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Lao People's Democratic Republic

Peace Independence Democracy Unity Prosperity

Ministry of Ministry of Public Works and Transport

Department of Roads

Local Resource Solutions to Problematic Rural Road Access in Lao (PDR)

SEACAP 17 Rural Access Roads on Route No.3

Module 3 – Data Interpretation Report

December 2008

1 Palace Street
London
SW1E 5HE
United Kingdom

A2 Omega Park
Electron Way
Chandlers Ford
SO53 4SE
United Kingdom

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The Director General of Roads

Ministry of Public Works and Transport
Department of Roads

Lane Xang Avenue
PO Box 4467
Vientiane
Lao People's Democratic Republic

roughton international

A2 Omega Park, Electron Way
Chandlers Ford
Hampshire SO53 4SE
United Kingdom
tel: + 44 (0)23 8027 8600
fax: + 44 (0)23 8027 8601
email: hq@roughton.com

FAO: Mr. Laokham Sompheth

Dear Sir

Local Resource Solutions to Problematic Rural Road Access in Lao (PDR)

SEACAP 17 Rural Access Roads on Route No.3

<u>Module 3 –Data Interpretation Report</u>

It is with great please that we submit seven copies of the Module 3 Report for this project with the final comments from the DFID Technical Manager incorporated.

The Final Report will incorporate all four modules and will be submitted in both English and Lao.

Yours faithfully

Dr. S.D.Gillett

Enc.

Local Resource Solutions to Problematic Rural Road Access in Lao PDR
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www.seacap-info.org

Abbreviations

ABD	Asian Development Bank CRM Community Road Model
CBR	California Bearing Ratio
CRM	Community Road Model
DCP	Dynamic Cone Penetrometer
DCTPC	Department of Communication Transport Post and Construction
DFID	Department for International Development
DOR	Department of Roads
DRR	District and Rural Roads
DWPT	Department of Public Works and Transport, previously DCTPC
EOD	Environmentally Optimised Design
GOL	Government of Laos
gTKP	global Transport Knowledge Partnership
IFG	International Focus Group
IRAP	Integrated Rural Accessibility Planning
IRI	International Roughness Index (m/km)
KfW	Kreditanstalt fur Wiederaufbrau
LAK	Lao Kip
LBES	Labour Based Equipment Supported Maintenance
LECS	Lao Expenditure and Consumption Survey
LRD	Local Road Division
LRN	Local Road Network
LSRSP	Lao Swedish Road Sector Project
LTEC	Lao Transport Engineering Consult
LVRR	Low Volume Rural Roads
MCTPC	Ministry of Communication Transport Post and Construction
MDD	Maximum Dry Density
MPWT	Ministry of Public Works and Transport, previously MCTPC
NEC	Northern Economic Corridor
NGL	Natural Ground Level
NGPES	National Growth and Poverty Eradication Strategy
NPV	Net Present Value
NRN	National Road Network
PRC	People's Republic of China
PRoMMS	Provincial Road Maintenance Management System
PRTP	Participatory Rural Transport Planning
QA	Quality Assurance
RIP	Rural Infrastructure Project
RMF	Road Maintenance Fund
RMI	Road Maintenance Initiative under the Sub Saharan Africa Transport Policy Programme
RMP1	Road Maintenance Project 1
RMP2	Road Maintenance Project 2
RMS	Road Management System
RRSR	Rural Road Surfaces Research
SATCC	South Africa Transport and Communications Commission
SEACAP	South East Asia Community Access Programme
SID	Spot Improvement Design
Sida	Swedish International Development Cooperation Agency
SPM	SEACAP Practitioners Meeting
TCTI	Transport and Communication Training Institute
THIP	Third Highway Improvement Project
TKP	Transport Knowledge Partnership
USD	United States Dollar
VMC	Village Maintenance Committees
VOC	Vehicle Operating Costs

Local Resource Solutions to Problematic Rural Road Access in Lao PDR

EXECUTIVE SUMMARY

The Lao PDR People's Democratic Republic is in the centre of the Mekong region of South East Asia. Lao PDR is an agrarian economy with more than three-quarters of the population living in rural areas, dependent on agriculture. It is estimated that some 90% of the poverty in Lao PDR is rural-based with a strong correlation between access to basic infrastructure services and the incidence of poverty.

SEACAP's goal is to support the uptake of low cost, sustainable solutions for rural access. Improving the sustainability and affordability of rural access will lead to improved access to economic opportunities, and health and education services; thereby creating opportunities for pro-poor growth and poverty alleviation. SEACAP 17 aims at identifying cost-effective methods of improving all-year access to the rural poor through low-cost locally resource based improvement of problematic lengths of road resulting in sustainable rural access roads.

Having completed the construction of the SEACAP access roads and collected the base data as described in the Module 2 report this report concentrates on the interpretation of the data. While significant knowledge was gained during the construction phase of this project, little performance data is available as only the basic post-construction data has been collected.

Algorithms defining under which conditions particular surface types are best suited have been formulated, however, only after the long term monitoring of the pavements will it be possible to derive relationships between surface performance and key road environment factors.

Environmentally Optimised Design (EOD) and Spot Improvement Design (SID) are discussed in combination as a road design tool that considers the variation of the different road environments along the length of the road and the need to tailor design to the relevant circumstances of each critical section. Based on knowledge of the key factors of geometry, pavement structure, drainage, and slope stability the optimum road construction can be selected and designed.

During the construction of the trial pavements it became apparent that some pavement structures or surface types are more appropriate in certain circumstances. For example, the sand sealed surfaces are only appropriate for low traffic volumes on flat undemanding terrain – primarily providing a comfortable ride with little dust pollution – whereas the hand packed stone, which results in a rough surface, is more appropriate on very steep sections of road which would otherwise be impassable in the wet season. However, what has become clear is that the EOD/SID design philosophy requires that substantial time is taken in the field by experienced Engineers in order that suitable pavement structures are selected for short lengths of problematic road in order to overcome particular problems at those spots.

1 INTRODUCTION

1.1 Background

The Lao People's Democratic Republic is in the centre of the Mekong region of South East Asia. It has an agrarian economy with more than three-quarters of the population living in rural areas and dependent on agriculture. It is estimated that some 90% of the poverty in Lao PDR is rural-based and there is a strong correlation between access to basic infrastructure services and the incidence of poverty.

The goal of the South East Asia Community Access Programme (SEACAP) is to support the uptake of low cost, sustainable solutions for rural access. Improving the sustainability and affordability of rural access will lead to improved access to economic opportunities and to health and education services, thereby creating opportunities for pro-poor growth and poverty alleviation. SEACAP 17 aims at identifying cost-effective methods of improving all-year access to the rural poor through low-cost locally resource based improvement of problematic lengths of road resulting in effective and sustainable rural access roads.

The project has been implemented in conjunction with the Asian Development Bank (ADB) funded Northern Economic Corridor Project (NEC) to carry out research on a group of rural access roads in Houay Xai district of the Lao PDR. The project has required close collaboration between Ministry of Public Works and Transport ADB, SEACAP and the Consultant.

The research has been implemented in four modules as follows:

- Module 1: Project Planning and Initiation Report Submitted June 2005[1]
- Module 2: The Construction Phase and Base Data Capture
- Module 3: Operational Data Capture and Interpretation
- Module 4: Information Dissemination and Training

The approach adopted has been to identify key sections at specific locations along the access roads and to replace the standard NEC gravel pavement proposed for these sections with a SEACAP trial pavement. The pavement types selected for the trials were taken from those presented at the Knowledge Exchange Workshop in December 2004 (set out in the Module 1 report) and the specification for each of the trial pavements has been developed from similar projects in the region and worldwide as follows:

1. **Standard NEC Gravel**, this construction comprises 200 mm of gravel wearing course with a bearing capacity of CBR≥25% constructed on an in-situ subgrade which, after mechanical modification, should have a bearing capacity of CBR≥8% in fill and CBR≥5% in cut. Alternatively, where the in-situ subgrade does not meet these standards a 300 mm thick selected subgrade layer should be imported having a bearing capacity of CBR≥8%.
2. **Bamboo Reinforced Concrete**, a bamboo reinforced surface consists of a layer of concrete, reinforced with strips of bamboo, and laid upon a compacted base.
3. **Geocell**, 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.
4. **Mortared Stone**, this surface 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.

