Intech Associates
CONSULTING ENGINEERS

TRL

Department for International Development
SEACAP PROGRAMME

Managed by
Crown Agents & Halcrow Group

SEACAP 8
CAMBODIA Low Cost Surfacing Phase 2

INCEPTION DOCUMENT

LCS WORKING PAPER No 20

July 2004

KaR 7782

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Office Suite 1314, 49 Hai Ba Trung Street, Hanoi, Vietnam
Tel: Direct Line: Int (84 4) 9343959 Reception: Int (84 4) 9343968
Fax (Reception): Int (84 4) 9343966 e-mail: intech-trl@fpt.vn

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Our Ref: SEACAP8-94
Your Ref:

5 August 2004

Attention H E Suos Kong, P.Eng., ASEAN Eng., MRDM
Secretary of State
Ministry of Rural Development
Royal Government of Cambodia
Phnom Penh, Cambodia

Dear Excellency Suos Kong,

RE: SEACAP 8 – Low Cost Surfacing (LCS) Phase 2 Investigations
INCEPTION DOCUMENT – Working Paper No 20

Please find attached a draft copy of the above document in English language covering the initial investigations under the LCS Phase 2 contract with SEACAP and DFID.

We have copied the draft document to the members of the provisional steering committee and key persons cooperating with the initiative, and we welcome any comments.

Yours sincerely

Robert Petts
Project Manager

cc Lim Sidenine MPWT
Yit Bunna MPWT
Julian Abrams SEILA, Phnom Penh
SEACAP Hanoi
DFID Phnom Penh
DFID Hanoi
ILO Phnom Penh
Intech Phnom Penh

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ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
AFEO	Asian Federation of Engineering Organisations
ASEAN	Association of Southeast Asian Nations
AusAID	Australian Agency for International Aid
CFRTD	Cambodia Forum for Rural Transport Development
CNCTP	Cambodia National Community of Transport Practitioners
CSIR	Council for Scientific and Industrial Research
DFID	Department for International Development
DST	Department of Sience and Technology
DTW	A Mechanical Engineering NGO
EDC	Economically emerging and Developing Country
EU	European Union
FAO	Food and Agriculture Organisation
FFW	Food For Work
GMSARN	Greater Mekong Sub-region Academic & Research Network
GTZ	German Agency for Technical Co-operation
hp	horsepower
HQ	Head Quarter
IFAD	International Funds for Agricultural Development
IFG	International Focus Group (for Rural Road Engineering)
IFRTD	International Forum for Rural Transport Development
ILO	International Labour Organisation
IRAP	Integrated Rural Accessibility Planning
IRD	Integrated Rural Development
ITST	Institute of Transport Science and Technology
JFPR	Japanese Fund for Poverty Reduction
JICA	Japanese International Co-operation Agency
KaR	Knowledge and Research
km	kilometre
kW	kilowatt
LB	Labour Based
LBAT	Labour-Based Appropriate Technology
LBRIRMP	Labour-Based Rural Infrastructure Rehabilitation and Maintenance Project
LCS	Low Cost Surfacing
M	metre
MARD	Ministry of Agriculture and Rural Development
MoF	Ministry of Finance
MoT	Ministry of Transport
MPW&T	Ministry of Public Works and Transport (Cambodia)
MRD	Ministry of Rural Development (Cambodia)
NCP	National Community of Practitioners
NFG	National Focus Group (for Rural Road Engineering)
NGOs	Non-Governmental Organisations
NPA	Norwegian People's Aid
NPRD	National Programme to Rehabilitate and Develop Cambodia
NRDP	North-western Rural Development Project
ODA	Official Development Assistance
PDP	Provincial Development Programme

PDRD	Provincial Department of Rural Development
PIARC	World Road Association
PIP	Public Investment Programme
PMU	Project Management Unit
PRASAC	Programme de Rehabilitation et d'Appui au Secteur Agricole du
PRDC	Provincial Rural Development Committee
PRIP	Provincial and Rural Infrastructure Programme
RD&RP	Rural Development and Resettlement Project
RDS	Rural Development Structure
RGC	Royal Government of Cambodia
RIIP	Rural Infrastructure Improvement Project
RRGAP	The Rural Road Gravel Assessment Programme
RRSR	The Rural Road Surfacing Research
RRST	Rural Roads Surfacing Trials
RT2	Rural Transport 2nd Project, Vietnam
SEACAP	South East Asia Community Access Programme
SEDP I	First Five-Year Socio-Economic Development Plan, 1996-2000
SEDP II	Second Five-Year Socio-Economic Development Plan, 2001-2005
SEILA	Multilateral donors - Government Rural Infrastructure Development Programme
SIDA	Swedish International Development Agency
SWOT	Strengths, Weaknesses, Opportunities & Treats
TDSI	Transport Development Strategy Institute
TEDI	Transport Engineering Design Incorporation
TKP	Transport Knowledge Partnership
TMP	Tansport Mainstreaming Partnership
ToR	Terms of Reference
TRIP	Tertiary Roads Improvement Project
TRL	Transport Research Laboratory
UK	United Kingdom
UN	United Nations
UNCDF	United Nations Capital Development Fund
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
VDC	Village Development Committee
WB	World Bank
WFP	World Food Programme
WSP	A firm of International Management Consultants
ZOPP	German acronym for Goal Orientated Project Planning

FOREWORD

THE LOW COST ROAD SURFACING INITIATIVE

The Low Cost Road Surfacing (LCS) initiative aims to provide documentation and international guidelines on the provision and maintenance of low cost road surfaces and basic access for rural communities in economically emerging and developing countries (EDCs). It is based on a research project funded principally by the British Department For International Development (DFID) under its Knowledge and Research (KaR) programme and South East Asia Community Access Programme (SEACAP). The initiative is led by UK-based specialist consultants Intech Associates in association with TRL Ltd. Collaboration has been established with a number of organisations with interests or experience in the sector, including CSIR, ILO/ASIST Africa and Asia-Pacific, the ILO-SIDA funded Upstream Project and Ministry of Rural Development Cambodia, WSP International, Ministry of Transport Vietnam, Greater Mekong Sub-region Academic Research Network, The Institute of Technology of Cambodia (ITC), Chieng Mai University Thailand, the Committee C20 (Appropriate Development) and Committee TC2.5 (Rural Roads and Accessibility) of PIARC (World Road Association) and the International Focus Group (IFG) for Rural Road Engineering. The LCS programme is being implemented over a 4 year period from 2001 to 2004.

The LCS programme is concerned with supporting sustainable improvements in low cost, road surfacing and basic access to support poverty reduction initiatives in rural communities. This implies the effective use of local resources, particularly human resources, locally available and alternative materials, and readily available and low cost intermediate equipment wherever possible. In the situation of scarce financial resources, it also requires the application of affordable and appropriate standards and adoption of techniques suitable for use by the indigenous private sector (particularly small domestic construction enterprises) and local communities. The application of good management practices coupled with adequate technical inputs are necessary to achieve appropriate and sustainable access.

