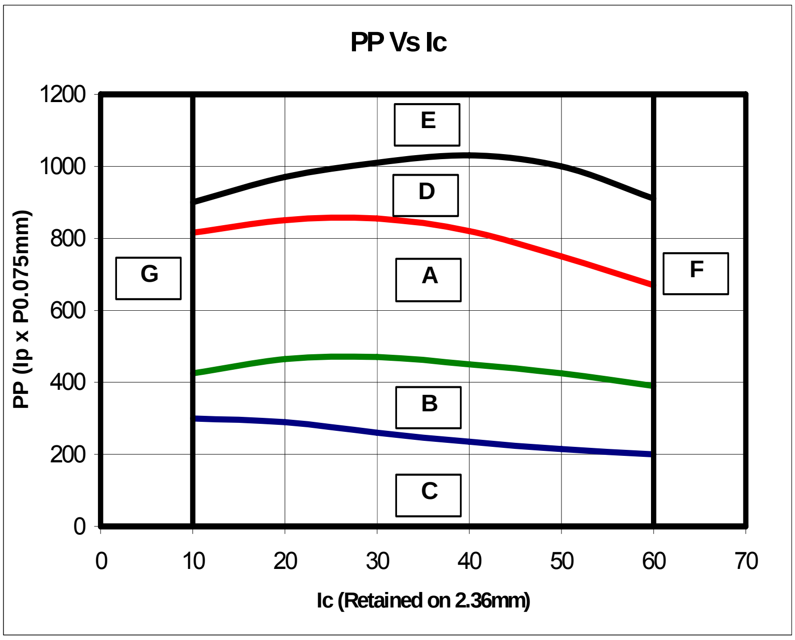
(2) P.075 = % material passing the 0.075mm sieve

(3) R2.00 = % material retained on the 2.00mm sieve = Ic

(4) PP = Plasticity Product (1) x (2)

The value of PP against Ic is an empirical figure used as standard assessment of gravel suitability, as shown in Figure 2.

Figure 2, 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 trafiic
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

4 Trials Monitoring Discussion

Unsealed gravel and natural surface trials

A total of nine unsealed sections were surveyed: Eight gravel and one Engineered Natural Surface (NEC). Key condition summaries are shown on Table 6.

Table 6, 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	

The three worst performing gravel roads are those where the IRI roughness is also deteriorating.

In the other five gravel roads, the surface is apparently becoming smoother. This is likely to be at least partly due to material characteristics.

The performance of unsealed roads is discussed further in Section 5.

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 7.

Table 7, 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:

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 3);
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).
5. Secondary deterioration forms are minor rutting (CDI<10%) and seal cracking (CDI<30%); and,
6. The defects for this group are a consequence of surface deterioration rather than structural problems.

Figure 3, Defects in Otta Seal – possibly construction related.

Figure 4, Seal erosion and shallow potholes - Road 1032.01

Hand-packed Stone

Two hand-packed stone options were constructed over a gravel sub-base: one mortared; and, one non-mortared (Table 8).

Table 8, 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:

1. The visual appearance of both these option is poor and the evident roughness of the 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 5);
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 6).

Figure 5, Rough stone surface.

Figure 6, Traffic using shoulder rather than rough carriageway.

Geocells

Three thicknesses of geocell were constructed over a 125mm thickness of gravel sub-base (Table 9).

Table 9, 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:

1. These options were generally in 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 7); and,
3. There was no evidence of structural cracking through cells (Figure 8)

Figure 7, Erosion adjacent to cell boundaries.

Figure 8, Cracks in surface screed following cell boundaries.

Concrete blocks

This option comprised an unsealed surface of unsealed sand jointed blocks over a gravel sub-base (Table 10).

Table 10, Concrete Blocks Summary.

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:

1. The principal deterioration issue is erosion of the unsealed sand joints - with an individual DCI of 30% (Figures 9 and 10);
2. There is 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 strength specification; and,
3. The decrease in roughness with time probably reflects a bedding-down effect on the blocks in the sand layer.