[1] ***Local Resource Solutions to Problematic Rural Roads Access in Lao PDR**, SEACAP Access Roads on Route 3. SEACAP 17, Module 1 Report, July 2005*

5. **Hand Packed Stone**, this surface 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.
6. **Concrete Paving Blocks**, the blocks are precast in moulds and then laid side by side on a prepared subbase. Gaps between blocks are filled with fine material to form a strong and semi-impervious layer.
7. **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.
8. **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.
9. **Engineered Natural Surface**, this construction is used where the existing subgrade material comprises natural gravel with the same engineering characteristics as the pavement layer.

In order to monitor the pavement trials, various preliminary data have been collected, specifically; the bearing capacity of the road foundations, the gradients and alignment, predicted traffic loading and climatic data. This data is stored in a database (developed in Microsoft Access) which is owned by the Ministry of Public Works and Transport (MPWT).

On completion of the trial sections, base condition monitoring was conducted as follows:

- Visual Inspection and surface condition logging;
- Photographic logging;
- Surface deformation recording (dipped levels and rut measurement);
- Surface roughness using a MERLIN apparatus;
- Surface Texture (sand patch test);
- Classified traffic counts, and;
- Structural integrity using a Dynatest 3031 LWD Light Weight Deflectometer.

The records have been collected in a similar method to that of other SEACAP projects and stored in a similar format (an MS Excel based database) so that comparisons with trial sections on other projects can be made.

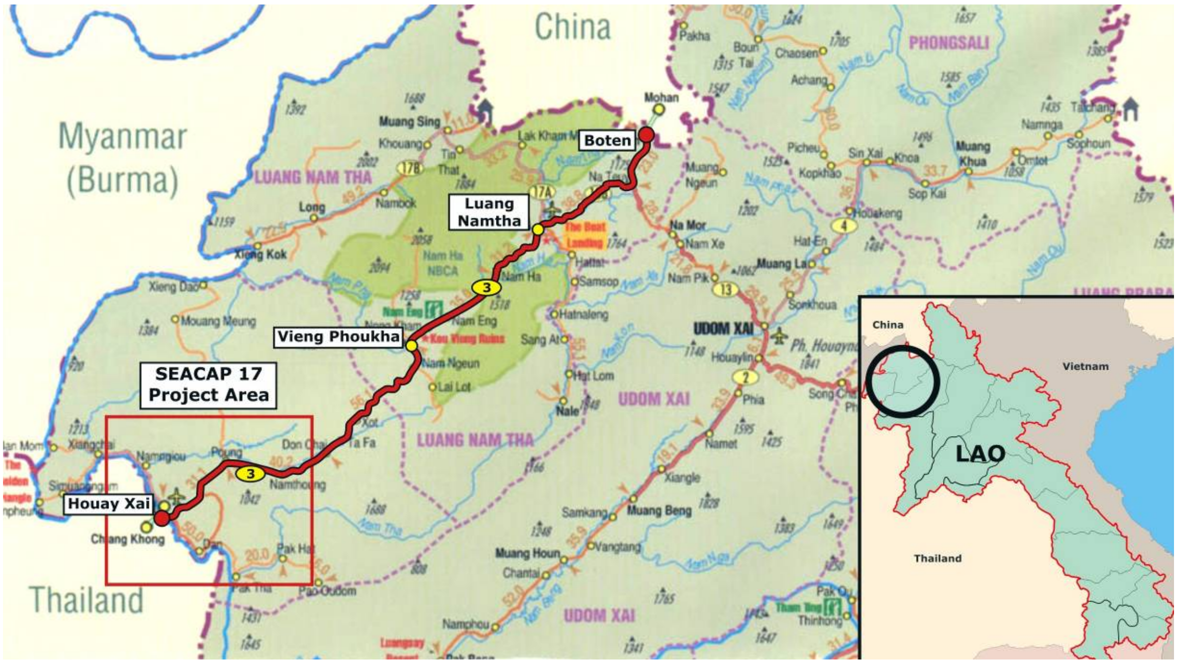
Having examined the performance of various pavement types, one of the main objectives of the project is to disseminate the findings to regional and international agencies. Workshops and seminars will allow all practitioners to share experiences from projects within Lao PDR, the SE Asia region and worldwide.

1.2 Northern Economic Corridor Project

The NEC project aims to improve the Route No.3 (R3) road from Houay Xai on the Thai border with Lao PDR to Boten on the Chinese border. This will to create an international north - south corridor linking Thailand and the People's Republic of China (PRC). The location of Road No.3 is shown in Figure 1, also shown in this figure is the SEACAP 17 Project area.

The 228 km long NEC Route 3 will be upgraded from the existing poor quality gravel road which has been known to become impassable during the set season to a combination of Class II and Class III of the Lao PDR standards. This will result in a 7 m wide paved carriageway with surface dressed shoulders of between 1.5 and 2.5 m wide.

Figure 1 Location of Road No.3 and the NEC Project



1.3 The SEACAP 17 Project Rationale

The overall goals of SEACAP 17 are to investigate and to promote suitable methods of sustainable technology for the construction of low volume roads. Essentially, the project has investigated the practicalities of gravel surfacing over the long term with a view to developing options and strategies for alternative more sustainable pavement structures. The project has required close collaboration between MCTPC, ADB, SEACAP and the Consultant and it was agreed that the following approach must be taken:

- Trial sections should not be isolated on part of a road but should be assembled together on complete roads.
- The cost of civil works on trial sections should not be significantly different to the costs proposed under the ADB NEC loan.
- The SEACAP (DFID) consultant should be responsible for construction supervision of the complete access roads adopted for trial sections.
- There should be a workable programme.

The ADB requested that trial sections should not be distributed over several access roads. In principle, they suggested that trials be assembled along the full length of an access road or small number of roads to avoid excessive disruption of the NEC access road programme and fragmentation of responsibilities. At least any road that contained a trial section must become a SEACAP Access Road in its entirety. The location of the access roads and the location and type of each of the trial sections is listed in Table 1.

Table 1 List of the SEACAP Trial Sections

Access Road						Trial Section Pavement Type		Lengths		
No.	From	To	Start (km)	End (km)	Length (m)			Start (km)	End (km)	Length (m)
1-1	B.Phimonsine	B.Chomkeo	0.000	2.183	2,183	*Control Section*	*NEC Standard Gravel*	0.500	0.700	200
						Training Section	*None*			
						Pavement Trial	None			
1-3	B.Chansavang	B.Siphosai	0.600	3.487	2,887	*Control Section*	*NEC Standard Gravel*	1.220	1.420	200
						Training Section	*None*			
						Pavement Trial	None			
2	B Namphoukang	B.Namsamokneua	0.000	5.350	5,350	*Control Section*	*NEC Standard Gravel*	0.400	0.600	200
						Pavement Trial	Hand Packed Stone	0.600	1.080	480
						Training Section	Hand Packed Stone	1.080	1.100	20
3-2	B.Bolek	B.Namtong Nuea	0.000	6.880	6,880	*Training Section*	Single Otta Seal	0.020	0.120	100
						Pavement Trial	Single Otta Seal	0.120	0.320	200
						Pavement Trial	Double Otta Seal	0.320	0.520	200
						Training Section	Eng' Nat.Surface	0.520	0.620	100
						Pavement Trial	Eng' Nat.Surface	0.620	0.920	300
						Training Section	Mortared Stone	0.920	1.020	100
						Pavement Trial	Mortared Stone	1.020	1.520	500
						Control Section	*NEC Standard Gravel*	1.520	1.720	200
3-3	B.Namtin	B.Phouvanekao	0.000	2.000	2,000	*Control Section*	*NEC Standard Gravel*	1.600	1.800	200
						Training Section	*None*			
						Pavement Trial	None			