It is intended that dissemination of the guidelines will be through electronic media as well as more traditional publication routes.

INTERNATIONAL FOCUS GROUP

TRL have been carrying out a number of research projects on low volume sealed and unsealed roads for DFID and other donors. Intech Associates have been carrying out research on low cost surfacing and rural road maintenance with a number of partners. As part of these projects, an International Focus Group (IFG) has been established. The intended function of the IFG was to thoroughly examine technical, economic and social issues arising from the project work. The group would also provide a focus to improve opportunities for dissemination of project results. The IFG is continuing to develop as an international forum and will comprise technical experts and engineers from a number of African, Asian, American and other countries as well as other international experts. Participation in the IFG will provide opportunities to:

- *build regional and international partnerships*
- *exchange ideas, experiences, information and data*
- *strengthen local knowledge with new information*
- *build on existing local research*
- *promote wider acceptance and mainstreaming of the Rural Road Engineering knowledge*

Four projects listed below, were the foundation of the IFG. Projects 1, 2 and 4 are part of the DFID's Knowledge and Research programme, whilst Project 3, is a collaborative research project involving a number of different donors:-

Project 1: Reducing Whole Life Costs: Environmentally Optimised Design

Project 2: Minimising the Cost of Sustainable Basic Rural Road Access

Project 3: Engineering Standards for Labour-based Roads

Project 4: Low Cost Road Surfacing

Further information may be obtained from:- www.ifgworld.org

TRANSPORT KNOWLEDGE PARTNERSHIP

The Transport Knowledge Partnership (TKP) is a global initiative that has the broad aims of making knowledge more accessible to its partners, providing a global transport resource, and encouraging a greater up-take of existing knowledge. A main principle of TKP is that it will work in support of existing initiatives and structures. TKP will also work principally for the benefit of developing countries, giving them greater voice in the way that knowledge is generated and managed, and providing them with greater and more appropriate access to knowledge. IFG is one of the TKP partners.

Further information may be obtained from:- www.gtkp.org

TRANSPORT LINKS

DFID and previous UK government administrations have a long history in funding, promoting and disseminating transport research for developing countries and countries in transition. Through the Knowledge and Research (KaR) programme, DFID supports a range of research projects addressing technical, economic, management and policy issues in transport development.

Many of the research outputs may be downloaded from:

www.transport-links.org

THIS REPORT

This report is the Inception Document for Phase 2 of the Low Cost Road Surfacing (LCS) initiative (KaR7782). It relates to a contract financed by DFID and managed through the SEACAP initiative by Crown Agents and Halcrow.

The LCS Project welcomes dialogue with engineers, managers, organisations, communities and individuals active or interested in the rural transport sector with the objective of the promotion of a sustainable rural access approach for EDCs.

Contact: intech-trl@fpt.vn

This document is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of the DFID.

CAMBODIA PHASE 2 INCEPTION DOCUMENT

First Edition: July 2004 (draft)

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LCS WORKING PAPER No. 20

CAMBODIA PHASE 2 INCEPTION DOCUMENT

PUOK MARKET TRIAL ROAD: PROPOSALS FOR MAINTANCE AND REPAIR

1 INTRODUCTION

1.1 Background

Under the KaR 7782 Project Phase 1, investigations have been carried out and guidelines are being developed on alternative low cost rural road surfaces, which in appropriate circumstances will have lower whole-life-costs than gravel. The alternative surfaces can also have better local resource use attributes; with the effect of injecting more of the road works costs into the local community through labour employment, use of local materials and enterprises.

As part of the Phase 1 work, 10 sections of alternative paving were constructed at Puok Market, Siem Reap Province in Cambodia on a tertiary rural route, Figures 1.1, and 1.2. The Puok Market paving trials have been constructed under a cooperation initiative between Intech Associates, ILO Upstream Project, Ministry of Public Works & Transport and Ministry of Rural Development, Cambodia, with principal funding from DFID and SIDA. Two local contractors, using the minimum of equipment and the maximum input of local unskilled and skilled labour, constructed the trials in mid 2002.

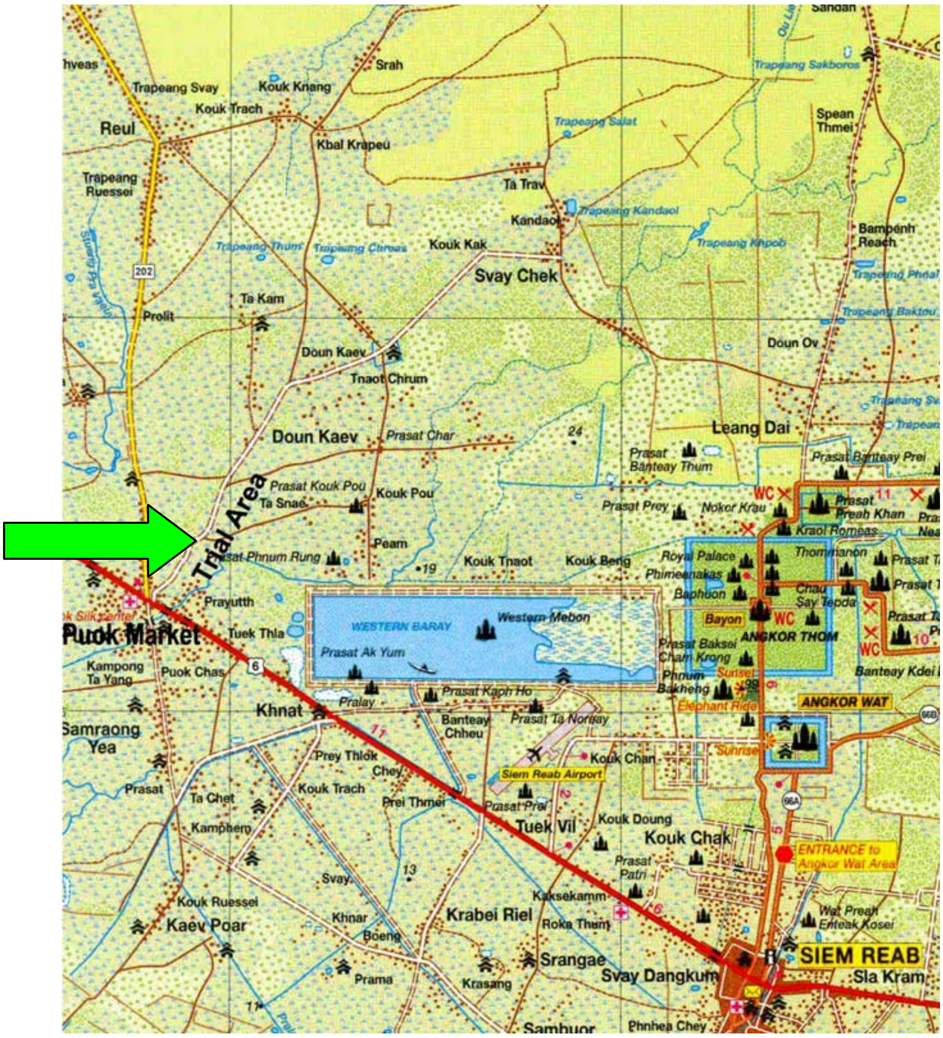

Figure 1.1 Location of Puok Trials

Figure 1.2 Puok Trials construction works

The aim of the paving trials was to investigate and demonstrate the construction of a range of paving techniques as an alternative to gravel/laterite, suitable for secondary and minor roads using local-resource-based techniques wherever possible. The trials will also be the basis of assessing whole life costs of the various paving options. The rationale for investigating alternatives to gravel/laterite is contained in LCS Working Paper No 1. The construction of the Puok Market trial sections was completed in September 2002. Initial monitoring of the trials was carried out in April-May 2003 and they were found to be in good condition.