Figure 9, Grass growing within joints may loosen blocks.

Figure 10, Eroded badly spaced joints with one cracked block

Bamboo reinforced concrete

Two thickness of bamboo reinforced concrete were constructed over a 125mm thick gravel sub-base (Table 11).

Table 11 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:

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 11).
2. The inter-block seal condition is shown separately as a significant deterioration factor that should be dealt with easily by routine maintenance.

Figure 11, Typical corner edge crack in concrete slab.

5 Lao Gravel Assessment Programme Discussion

Road Geometry

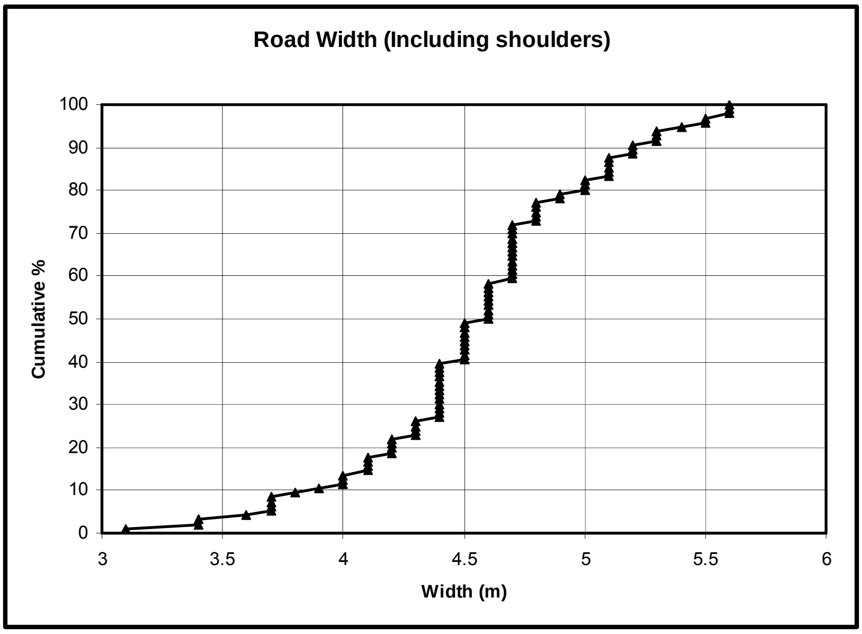
The new LVRR Geometric Standards for Lao require a minimum road width (carriageway + shoulders) of 4.5m for a 2.5m wide carriageway and 5.5m for a 3.5m wide carriageway. The latter is recommended where vehicles larger than a Kao Lao[7] are likely to use the road. A minimum shoulder with of 1.0m is recommended unless significant amounts of mixed traffic require a wider 1.5m shoulder on safety grounds.

A significant variation in road width was indicated within the surveyed roads. The carriageway varied from 2.3m to 4.0m, with shoulders mainly from 0.5m to 0.7m. The roads were constructed at gradients from 0-15%.

[7] Locally made light truck.

Compared to the proposed standards[8], the carriageway widths were largely compliant, provided the smaller vehicle option was assumed. The overall road widths were however below standard at about 40% of the sites, largely due to the narrow shoulders (Figure 12). Shoulders below 1.0m are not permitted in the proposed LVRR standards.

Figure 12, Surveyed Road Widths.



Gravel loss

The SEACAP 4 gravel 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.