Access Road						Trial Section Pavement Type		Lengths		
No.	From	To	Start (km)	End (km)	Length (m)			Start (km)	End (km)	Length (m)
5	B Gam Mining	B.Houaysala	0.000	6.093	6,093	*Training Section*	Concrete Paving Blocks	0.900	0.920	20
						Pavement Trial	Concrete Paving Blocks	0.920	1.400	480
						Pavement Trial	Bamboo Concrete	1.950	2.325	375
						Pavement Trial	Bamboo Concrete	2.325	2.500	175
						Training Section	Bamboo Concrete	2.500	2.525	25
						Pavement Trial	Geocells	2.750	2.950	200
						Pavement Trial	Geocells	2.950	3.050	100
						Pavement Trial	Geocells	3.050	3.125	75
						Training Section	Geocells	3.125	3.150	25
						Control Section	*NEC Standard Gravel*	4.500	4.700	200
8	B.Chomchouk	B.Namkhamneua	0.000	2.770	2,770	*Training Section*	Sand Seal	1.500	1.630	130
						Pavement Trial	Sand Seal	1.670	2.200	495
						Causeway	35.400			
						Control Section	*NEC Standard Gravel*	2.200	2.400	200
				Total:	**28,164**				**Total:**	**5,500**

2 INTERPRETATION OF THE DATA

Having completed the construction of the SEACAP access roads and collected the base data as described in the Module 2 report this report concentrates on the interpretation of the data. While significant knowledge was gained during the construction phase of this project little performance data is available as only the basic post-construction data has been collected.

2.1 Quality Assurance of Collected Data

During the collection of the data a Quality Assurance (QA) procedure was undertaken in order to ensure that no errors were made, as follows:

a) Measurement teams were trained in the data capture methodology prior to actual field measurements.
b) Brief inspection manuals and data capture forms were drawn up and discussed prior to actual field measurements.
c) A calibration exercise was undertaken whereby the inspectors undertook a brief measurement survey on the same section independently and then compared the results. By discussing any differences it was possible to identify where a surveyor was misinterpreting the requirements of the data capture.
d) Once collected, the data was checked for any anomalies or data entry mistakes.

The data has been entered into spreadsheets which are accessed via the database as provided in the Module 2 report.

2.2 Data Analysis

One of the main purposes of this study is to define where particular robust surface types are best suited to be used. In time, with the long term monitoring of the pavements, it will be possible to derive surface performance relationships with key road environment factors, however, at present only indicative recommendations can be made. This section sets out when certain pavement types should be considered.

2.2.1 Environmentally Optimised Design and Spot Improvement Design

Environmentally Optimised Design (EOD) has been defined as a system of road design that considers the variation of the different road environments along the length of the road. Thus the specific circumstances of different road sections such as climbing steep gradients, crossing wet and marshy areas as well as the converse situation of the passage over easy terrain are considered in the design. At one end of the scale, easy gravel pavement sections may require little more than shaping of the surface to ensure water does not collect on the surface whereas at the other end of the scale robust surfaced pavement solutions may be necessary to allow vehicles to climb otherwise impassable, steep slippery gradients.

Considering the analogy with a chain being only as strong as its weakest link, a road will only remain open to traffic all year round if the worst sections remain passable to traffic at the worst times of the year. The Spot Improvement Design (SID) methodology is applied to the EOD philosophy and concentrates on ensuring that each section of a road is provided with the most suitable pavement type for the specific circumstances, ensuring in particular, that each bad or difficult section, 'Spot', is properly designed and that robust, appropriate solutions (pavement, drainage and slopes) are applied. The worst sections may only comprise a small percentage of the length of the road but can consume much of the cost of the construction of the road pavement.

The main factors likely to render a gravel road impassable are:

- Steep gradients that are made slippery due to water on the road surface or very bumpy due to erosion from rain water flowing down the road;
- Wet areas where the vehicle sinks into the soft material comprising or underlying the pavement structure;
- Severe erosion of the road and embankment due to water flowing across the road path, also relevant to paved roads;
- Debris on the road due to material being washed from side slopes by rain water or in the extreme case due to a landslide, also relevant to paved roads, and;
- Slope failures from poorly designed slopes above and below the road, usually triggered by high rainfall; also relevant to paved roads.

The common factor in all of these failures and problems is water. The answer to the simple question 'when will the road be impassable?' is almost always 'during the wet season'. It can be concluded, therefore, that the management of the water or 'drainage design' is paramount when designing roads and in particular Low Volume Rural Roads (LVRR) which are particular susceptible to the influence of water and receive little or no routine maintenance throughout the year.

During the wet season, it is not uncommon for failures to occur to rural roads of all levels. Many of these failures result in the road links becoming impassable and dangerous for users, consequently the various Roads Departments deploy teams to repair these failures. This is appropriately termed 'Emergency Maintenance'. This emergency maintenance work is often undertaken in a hurry, in adverse conditions and with little regard to the science of engineering, following the approach that the road should be repaired and opened temporarily as the problem will be rectified properly later on. This is an expensive and often ineffective method of repairing roads. Little engineering care is taken in the methods, and specifications and future consequences of the work are disregarded in the urgency to keep the road open. Obviously, and understandably, under pressure of an emergency there is very little appreciation of the requirements for a sustainable solution to the problem and only the most obvious and elementary work is undertaken. After the rainy season has passed, due to small maintenance budgets and high demands, many of these temporary works do not get rectified properly and they then reoccur in the following year.

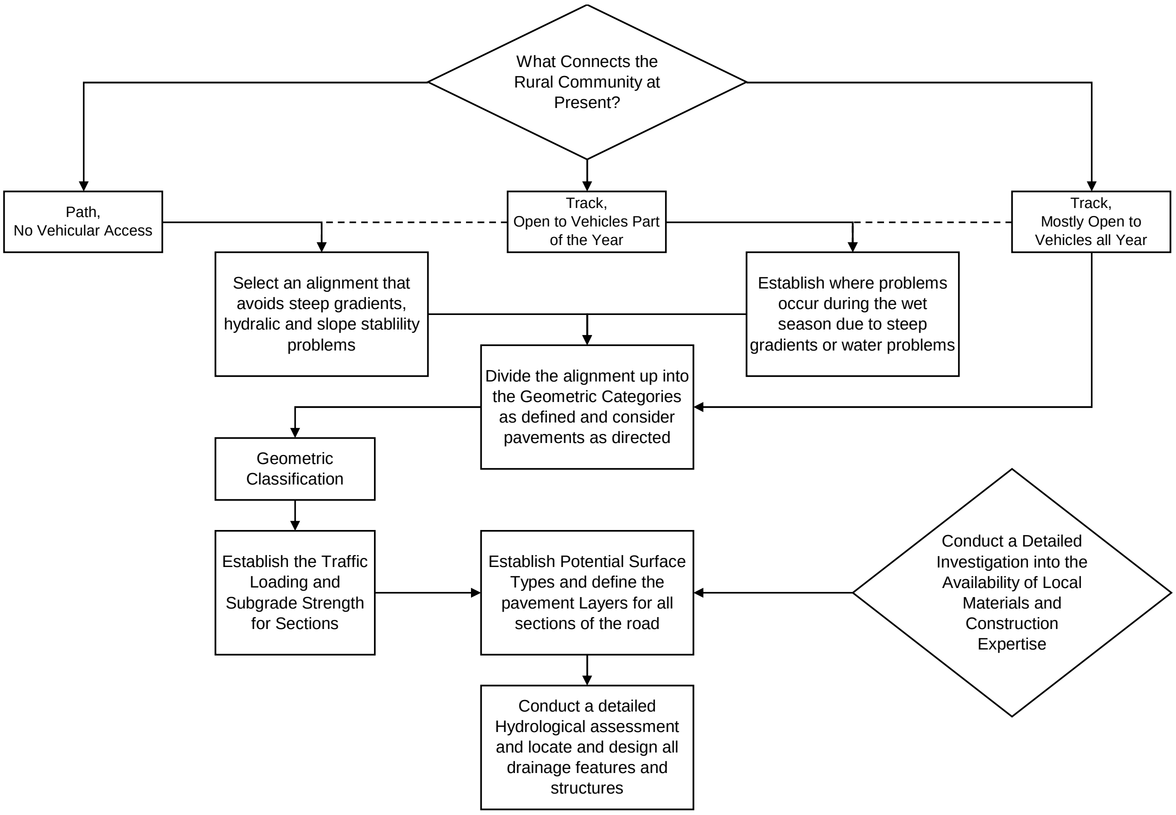
It is in these circumstances that the SID philosophy is likely to be of great value. In order to provide a substantial improvement in the utility of the road it is only necessary to carry out properly engineered 'Spot Improvements' on the sections of the road now known to be most unreliable to achieve the maximum return for a given expenditure. Spot Improvement might, therefore, be considered as 'Improvement through Maintenance conducted in the Dry Season'. Ideally, of course, the works would be conducted prior to any emergency occurring; in reality this is unlikely. The big advantage of Spot Improvement over Emergency Maintenance is that there is time to fully understand the problem and to apply the most appropriate long term solution as identified by experienced engineers in controlled conditions.