During the mid year 2003 wet season, the Puok Trial sections have been subjected to significant numbers of sand haulage trucks. It was apparent that these trucks are heavily overloaded, hauling wet sand, and used the road on a regular daily basis. The result has been that one section of the trials (No 4) became severely damaged and other sections are also showed signs of distress.

In October 2003 an assessment of the condition of trial pavements was undertaken by Intech Associates and reported in LCS Working Paper 18.

1.2 Report Objectives

The objectives of this (Working Paper 20) report are as follows:

1. Supply updated data on the condition of the trial sections.
2. Provide current trial road information on relevant issues such as traffic, construction materials and construction costs.
3. Provide comment on the condition of the trial road and related issues.
4. Supply engineering options for the repair and rehabilitation of the trial sections.
5. Recommend the most cost-effective options together with a costed programme of construction and supervision.
6. Report on initial axle loading investigations, June 2004.

2 MONITORING AND INVESTIGATIONS: OCTOBER 2003

Dr J R Cook together with the project Site Engineer Heng Kackada visited the Puok Market sections from 9th to 11th October 2003 and undertook a programme of sub-surface and surface condition assessments. This work was concentrated on Section 4 and Section 9, although a general condition assessment was made of the other trial sections.

The principal comments with respect to the condition of the trials sections at that time were:

- The rapid deterioration of Section 4 pavement, and the onset of Section 9 deterioration, is primarily the result of excessive traffic loading.
- Although the impact of heavy traffic on a light rural road design is the prime cause of failure, it should be noted that both Section 4 and Section 9 have been constructed with marginal materials that are probably outside the anticipated design specification.
- Once the surface seal integrity is broken, particularly during the rainy season. Section 4 will continue to deteriorate and there is a danger that it may shortly become impassable following heavy rain.
- It is expected that Section 9 will deteriorate in similar fashion to Section 4.
- The designs of Sections 4 and 9 are suitable only for light rural traffic loadings and are well below the strengths required for heavy commercial traffic, and even more so for the grossly overloaded sand trucks that have been using the road.
- The heavier duty load spreading options, such the reinforced concrete or the dressed stone surfacings may have a better chance of resisting the impacts of the overloaded sand trucks.

Condition assessment data for October 2003 is included in LCS Working Paper No 18.

3 WORK UNDERTAKEN: JANUARY-FEBRUARY 2004

3.1 Scope

An Intech Associates technical team comprising, Mr Rob Petts, Mr Heng Kackada and Dr Jasper Cook, visited the trial site between 21st and 24th January 2004. The principal activities undertaken are summarised as follows;

- Discussions with Puok District officials on traffic, road repair and maintenance issues,
- Assessment of the trials surface conditions and also the adjacent ILO bamboo reinforced concrete road section,
- Assessment of locally available construction materials.

3.2 District-Level Discussions

Discussions were held with the Puok District Authority officials and the owner of the transport company responsible for trafficing the trial roads with overloaded sand haulage trucks. The meeting took place on 21 January 2004.

Present:	Mao Visoth	District Road Engineer
	Pech Sokhalay	Deputy District Chief
	Tes Chankiri	District Chief
	Hing Vanny	Neak VII Co (Seven Dragons)
	Robert Petts	Intech Associates
	Heng Kackada	Intech Associates
	Jasper Cook .	Intech Associates

The trials pavement damage had been caused principally by 17 – 20 m³ struck capacity, 3 axle trucks hauling wet sand from a new pit opened up in the area which the trials road services. A visit to the sand pit allowed an estimate of the quantity of hauled material to be assessed. This was calculated to be approximately 30,000 tonnes.

After detailed discussions it was agreed that the sand haulier would make a payment of US$1,300 towards the repairs of the damaged road. It was accepted that the damage was not all the fault of the principal sand haulier. The agreed amount was decided as a fair contribution to the damaged caused by the haulage company. The agreed amount was paid to Intech Associates to hold until the repair works could be organised.

It was agreed that the usage of the route by overloaded trucks would be discontinued by agreement between the haulier and the local authority.

Figure 3.1 – Part of the Sand Pit area

It was agreed that Intech Associates would meet the District Maintenance Committee on a future visit, to discuss the rehabilitation of the trial road and also maintenance arrangements for the route.

The District Maintenance Committee comprises the following persons:-

- District Chief (chairperson)
- District Engineer
- Member of Police
- District Accountant
- District Woman's Affairs representative

- A monk (Honorary)
  - District Military representative
- District Customs Dept representative
- All commune chiefs
- Director PDRD

3.3 Road Condition Assessment

The principal activities carried out were as follows:

1. Visual inspection of the ILO road section
2. In situ testing by DCP profiling of the short unsealed transition section (T) between the trials and the ILO section. Results are presented in Figure 3.2
3. Detailed visual survey of the surface condition of trial sections 4and 9. Figures 3.3
4. Walkover survey of other trial sections, summarised in Table 3.1
5. Rut depth measurements in trial Sections 6, 7,8 and 9 wheel track areas, Figures 3.4, 3.5 and 3.6.

Section	General Condition	Rutting/Cracking
1	Some erosion of shoulders on both sides to a depth of 50mm)	None
2	Some variable loss of fines/binder from chip seal, mainly confined to wheel track areas. Some carriageway edge deterioration, particularly at access points.	None – variable cross profile resulting from construction
3	Local surface irregularities +/- 20mm	Local depressions eg Ch 20m WTL – 30mm
5	Some shoulder erosion Ch 0 – 5m Local surface irregularities +/- 20mm	Local depressions eg Ch 15-16 WTR – 10mm Ch 34-35 WTL - 15mm Ch 44-45 WTR – 15mm
6	Patchy fines/binder erosion of chip seal, significant in places at wheel track edges. Some erosion of pavement edge Potholes:; Ch 7.5 RHE; 0.4mx0.9m, aggregate exposed Ch 11.5, LHE 0.4mx 0.8m, aggregate exposed.	No cracking. Shallow rutting in left and right wheel tracks. (Figure 3.4) .
7	Patchy fines/binder erosion of chip seal, mainly WTR. Some erosion of shoulders and pavement edge. Small holes in surfacing Ch 34 (0.4m from left edge), 34.2 (at CL); Ch 34.8 (0.4m from left edge)	No cracking. Shallow rutting in left and right wheel tracks. (Figure 3.4) Some erosion of pavement edge
8	Local erosion of shoulders leading to localised edge cracking and small edge failure – Ch90.0 Locally loss of aggregate in seal Ch 67.7 and Ch 75.5	No cracking. Shallow rutting in left wheel track. (Figure 3.4) Some erosion of pavement edge
10	Erosion of laterite cover - almost complete at Ch 0m – 10m	