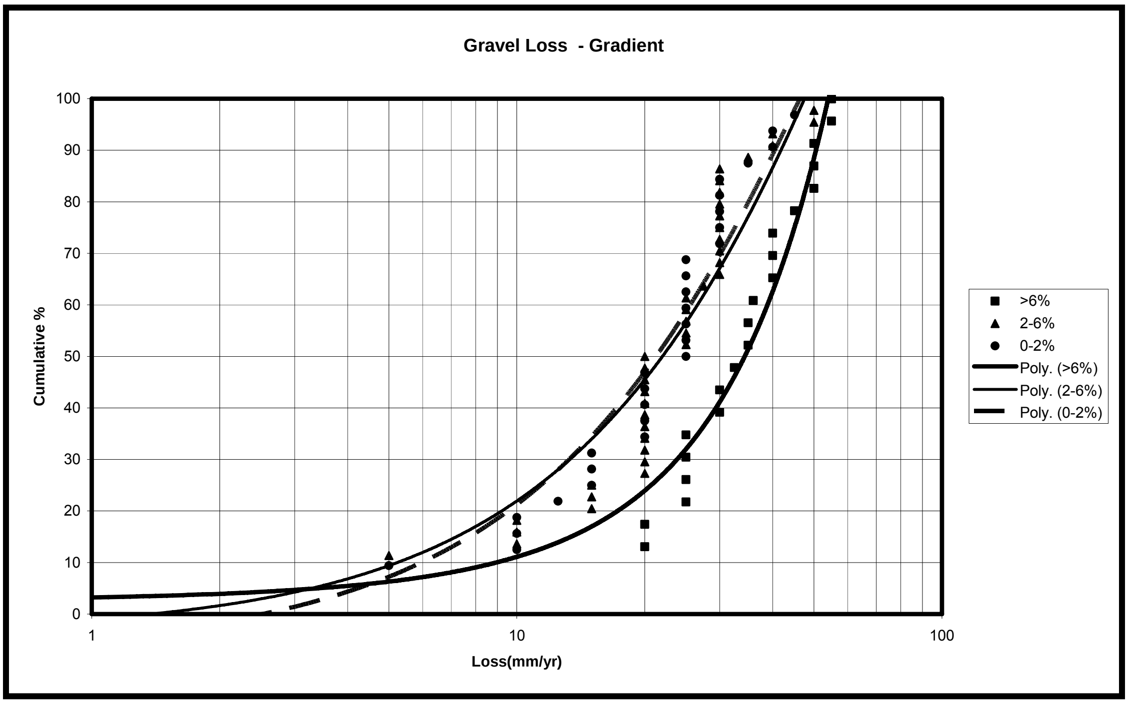
The gravel loss figure for the LGAP roads were assessed with particular attention focussed on the 6% gradient limit imposed by the LVRR Standards. The analysis was based on the following assumptions:

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

The gravel losses were calculated for 3 different gradient ranges: 0-2%; 2.1-6%; and >6%, as shown in Figure 13.

[8] The MPWT are reviewing the Standards and Specifications developed through SEACAP 3 project.

Figure 13 LGAP Gravel Loss



The following key points arise out of this analysis:

1. The gravel loss figures for 0-2% and 2-6% are 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 some effective shape maintenance, these roads could be sustainable; and,

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 should not be considered sustainable.

Road shape

A related analysis looked at the existing shape and loss of camber on the LGAP roads. Table 14 shows loss of shape in relation to gradient, including the non NEC roads. 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.
2. On high gradients 30% of the NEC roads are significantly below shape (Figure 15).
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

Table 14, 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

Figure 15, Eroded gravel on steep section of NEC package II road 201. Shape prevents run-off into well constructed drain.

Erosion

The visual assessments of surface erosion of the carriageway and shoulders (Table 13), confirm the impact of gradient on unsealed surfaces. It is worth noting that even on very low gradient there are very few sections showing no evidence of erosion.

Table 13, 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

Trials Condition Monitoring

The interim survey of trial road conditions 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 water resistant bitumen-sand mix are likely to be more sustainable options. More stringent compliance with block strength specifications 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; and,
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.

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 to roadway width;
3. Unsealed gravel roads built with suitable materials can be a sustainable option if combined with some minimum road shape maintenance; and,
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.

7 Acknowledgements

This paper was produced as part of the SEACAP 17.02 project contracted to LTEC in principal association with OtB Engineering (International) Ltd. The drafting of the original report was undertaken by Dr Jasper Cook (OtB Engineering). The efficient LTEC fieldwork and analysis teams were managed by the LTEC Project Manager Bounta Meksavanh. David Salter, the SEACAP Programme Manager, provided key facilitation, guidance and programme support.