The optimum type of road construction can be selected and designed on the basis of four key factors, these are:

- Geometry;
- Pavement Structure;
- Drainage; and
- Slope Stability.

The EOD/SID Design methodology is set out in Figure 2, which illustrates the interaction of the four key factors. Whilst maintenance is not shown in this figure, it is still an important consideration when selecting a pavement structure or surface type. While no road is entirely maintenance free some surface types will require maintenance less frequently that others. A concrete surface will not require overlays while a thin bituminous surface will need reseals every five to seven years.

Figure 2 Flow Chart describing the SID Methodology



2.2.2 Key Road Environment Factors

In determining the pavement structure or layer quality and thickness a number of key road environment factors should be considered. Table 2 gives an indication of the influence of these key road environment factors on the more major rural road design considerations.

2.2.3 Geometry (Terrain)

While it is easy to design roads geometrically in flat terrain it is more difficult in mountainous terrain. However, even in mountainous terrain, the alignments will frequently comprise mostly lengths of flat to moderate gradient with short sections classified as Steep or even Very Steep. A basic practical gradient classification is shown in Table 3. Ideally no part of the road will exceed moderate, however, as described in the Module 2 Report, this goal may result in large earthworks despite careful route selection. In these circumstances, an economical alignment may require the acceptance of some sections where steep gradients and sharp bends are unavoidable. In such sections it is particularly important that a robust solution to the pavement structure be applied to ensure year round trafficability and minimise future pavement deterioration. The flowchart shown in Figure 3 describes the process and makes some recommendations as to which of the SEACAP 17 pavements are suitable for the particular geometric terrains.

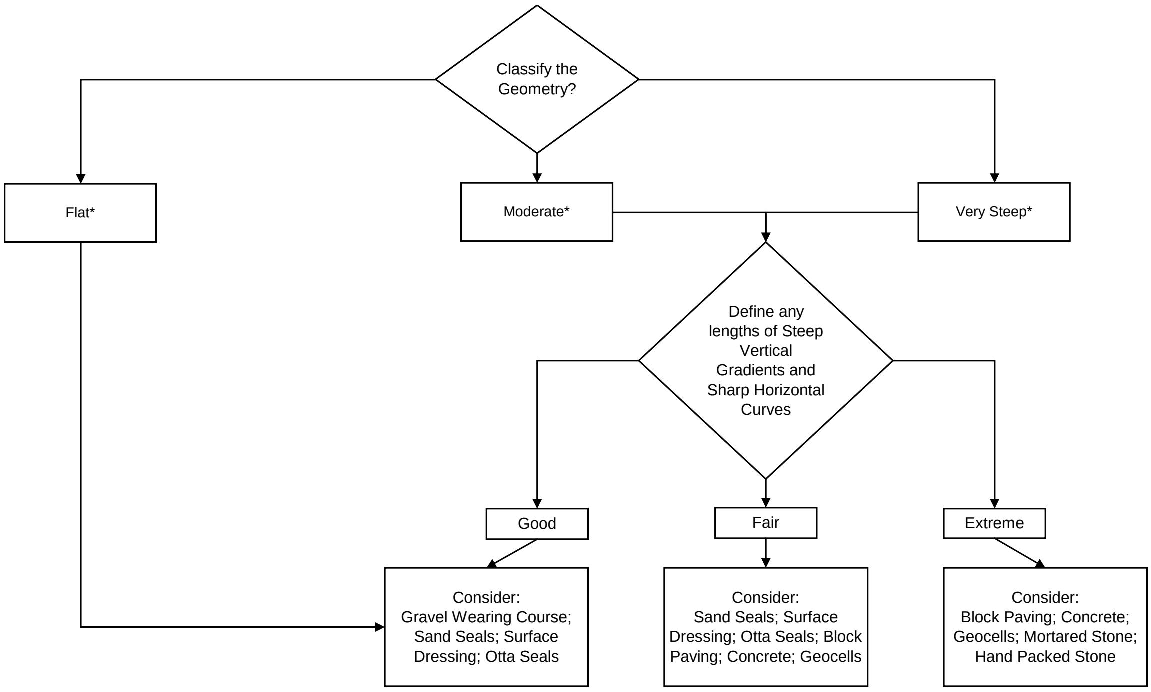
Table 2 Key Road Environment Factors

Key Road Environment Factors	Description	Geometry	Pavement Structure	Drainage	Slope Stability
➢ Subgrade Strength	The soil subgrade strength, i.e., the type of soil of which the subgrade is composed – sand, clay, silt		✓	✓	
➢ Traffic	The amount of traffic (classified into light and heavy vehicles) predicted over the life of the pavement	✓	✓		
➢ Hydrology	The influence of water (flooding) during the wet season on the road	✓		✓	✓
➢ Construction Materials	The availability and quality of the materials suitable for the pavement layers based on the subgrade strength and predicted traffic loading or number of vehicles		✓		
➢ Maintenance	What level of maintenance is expected and required on the road over the design life of the road, (routine and periodic maintenance)	✓	✓	✓	✓
➢ Climate	The effect of various climatic conditions, i.e. wet/ dry; hot/ cold, linked to hydrology		✓	✓	✓
➢ Terrain	The topography through which the road is to pass will define the gradients and curvature	✓		✓	✓
➢ Slope Failures	Unstable slopes above or below the road may fail during the wet season blocking the road – this can be important for geometrical design; eg. width of road might be adjusted to minimize impact	✓		✓	✓

Table 3 Basic Gradient Classification

Gradient	From	To
Flat	0.0%	3.0%
Slight	3.0%	5.0%
Moderate	5.0%	10.0%
Steep	10.0%	15.0%
Very Steep	15.0%	25.0%

Figure 3 Flow Chart showing Geometric Design of Rural Access Roads



Where 'Good' could be considered to have a gradient of <5% and no sharp curves, and 'Extreme' a gradient of >15% and many hairpin bends.

While this chart only considers the pavement structures applied during the SEACAP 17 project the results and methodology can easily be extrapolated to consider other pavement types. It must be stressed that it is important to undertake a detailed materials survey of the project area to establish what potential materials are available and what the local expertise in working with these materials is. Also, when selecting a particular pavement type, it is important to consider the required maintenance regime and the local capacity to undertake such a regime.