Table 3.1 Puok Trials Visual Survey: Sections 1-3, 5-8, 10 , January 2004

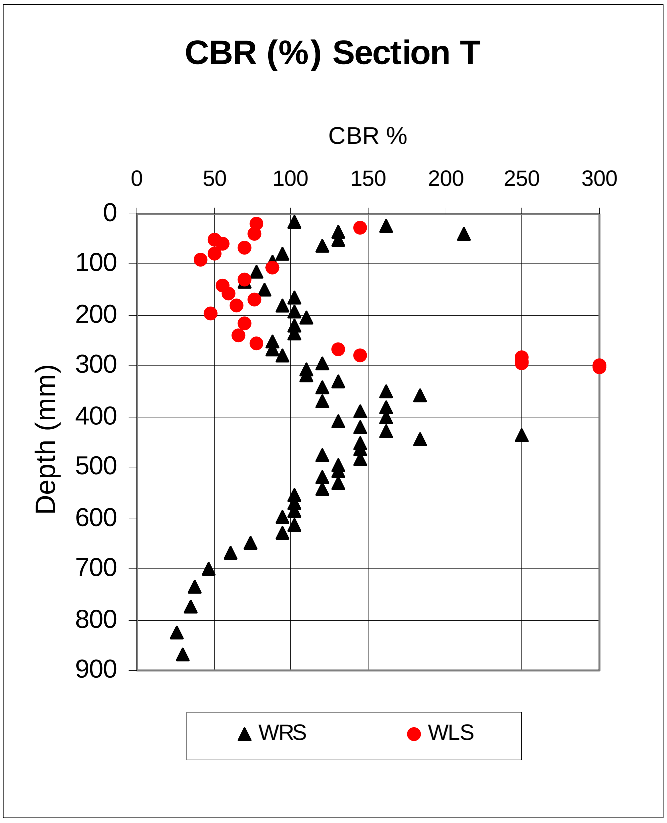

Figure 3.2 DCP Test in Section T

Section 4

Ch (m)	ER	WTR	C	WTL	EL	
0						
	C	6X	4	5X	C	3m
10	C	2	2	1	C	10m
	C	3	2	3	C	15m
	C	3R	2	5R	C	17m
20	1	3R	1	6X	C	23m
30	2-3	6X	3	6X	C	
40	2-3	6X	3	6X	C	
50	2-3	6X	3	6X	C	
60	2-3	6X	3	6X	C	
70	2-3	6X	3	6X	C	78m
80	0	4	1	6X	C	82m
	C	3	2	5	C	85m
90	0	0	0	0	0	95m
100	0	0	1	5R	C	

Section 9

Ch (m)	ER	WTR	C	WTL	EL	
0						
	0	4	3	6X	C	6m
10	0	0	3	5X	C	10m
	0	0	0	3	C	11m
20	0	0	0	0	0	
30	0	0	0	0	0	
40	0	0	0	0	0	
50	0	0	0	0	0	50m

Condition code

0	No cracks
1	Single crack
2	More than one crack - not connected
3	More than one crack - connected
4	Crocadile cracking
5	Crocadile cracking with individual blocks free to move
6	Surfacing completely destroyed
R	Severe rutting
X	Severe rutting penetrating base
C	Covered by debris
ER	Carriageway edge right
WTR	Wheel track right
C	Centre
WTL	Wheel track left
EL	Carriageway edge left