2.2.4 Pavement Structures

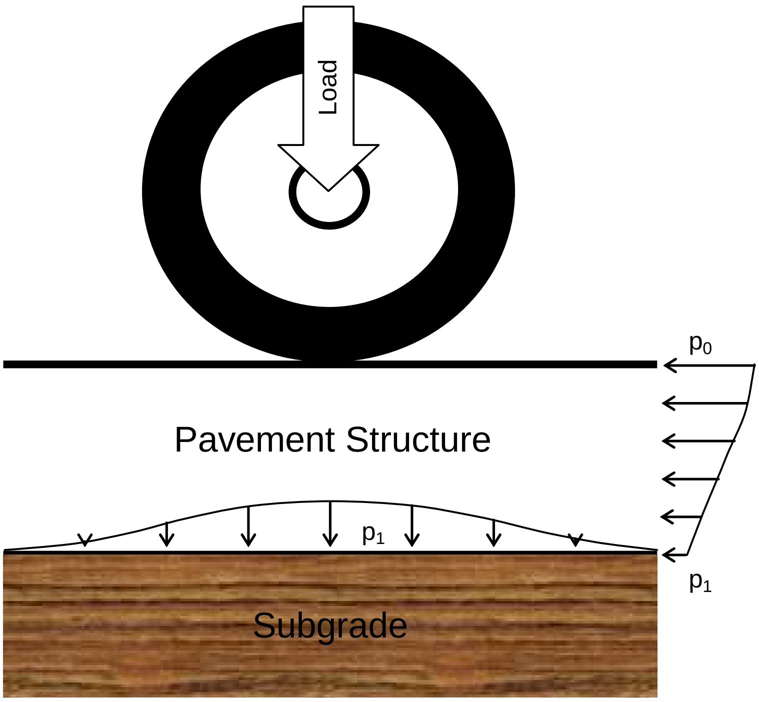
The provision of a pavement is intended to provide protection to the subgrade by the provision of pavement layers and to achieve a chosen level of service over the design period, as economically as possible. Thus selection of a pavement type encompasses factors of time, traffic, construction materials, foundation soils, environmental conditions, construction details and economic analysis.

The aim of pavement design is to produce a structurally balanced pavement that will carry traffic in the prevailing environment at an acceptable service level without major structural distress. It is vital that this is accomplished with a high level of confidence for the structural design period. Importantly, it is unlikely that a road pavement will complete its design life unless a strategy of routine and periodic maintenance is applied. The present worth of costs of alternative designs should be calculated over the full analysis period using an estimate of the rehabilitation and salvage value, and the most economical pavement structure chosen.

Broadly an acceptable level of service can be defined as the riding quality of the road as far as the ordinary road user is concerned. Riding quality can be defined as the general extent to which road users experience a ride that is smooth and comfortable or bumpy or downright unpleasant and perhaps dangerous.

The subgrade ultimately carries all traffic loads, therefore, the function of a pavement structure is to transfer and spread the wheel loads to the subgrade, without over stressing the strength of the subgrade or the internal strength of the pavement itself. Figure 4 shows the wheel load being transmitted to the pavement surface through the tyre. The pavement then spreads the wheel load to the subgrade which reduces the maximum pressure on the subgrade. The wheel load slightly deflects the pavement structure, causing both tensile and compressive stresses within the pavement layers and subgrade resulting in cracking and rutting if the pavement strength is inadequate. By proper selection of pavement materials and with adequate pavement thickness and strength, the pressure at the bottom of the pavement will be small enough to be easily supported by the subgrade and the pavement will be able to resist the internal stresses caused by the loading.

Figure 4 The Spread of a Wheel Load through a Pavement Structure



The Lower Pavement Structure

The South African TRH4[2] considers roads with low volumes and this method is used as an example here, however any guideline can be used to design the pavement structure. It is recommended that several design methods be used and compared against one another so that the optimum pavement structure can be determined.

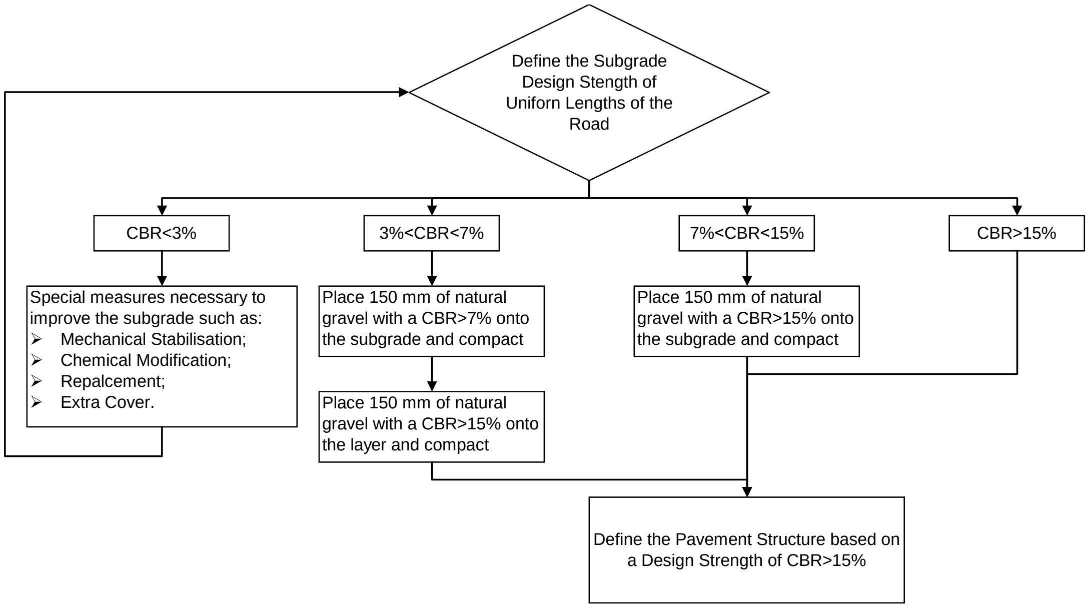
The design subgrade strength should be established along the road alignment at some suitable frequency, the higher the frequency the more reliable the design will be. A Dynamic Cone Penetrometer[3] is a proven effective and rapid tool which can achieve this, although some calibration against 4 day soaked laboratory subgrade CBR values is necessary. The road alignment can then be divided into sections with the same design subgrade strength CBR and the lower pavement/upper subgrade layers designed accordingly. It should be noted that the TRH4 methodology operates by improving the subgrade through the application of selected subgrade layers such that the subgrade design strength becomes uniform for all natural subgrade conditions; the upper pavement layers are then uniform along the entire length of the road for a set level of

2 ***Structural Design of Flexible Pavement for Interurban and Rural Road, TRH 4****, Committee of State Road Authorities, CSIR, Pretoria, South Africa, 1996*

3 ***Dynamic Cone Penetrometer Tests and Analysis****, Technical Information Note, Colin Jones, Transport Research Laboratory, Crowthorne, United Kingdom, May 2004.*

traffic loading. The TRH4 recommendations in respect of this subgrade improvement are shown graphically in Figure 5.

Figure 5 Design of the Lower Pavement Layers



Traffic Loading

It is recommended in the new Classification and Geometric Standards for Lao PDR[4] that the LVRR Classification should encompass roads that are suitable for 150 motorised 4-wheel vehicles per day with an upper axle load limit of 4.5 t. This limit is identified as appropriate for a substantial portion of the rural road network in consideration of current and likely future traffic demand, and the pragmatic management of the road network with the limited resources available.

Applying these values over design lives of 10 and 15 years and being very generous with the traffic volumes and the predicted loads, results in approximately 18,000 and 32,000 ESAs respectively as shown in Figure 6. It should be noted that the traffic counts and future predictions on the SEACAP 17 roads yielded no significant ESA traffic loads over a 10 year design life.

The Upper Pavement Structure

Under TRH4, the upper pavement structure depends more on the traffic loading than the subgrade strength; the method has four traffic loading categories under 100,000 ESA over the design life and these are shown in Figure 7. It should be noted that layer thicknesses and/or the material quality are reduced for the lower loading categories.

4 ***Low Volume Rural Road Standards and Specifications: Part I, Classification and Geometric Standards, SEACAP 3***, *Mainstreaming Appropriate Local Road Standards and Specifications and Developing a Strategy for the MPWT Research Capacity, Ministry of Public Works and Transport, Lao PDR, January 2008.*

Figure 6 Calculation of the 10 and 15 Year Predicted Traffic Loading

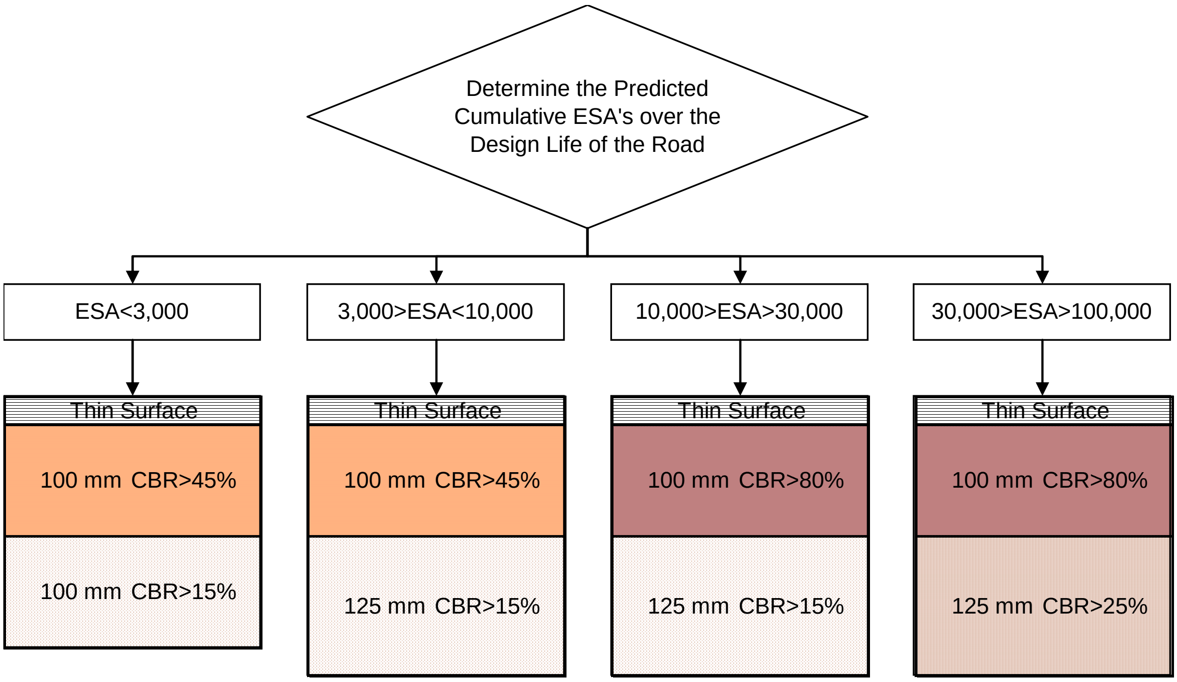
Vehicle Type	Axle Load (tonne)	ESA per Vehicle	No. per Day	Total ESA per Day
Light Motor Vehicle	0.7	0.0	100	0.011
Loaded Pickup	1.0	0.0	30	0.014
Small Truck	4.5	0.1	20	3.700
		Total	**150**	3.724

Therefore in the first year the ESA are **1359.230**

Discount Rate: 6%

		Annual	Cumulative	
Construction				
	Year 1	1,359	1,359	
	Year 2	1,441	2,800	
	Year 3	1,527	4,327	
	Year 4	1,619	5,946	
	Year 5	1,716	7,662	
	Year 6	1,819	9,481	
	Year 7	1,928	11,409	
	Year 8	2,044	13,453	
	Year 9	2,166	15,619	
Consider Upgrading	**Year 10**	2,296	**17,916**	0.018×10^6
	Year 11	2,434	20,350	
	Year 12	2,580	22,930	
	Year 13	2,735	25,665	
	Year 14	2,899	28,564	
Consider Upgrading	**Year 15**	3,073	**31,637**	0.032×10^6

Figure 7 Upper Pavement Structure



The methodology envisages the 'thin surface' being a single or double bituminous surface treatment.

SEACAP 17 Surfaces

In common with many other design methodologies for these traffic levels, TRH4 provides a design requiring a bituminous surface treatment running surface. Although this widely used, cost effective surface has been shown to be highly successful in many instances, it does have some drawbacks and may not always be the best solution for rural access roads that received little or no maintenance. As SEACAP 17 examined the use of various alternative surfacings the bituminous surface was substituted with the different surface types. The substitution of one surface for another should be conducted using the basic rules of pavement design. The following simple guidelines, based on the AASHTO structural number[5], might be adopted:

- The structural number is defined as an index number derived from an analysis of traffic, road-bed soil conditions and regional factor.
- The index number may be converted to thickness of various flexible-pavement layers through the use of suitable layer coefficients related to the type of material being used in each layer of the pavement structure.
- The layer coefficient is the empirical relationship between structural number for a pavement structure and layer thickness, which expresses the relative ability of a material to function as a structural component of the pavement.

Therefore, for example, the entire upper pavement structure as defined in TRH4 might be substituted by 150 mm of unreinforced concrete, or alternatively the surface and the base layer replaced by concrete blocks of 65 mm thickness.

2.2.5 Drainage

As stated above, it is clear that one of the most important aspects of the design of a road is the provision made for protecting the road from water. If water is allowed to enter the structure of the road, the pavement will be weakened and it will be much more susceptible to traffic damage resulting in surface failures on paved roads and impassable muddy areas on gravel roads.

The road surface should have a surface camber so that rainwater sheds quickly into the side drains or away from the road. Through flat marshy areas the top of the subgrade should be raised above the level of the water table and any flood levels. Both of these measures will help prevent water entering the pavement structure.

It is important to ensure that water is able to drain away from the road quickly without causing erosion. This will prevent the pavement from becoming soaked and will prevent damage to the road due to erosion within the pavement layers. With some knowledge of the rainfall intensity of the project area and basic topographic maps it is possible to estimate the flow (volume and velocity) of rainwater likely to affect the road. The basic hydrological design process is shown in Figure 8. It must be noted that the critical gradients of the side drains referred to in Figure 8 will depend on natural materials.

2.2.6 Slope Stability

The problems associated with unstable slopes are being investigated under SEACAP 21[6] where research is underway on several slopes along R 13 and R 7 in Lao PDR. A national slope stabilisation programme will be defined under this project.