Figure 3.3 Visual Surface Condition Assessment; Sections 4 and 9

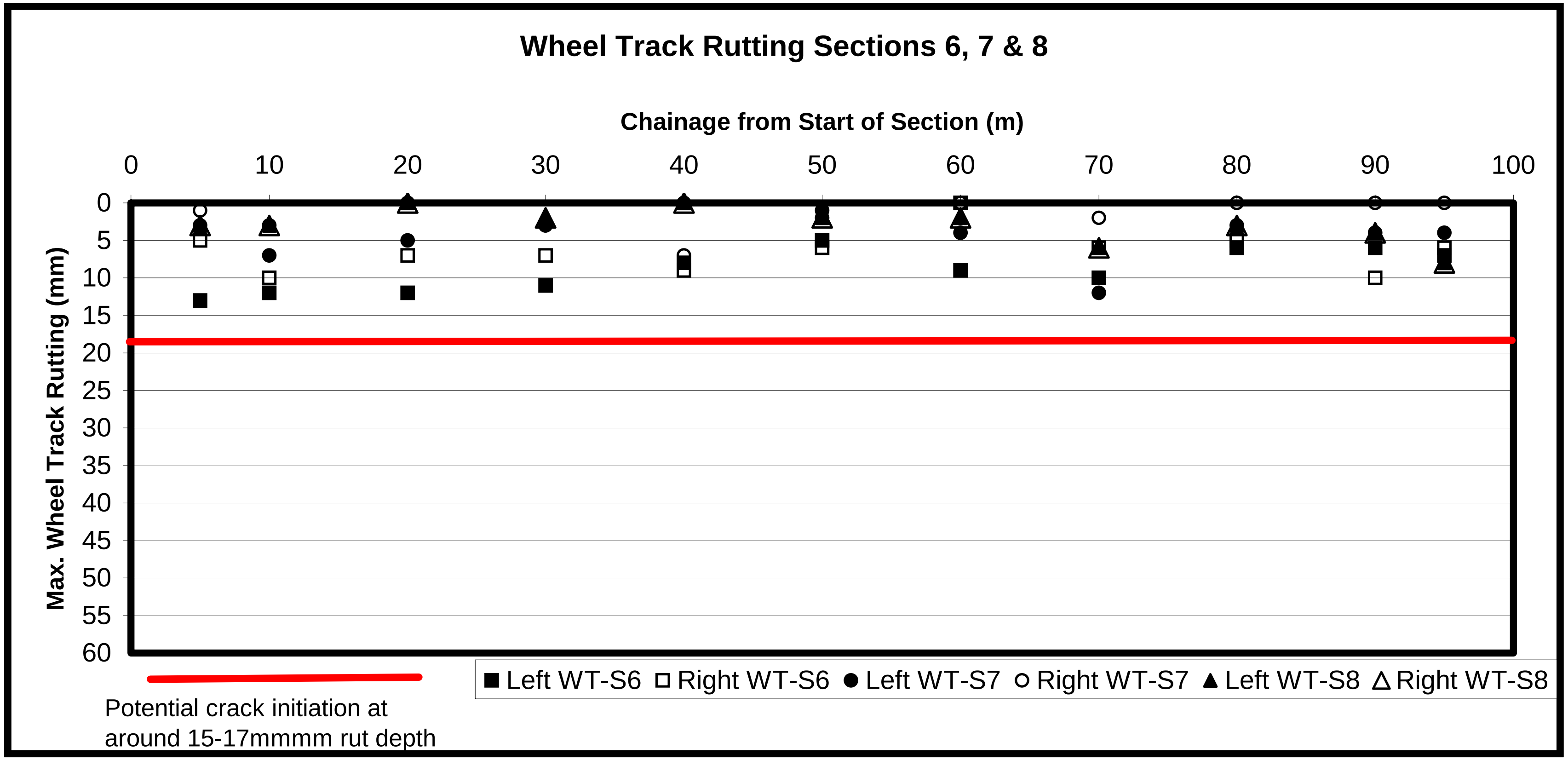

Figure 3.4 Longitudinal Rutting Data, Sections 6,7,8

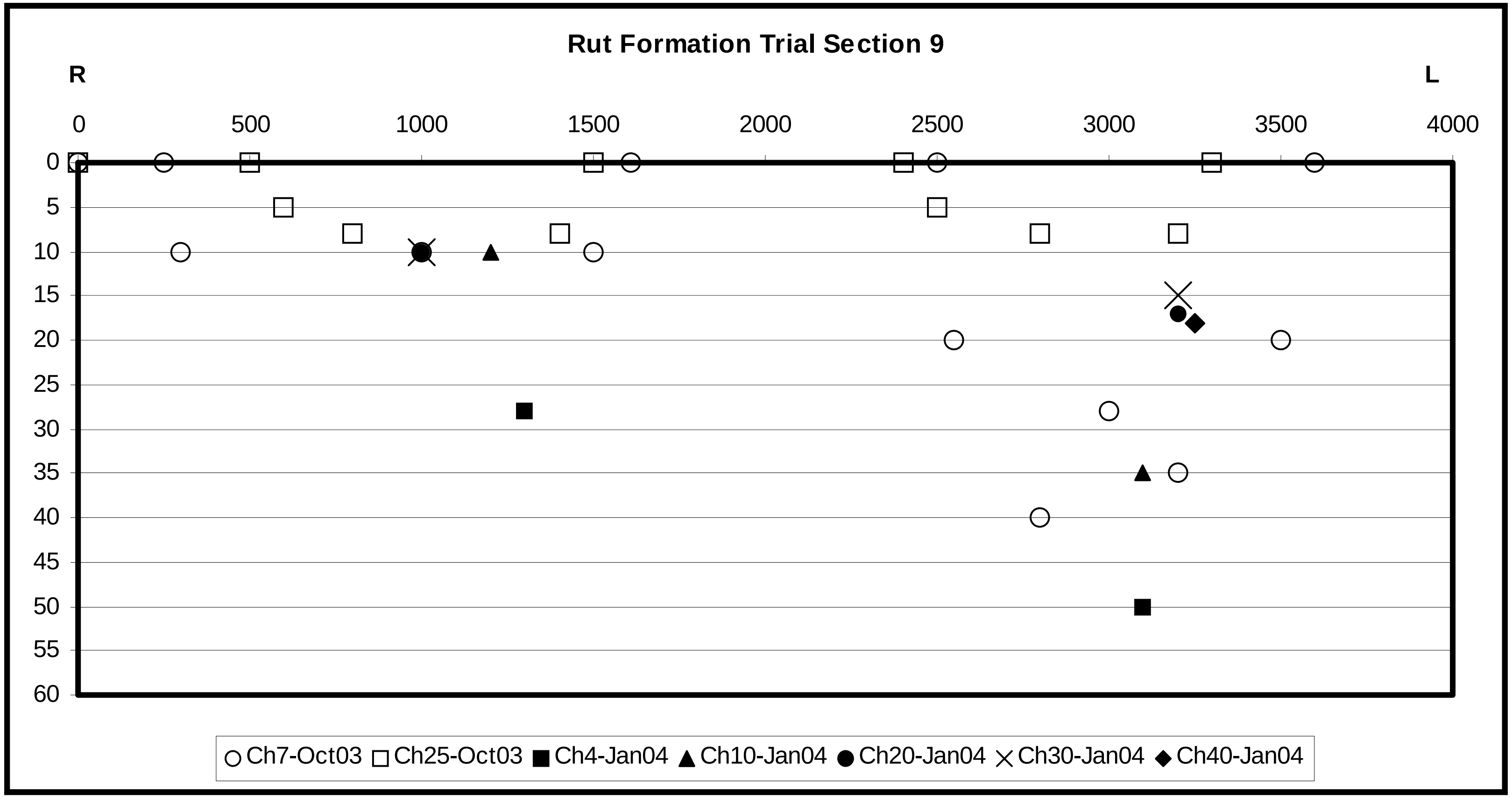

Figure 3.5 Cross-Sectional Rutting Data; Section 9

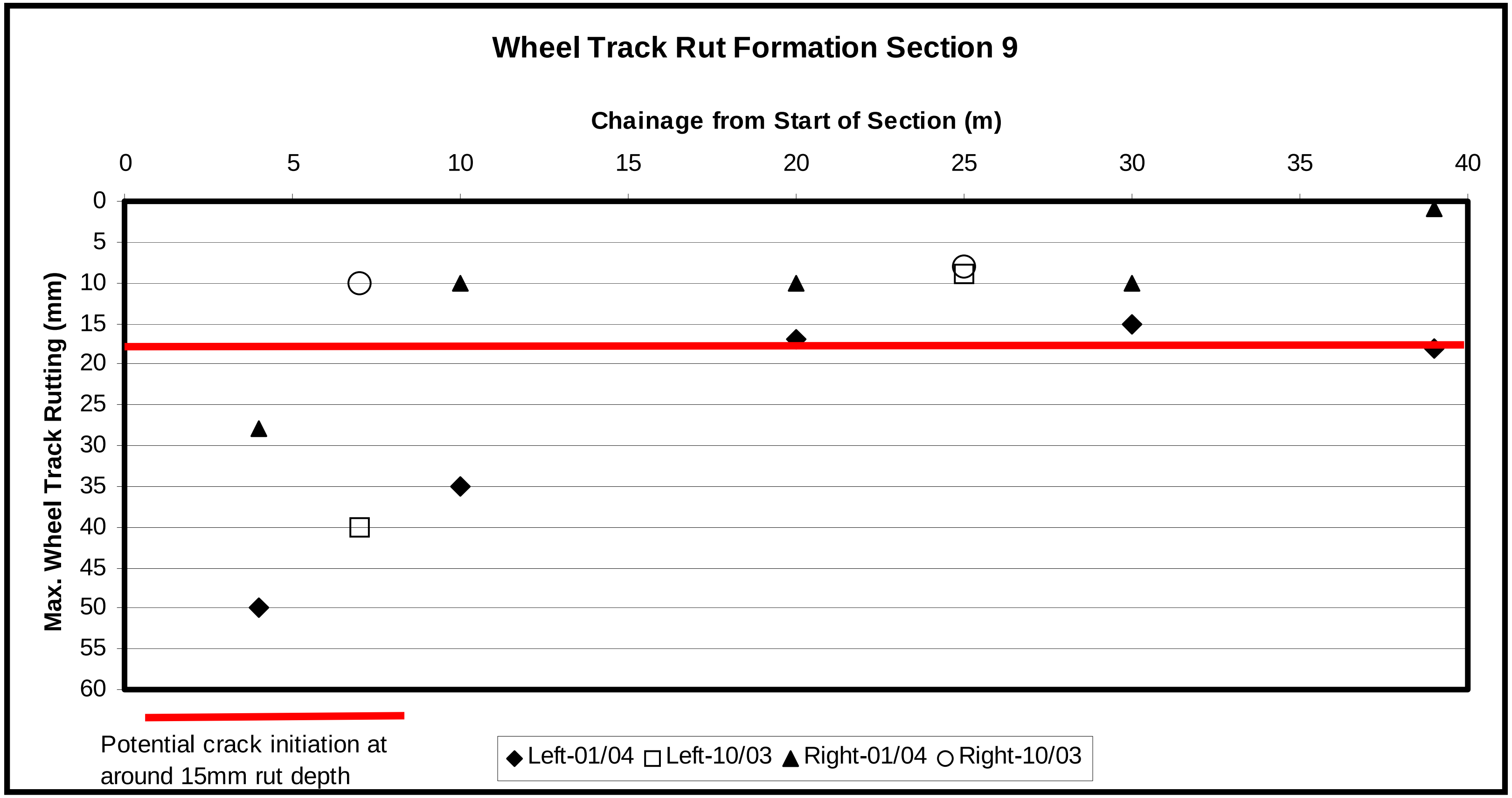

Figure 3.6 Longitudinal Rutting Data, Section 9

3.4 The ILO constructed Bamboo Reinforced Concrete Trial Paving

A detailed foot survey was made of the entire bamboo reinforced concrete paving (BRCP) trial (approximately 2km) constructed by the ILO Upstream Project in the year 2000. It is interesting to note that in the rain season that year the portion of the BRCP trial south of Highway 6 was flooded when the Tonle Sap Lake level rose.

The general condition of the BRCP is very good. There is some very slight wear of the surface on some of the slabs. Some of the joints exhibit cracks in the sand-bitumen filler in cooler temperatures. However, these reseal as temperatures rise.

Cracks only exist on two of the concrete slabs in the entire BRCP network. One is a small crack across the corner of one slab. The other is the final slab laid travelling northwards along the trial road, at the transition to the Intech managed trials. This slab has settled substantially and has probably failed due to a combination of poor foundation conditions, and being subjected to high loads as trucks impact onto this slab.

Figure 3.7 Single slab crack

Figure 3.8 Cracking on final slab, ILO paving

Figure 3.9 Maximum shoulder erosion

Figure 3.10 Side drain damage at Puok

The shoulders are generally in good condition, although in isolated locations erosion of up to 6cm was apparent. One section of the side drain in the Puok Market area had collapsed. Apart from this there are no defects to the paving despite no evidence of road maintenance since construction in the year 2000. The drains around Puok Market require to be cleaned.

3.5 Road Construction Materials

Five construction material sources were visited in the Siem Reap area in order to gauge the availability, cost and suitability of materials for the trial road rehabilitation. The sources locations are indicated on Figure 3.11. Summary information on the sources is listed in Table 3.2 and further details included as **Appendix A** to this report.

Ref.	Name -Type	Product	Cost/m3 (at source)	Excavation	Processing
Q1	Phnom Dei: Laterite	Laterite gravel.	N/A	Mechanical + manual	None
Q2	Phnom Tuch –1 Sandstone-conglomerate, rhyolite & tuff	Crushed rock aggregate	10-20mm: $9 6-8mm $8	Drill/blast	Single crusher +screen and labour-based
Q3	Phnom Tuch – 2 Sandstone, conglomerate. , rhyolite & tuff Colluvium and laterite	Crushed rock aggregate	10mm: $7.5	Drill/blast	Multiple jaw crusher + screen
		Natural and laterite gravel.	N/A	Mechanical	None
Q4	Phnom Troyng Quartzite sandstone	Crushed rock aggregate and blocks	Aggregate.: $8 Blocks $5	Hand	Labour-based
Q5	Doun Jaov	Sand	N/A	Small dredge-pump	None