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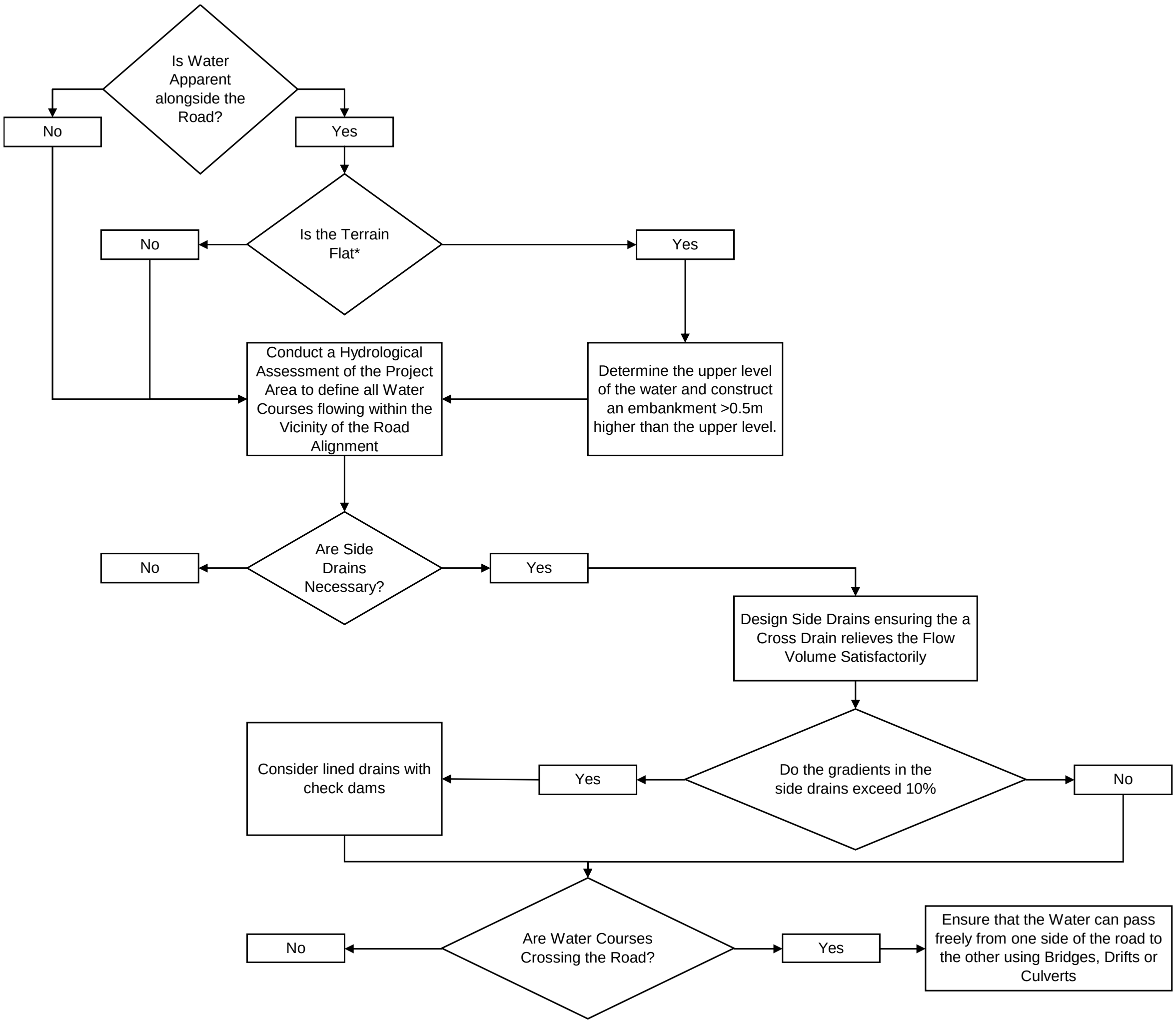
5 ***AASHO Road Test, Report 5**, Highway Research Board Special Report No.61E. Highway Research Board, National Research Council, USA, 1962*

6 ***Research, Local Resource Solutions to Problematic Rural Roads Access**, SEACAP 21, , Ministry of Public Works and Transport, Lao PDR, January 2008.*

Figure 8 Flow Chart showing the Design of Drainage for LVRRs



It suffices to say here that slope failures lead to road closures and may result in very dangerous situations with severe consequences. Proper slope stability solutions should be sought for all rural roads where problems are encountered and every effort should be made to avoid deep cuttings into potentially unstable slopes even if this means designing a longer route.

2.3 Ranking of Specific Materials and Pavement Structures

During the construction of the trial pavements it became apparent that some pavement structures or surface types are more appropriate in certain circumstances. For example, the sand sealed surfaces are only appropriate for low traffic volumes on flat undemanding terrain – primarily providing a comfortable ride with little dust pollution. By contrast, the hand packed stone, which results in a rough, but readily maintainable, surface is likely to be more appropriate on very steep sections of road which would otherwise be impassable in the wet season. However, what has become clear is that the EOD/SID design philosophy requires that substantial time is taken in the field by experienced Engineers in order that a suitable pavement structure is selected for each short length of problematic road in order to overcome the particular problems at that spot in the most appropriate and economic way.

The SEACAP 1 project compiled a table (Table 7.1 in the SEACAP 1 report) which defines a representative matrix of rural paving options appropriate to differing (Vietnamese) road environments. From the point of view of selecting the pavement structures in order to undertake a spot improvement design on rural access roads using small scale contractors, it can be seen that just about all of the options set out in this table are suitable. In fact, no matter how this table is considered, apart from the few definite disadvantages no real conclusions can be drawn apart from the fact that all of the pavement structures trialled will be useful in some situation or conditions. It can be noted that the dressed stone surface favourable in Vietnam was difficult to construct and very rough in Lao PDR under SEACAP 17 and that while the bamboo reinforced concrete was successfully constructed in both projects it has been found that the bamboo reinforcement offers no benefit over non-reinforced concrete.

This demonstrates to some degree the subjective nature of producing such tables of comparison and in particular, the possible problems of trying to apply the results reported in this table to another area and country. It might be argued that, if another contractor were used, the subjective ranking of the pavement structures for the same area might be different. However, in order to allow some comparison with other work a similar, but more simplistic, table has been completed for the nine pavement structures trialled in SEACAP 17 as shown in Table 4.

Table 4 Trial Pavements Assessed Against some Key Markers

Pavement Type	Key Markers									
	Local Materials	Flat Terrain	Steep Terrain	Populated Areas	Marshy Areas	Weak Subgrades	Small Contractor Suitability	Labour Based	Likely Cost Advantages	Maintenance Reduction
Standard NEC Gravel Pavement	✓	✓	✗	✗	✗	✗	✓	✓	✗	✗
Bamboo Reinforced Concrete	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
Geocell	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
Mortared Stone	✓	✗	✓	✗	✓	✓	✓	✓	✓	✗
Hand Packed Stone	✓	✗	✓	✗	✓	✓	✓	✓	✓	✗
Concrete Paving Blocks	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
Sand Seal	✗	✓	✗	✓	✗	✗	✓	✓	✓	✗
Otta Seal	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
Engineered Natural Surface	✓	✓	✗	✗	✗	✗	✓	✓	✓	✗

Note: ✓ Positive advantage

✗ Probable disadvantage

Based on this table it can be concluded that for this contract in this region of Lao PDR the pavement types selected were well suited to small labour based contractors. The robust pavement types are suitable for difficult terrain while the less expensive surfaces are suitable for flat and populated areas. The more expensive, robust pavements will require less maintenance than the cheaper options. The robust concrete pavements are advantageous in all situations, but may be found to be so expensive that they are never really applied. The real conclusion, based on this work and the work in Vietnam, is that all practical construction options should be investigated and considered during the design and the most suitable for the particular area selected. In Vietnam this may be dressed stone surfaces, in Houay Xai, however, the dressed stone option was extremely difficult to implement, although, it must be noted that was probably a failing of the particular contractor rather than of the pavement type.

2.4 Surface Performance

During this project a number of different surfaces (pavement structures) were applied and trials constructed, at present, these trial sections have only been monitored once, at the completion of the construction. Therefore we have no historic data on how they are performing against time and it is not possible to rank them against one another at this stage. It is hoped that long term monitoring will be conducted in the future.

Maintenance will be an important factor in the long term performance of the surfaces as all pavement structures require maintenance of some sort or another. Surface dressed pavements require reseals to be conducted a regular intervals in order to keep the surface malleable and waterproof so as to prevent cracking and the ingress of water into the pavement structure. Realistically, as described in the Module 2 report no maintenance can be expected to be conducted on these roads except perhaps, some elements of routine maintenance executed under a system of voluntary labour.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

During the course of this project it has become apparent that it is important to embrace local materials and expertise. It is considered that substantially more effort should be concentrated during the design phase to ensure that poor and good sections of the road to be identified and the correct pavement solutions applied.