Table 3.2 Summary Details of Construction Materials Sources

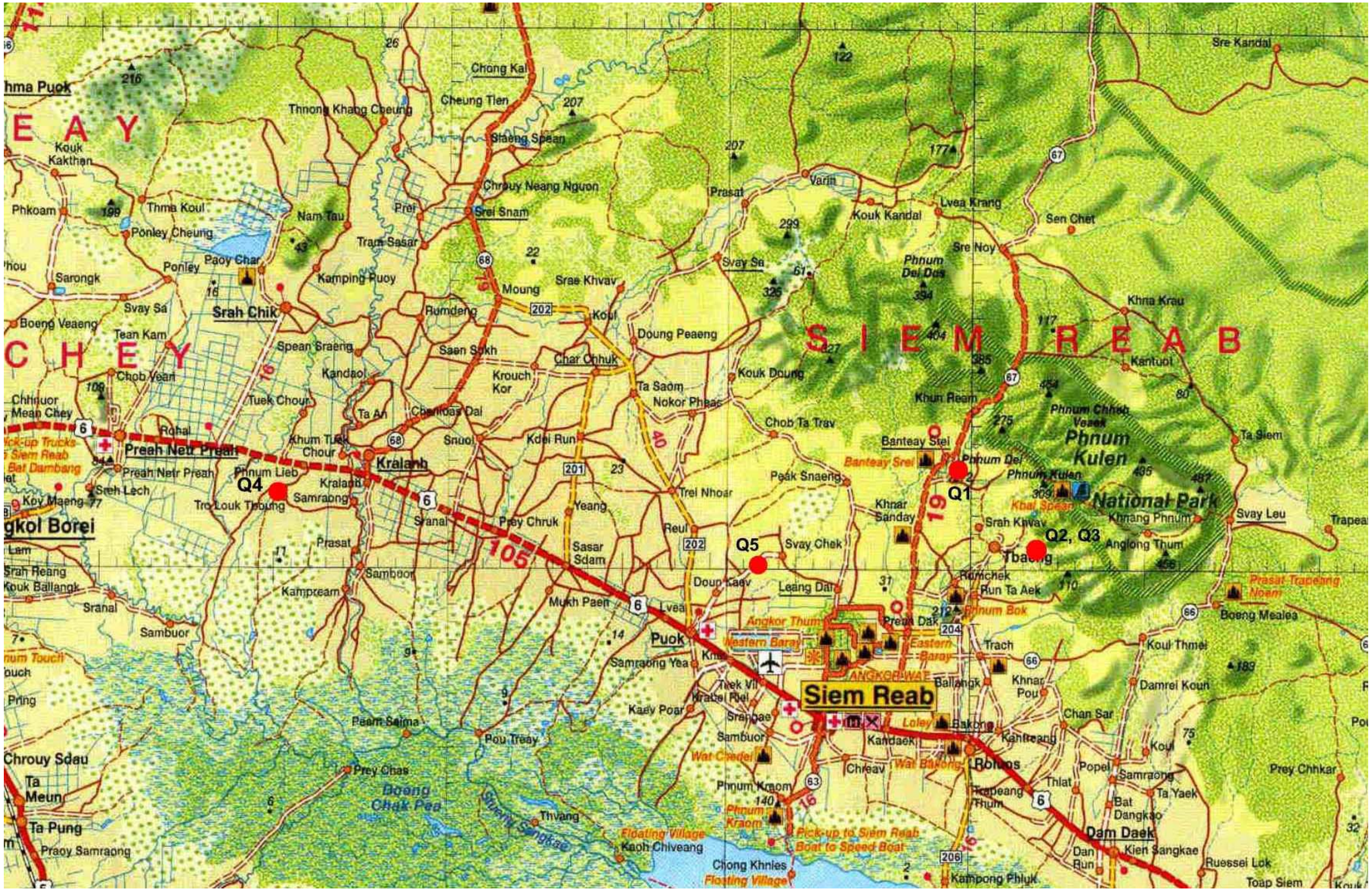

Figure 3.11 Construction Materials Locations

4 DISCUSSION

4.1 Road Conditions

The principal conclusions to be drawn from the assessment of the condition of the Puok road sections are:

1. Section 4 and section 9 have continued to deteriorate since October 2003, although at a reduced rate, possibly because of the reduction in overloaded traffic in the last 3 months, and the onset of the dry season.
2. There is some indication of increased erosion in the surface seals on sections 2,6, and 7
3. Although there is also increase in the shallow rutting in Sections 6, 7 and 8 this is below the 15mm depth level that was observed as being the critical depth for crack initiation in Sections 4 and 9
4. The stone block sections 3 and 5 have continued to perform well under heavy axle loading although some localised depressions have been identified.
5. The ILO bamboo reinforced concrete road has stood up well to the heavy traffic loading, and flooding of a major section in the year 2000. Only two of the slabs exhibit any cracking. No other significant deterioration is evident.

4.2 Traffic Issues

There is apparently local concern as to safety as aspects of the dressed stone sections in regard to two-wheeled traffic. Bicycles and motorcycles tend to use the laterite shoulders in preference to the more uneven surface of the stone paving.

Overloaded trucks have used the trials road, causing accelerated deterioration to two of the trial sections. This issue will be taken up under SEACAP 8 investigations, and is discussed further in Section 9 of this document.

It is evident, despite assurances from the council and principal haulier that overloading would discontinue, there is a likelihood that the route will continue to be subjected to overloaded trucks. Design of the repairs must take account of this risk.

4.3 Options for Repair and Rehabilitation

Table 4.1 lists the potential options for the repair and rehabilitation of the Trial sections.

The estimated costs are discussed in Section 5.

Section	Description	Condition Summary	Rehabilitation and Repair Option	Associated Risks
ILO	Bamboo Reinforced Concrete Pavement	No deterioration apart from cracking at the end of last (transition) slab and one other slab with a minor crack. Minor cracking of bitumen seal joints	Reconstruction of last 3m of last slab. Band seal on other minor crack. Ongoing condition monitoring Repair to shoulders and drainage	None anticipated
Transition	Laterite	Pavement level below adjacent sections. Some surface erosion	Excavate approx 150-200mm existing laterite, place/ & compact 200mm sand aggregate, overlay with diluted emulsion prime, and emulsion chip and sand seals.	Deterioration risk from overloaded trucks
1	Bamboo Reinforced Concrete Pavement	No deterioration apart from minor cracking of bitumen seal joints	Monitoring of construction joints	None anticipated
2	Sand-Aggregate Roadbase & Single Bitumen Stone Chip Seal		Small areas of patching to be identified on site. Sand seal overlay	Deterioration risk from overloaded trucks
3	Dressed Stone with Bitumen-Sand Sealed Joint	No significant deterioration. Localised shallow depressions	Provide diluted emulsion tack coat and emulsion slurry grouted stone regulating layer and sand seal..	None anticipated
4	Armoured Laterite Roadbase & Single Bitumen Stone Chip Seal	Severe rutting and break-up of road surface over majority of section	Excavation and reconstruction of whole section – 3 options: 1. Reconstruct with 200mm of sand aggregate base overlain by diluted emulsion prime and emulsion chip and sand seals. 2. Reconstruct armoured laterite option as before with 100mm of aggregate "armour". Overlain by diluted emulsion prime and emulsion chip and sand seal 3. Reconstruction with 200mm of hand packed stone, blinded with sand/fine aggregate, overlain by diluted emulsion prime and emulsion chip and sand seals.	Deterioration risk from overloaded trucks

Section	Description	Condition Summary	Rehabilitation and Repair Option	Associated Risks
5	Dressed Stone Pavement & Bitumen-Sand Seal Joint	No significant deterioration. Some shallow localised rutting	Provide diluted emulsion tack coat and emulsion slurry grouted stone regulating layer and sand seal .	None anticipated
6	Sand-Aggregate Roadbase & Single Bitumen Stone Chip Seal	Potholes. Minor pavement edge erosion Shallow rutting not impacting on the integrity of the seal.	Repair 2 potholes. Minor edge repairs. Continue condition monitoring	Deterioration risk from overloaded trucks. Increased rutting leading to cracking and pavement failure
7	Telford Water Bound Macadam & Single Bitumen Stone Chip Seal	Minor pavement edge erosion Shallow rutting not impacting on the integrity of the seal.	Small bridge - Provide diluted emulsion tack coat and emulsion slurry grouted stone regulating layer and sand seal Minor edge repairs. Continue condition monitoring.	Deterioration risk from overloaded trucks. Increased rutting leading to cracking and pavement failure
8	Water Bound Macadam & Double Bitumen Stone Chip Seal	Minor pavement edge erosion Shallow rutting not impacting on the integrity of the seal.	Minor edge repairs. Continue condition monitoring.	Deterioration risk from overloaded trucks. . Increased rutting leading to cracking and pavement failure
9	Armoured Laterite Roadbase & Sand Seal	Severe rutting and break-up of surface in one 8m length. Significant rutting in one wheel track.	Two options: 1. Reconstruct Ch0-15m as original armoured laterite design with emulsion grouted stone regulating and layer and sand blinded surface over remainder. 2. Reconstruct whole section 9 as section 4 (3 No sub-options).	Deterioration risk from overloaded trucks
10	Hand-Packed Stone & Laterite Wearing Coarse	Severe loss of laterite wearing course	Replacement of wearing course with 100mm of specification compliant laterite gravel	Loss of gravel wearing course

Table 4.1 Options for Repairs to the Puok Trial Sections

4.4 Engineering Risk

Although Engineering Risk and associated cost is the principal risk associated with road project such as the Puok Trial project, others may also need to be considered, namely:

Economic Risk: a function of the economic consequences of impaired or broken access.

Social Risk; a function of the impact on the local users of the various options (safety, health, maintenace burden and likelihood of resources/funds being available when required).