In order to keep a road open throughout the year in is necessary to manage the water during the wet season, this can be done by:

- Ensuring that the geometry is optimised to reduce both steep gradients and sharp curves even if this means increasing the length of the rural access road;
- Optimal pavement structures should be selected which use local materials and expertise as much as is practicable.
- Robust pavement structures should be applied to poor spots while more simple pavements are applied to the easy lengths;
- Depending on the materials and labour available it may be found beneficial to use more than one pavement design for different 'spots';
- The hydrology of the project area should be studied properly to allow a detailed drainage design to be conducted. The proper management of water will prevent weakening of the pavement structure due to ingress of water and erosion of the surface due to poor side and cross drainage;
- Detailed assessments of slopes where they cannot be avoided will allow proper engineered solutions to be implemented reducing the chances of slope failures during the wet season.

3.2 Recommendations

It is recommended that a suitable network of roads is identified and a spectrum of rural road design solutions incorporating EOD and SID using pavements varying from engineered natural material to gravel to durable paving be implemented and constructed. A rural road project would form an ideal testing ground in order to:

- Trial and formalise a detailed EOD taking into consideration the following main design aspects:
  - Alignment (Vertical and horizontal) selection;
  - The investigation into local materials and their construction suitability;
  - Appropriate pavement structure (Surface) selection that will vary along the length of the road depending on need;
  - Detailed hydrological design and the selection of suitable drainage structures, and;
  - Areas requiring specific slope stability solutions.
- Compilation of a Detailed Construction Methodology (considering different construction options) and the compilation of a Standard Construction Contract with the construction options which can be used on similar future projects.
- It is well known that the maintenance budgets for rural access roads are severely limited and therefore such a project should provide a maintenance approach will help practitioners to define the correct pavement structure and corresponding maintenance scenario during the design stage. A much better understanding of the true cost of the rural roads in whole life terms will result which will enable more accurate maintenance budget allocation by central funding or donor-related sources.

It is concluded that the successes and failures from this project, and other similar projects, cannot simply be applied elsewhere. While note should be take of the materials and methods of construction reported here, a detailed investigation must be conducted in the particular region where work is proposed.

Appendix A
The Basic Requirements of the Terms of Reference

Module 1 – Project Planning and Initiation

Close liaison with other practitioners and with international donor agencies should be a feature of the consultant's work programme for Module 1. In particular, liaison with the ADB, the World Bank and the Swedish International Development Cooperation Agency and their consultants/ contractors in relation their rural road development activities in Lao PDR, should form an integral part of the Module 1 planning process. Module 1 should comprise the following key activities:

a) Develop a working arrangement with the MCTPC's (MPWT) Project Management Unit.
b) Develop a working arrangement with LTEC, the MCTPC's (MPWT) domestic consultants. The consultant should make maximum use of local consultants for implementing this project to enable knowledge transfer.
c) Develop a working arrangement with the NEC project consultants.
d) Access primary information relevant to other road development activities.
e) Access or derive where possible ancillary data sets, e.g. climate, terrain, geology etc.
f) Input and collate existing data into a finalised database under key planning data sets, for example e.g. province and gravel type.
g) Prepare a final list of the trial sections that are to be tested based on a likely spread of matrix variables. Provide rationale for selecting a specific trial method for each trial sections.
h) Prepare a detailed design for specific trial sections (pavement surface, pavement structure, subgrade or any special structure required for the specific technology) based on a literature review of suitable solutions. The Consultant shall make maximum use of the existing detailed design provided by the NEC project consultant to avoid duplication of work and to provide cost savings.
i) In conjunction with the MCTPC (MPWT) and the NEC project consultant review the access roads proposed for inclusion in the SEACAP programme.
j) Undertake detailed planning of the main field programme based on the final road sections identified.
k) Identify specifications and costings and prepare detailed bills of quantity for the surfacing trials to be undertaken by the successful SEACAP funded contractors.
l) Following receipt of the bid documents for the SEACAP access road contracts from the MCTPC, superimpose the detailed designs and bills of quantity on to the bid documents.
m) Where necessary, make modifications to the location of the trial sections on the SEACAP access roads based on the data (survey, ground conditions, materials, etc.) as received from the NEC project consultant.
n) Verify the suitability of the detailed pavement design for the remaining length of the SEACAP access roads.
o) Draft a detailed data collection programme.
p) Draft an information dissemination and training strategy, based on the overall SEACAP information dissemination process in South East Asia.
q) Submit a report detailing project actions and outcomes.
r) Assist MCTPC (MPWT) in the assessment and award of the works contracts.
s) Prepare proposal for slope stabilisation trials on alternate routes.

Module 2 – Representative Data Capture

The consultant should undertake the following key data collection and management activities:

a) Construction of SEACAP Access Roads
   (i) Instruct the contractors appointed by the MCTPC for conducting the SEACAP access roads. These instructions will include the type of surfacing technology to be used and the procedure for implementing it at the identified locations.
   (ii) Supervise the construction of the SEACAP access roads at the identified locations.
   (iii) In the event that a particular SEACAP access road does not succeed, the SEACAP consultant will provide supervision for the rehabilitation of the section so that this does not cause any lasting problem with access.

b) Data Capture
   (i) Liaise with survey teams appointed for undertaking the main data collection phase.
   (ii) Instruct the survey teams on the objectives, methodology and procedures associated with the research project, probably by means of a training workshop.
   (iii) Supervise initial data collection surveys in selected provinces as a follow-up to the training process.
   (iv) Incorporate any minor adjustments in the procedures resulting from the training programme.
   (v) Implement the data collection programme.
   (vi) Complete the principal road condition data capture programme
   (vii) Collect relevant village and district based information such as, maintenance activity, flood data, local climate etc.
   (viii) Ensure the quality of the recovered data by undertaking crosschecks on the field teams' procedures
   (ix) Carry out laboratory testing on collected samples e.g. particle size, Atterberg Limits and visual inspection and classification, and document the results
   (x) Input acquired data into a database
   (xi) Submit reports detailing project actions and outcomes.

Module 3 – Data Interpretation

The consultant should undertake the following key activities:

a) Quality assurance of collected data.
b) Analysis of data including the derivation of surface performance relationships with key road environment factors.
c) Recommendations as to ranking of specific material usage within differing Lao PDR road environments utilising an appropriate performance model.
d) Reporting on surface performance, including input to rural road decision-making process together with recommendations for long term monitoring.

Module 4 – Information Dissemination

The consultant should undertake the following key activities:

a) Based on the technology solutions arrived at from the earlier modules, implement the information dissemination strategy.
b) At an early stage in the project, the consultant will conduct a Knowledge Exchange Workshop to bring together key stakeholders in Lao PDR. The object of this Workshop will be to disseminate information relating to the proposed project and to collect relevant information that will assist the implementation of the proposed project.
c) Ensure training sessions are conducted throughout all Modules for transferring knowledge at all hierarchical levels in the provinces. These will form part of a continuous programme of training, technology transfer and capacity building throughout the research activities.
d) Deliver a series of guidelines, design manuals and specifications for each technology option evaluated in the earlier Modules. This will be in a format which can be readily adopted by future road development projects or used for independent spot improvements.
e) Conduct a Pavement Design Workshop in Vientiane at the end of the research project. The consultant will prepare and facilitate briefing documents for the workshop. The main object of the workshop will be to generate buy-in from various stakeholders on the strategy for pavement design and to identify further investigations and support that will be required to mainstream it, if possible, this Workshop should be organised under the domain of the Transport Knowledge Partnership or the International Focus Group.