Three principal factors (or group of factors) can be considered as combining to constitute the total risk on the Puok Trial sections. These are:

A. The natural road environment. (Terrain, Climate)

B. The normal controllable road enviornment (Normal Traffic, Maintenance Regime)

C. Abnormal impacts (Overloaded Trucks)

The Puok Trial pavements were designed to cope with and adequately withstand risk factors A and B. They were clearly not designed to withstand the impacts of risk factor C. Nevertheless it is apparent that some of the trials paving options are able to withstand this additional risk better than others.

Although there are obviously close cross relationships between the engineering, economic and social risks, there are some apparent differences as indicated in Table 4.1, where assessed risk is defined in comparative terms as:

1: Negligable risk
2 Low risk
3 Moderate risk
4 High risk
5 Excessive risk

Section	Engineering Risk (A+B)	Engineering Risk (A+B+C)	Combined Socio-economic Risk (A+B)	Combined Socio-economic Risk (A+B+C)
1	1	1	1	1
2	2	4	2	3
3	1	2	3	3
4	2	5	2	4
5	1	2	2	3
6	2	4	2	2
7	2	4	2	2
8	2	4	2	2
9	2	5	2	3
10	3	4	4	4

Table 4.1 Comparative Risk for Trial Paving Options

5 REHABILITATION AND REPAIR COSTS

The budget for the repairs to the trials has been developed from a detailed bill of quantities for the works. The total works financing cost is £6,200 after allowance for the US$1,300 contribution from the sand haulier. The breakdown of cost for each trials section is shown in Appendix A. This amount is therefore requested to be made available by Crown Agents for the repair works through SEACAP programme for Intech-TRL to manage the repair works and pay the contractor. This is the arrangement agreed by DFID for the original trials works.

The works supervision costs for the works are already included in the Intech-TRL SEACAP 8 contract.

Various options have been costed for the rehabilitation of the pavement failures on sections 4 and 9. However the selected repair options are believed to offer the lowest risk of repeat failure due to overloaded trucks continuing to use the route.

Intech-TRL will prepare the contract documents for the trials repairs.

The routine maintenance works required to be carried out will be discussed with the District authorities. The aim will be to achieve agreement for the District Authorities to arrange and pay for this work. This will include the repair to the drain at Puok Market (Figure 3.10).

6 ROUTINE MAINTENANCE

Routine Maintenance arrangements for the Puok Trial Sections will be discussed with the District Maintenance Committee and addressed in the next progress report.

7 FURTHER TRIAL SECTIONS

From ongoing investigations and discussions with sector personnel, there are a number of other rural road surfacing types which justify further demonstration through trials. These should be considered for the regional expansion of trials under the SEACAP programme.

These paving types include:-

- Rice husk fired clay bricks (a technique reported to be established in the Battambang area)
- Cement stabilisation (of fine granular soils)
- Concrete block paving
- Engineered natural surface (Engineered earth road)
- Lime stabilised earth road
- Slurry bound macadam
- Slurry seal

All bitumen emulsion is currently imported. The local production of bitumen emulsion would provide an economic boost to the labour friendly (and suitable for small contractors) surfacing techniques using this approach. The feasibility of local manufacture of emulsion making plant should be investigated.

Preliminary testing of local sand sources (Q5 in Table 3.2) indicates that it could be suitable for cement stabilisation as a sub-base or basecourse material, Figure 7.1. Further testing, however, would be required to fully evaluate engineering and economic parameters for this option.

Appendix B provides the latest listing of rural road surface options. Many of these options will have better whole life cost and local resource attributes than gravel/laterite in particular circumstances.

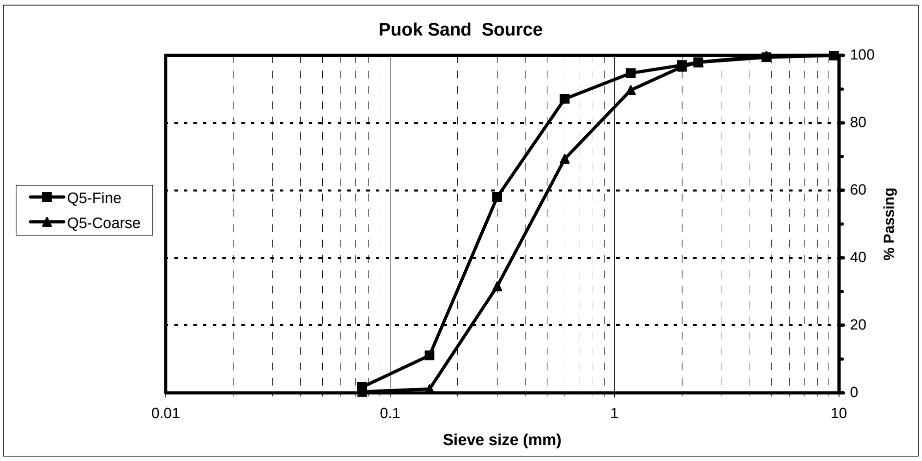

Figure 7.1 Grading of Sand Samples from Doun Jaov (Puok)

8 TRIALS REHABILITATION ARRANGEMENTS

One of the two contractors for the original work has been identified as the contractor for this work. He will be directly appointed as in the original trials. Repairs are to be funded by DFID through SEACAP. Intech-TRL will prepare a contract document based on the format of the original trials construction. Supervision of the work will be carried out by Intech-TRL.

9 AXLE LOADING INVESTIGATIONS

9.1 Current Axle Loading Regulations

Legal Load limits were set in November 1999 for National Primary and National Secondary Roads. There do not appear to be legal limits for other categories of road. The limits are based on Gross Vehicle Weight with some limitations on individual axle loads. The limits are based on a maximum load of 10 tonnes on a single axle and 19 tonnes on a tandem group on National Primary routes.

Vehicle Category	National Primary Permitted Gross Vehicle Weight	National Secondary Permitted Gross Vehicle Weight
2 axle rigid truck	16 t	16 t
3 axle rigid truck	25 t	20 t
4 axle truck and trailer	35 t	30 t
5 axle truck and semi-trailer	40 t	35 t

Table 9.1 Current Cambodia Legal Axle Load Limits

Tables of penalty fines are provided for axle and Gross Vehicle Weight overloading.

From initial inspection it appears that the regulations are influenced by the manufacturer's ratings of individual axle loading. It must be appreciated that in-service performance of vehicles and tyres is well in excess of the manufacturer's ratings. Vehicles and tyres can normally endure loadings well in excess of the manufacturer's ratings without undue damage or excessive operating costs.

The operational environment and economics of transportation in developing countries encourage widespread overloading.

9.2 Pavement Design Issues

Bituminous (flexible) pavement design is normally based on assessment of the expected vehicle axle loading during the 'life' of the road pavement. Axle loading by heavy vehicles is of particular concern for all paved routes. Developing countries usually suffer from widespread vehicle overloading. Efforts to control axle loading in developing countries are generally unsuccessful [1]. It is therefore necessary to be aware of the situation and influence of overloading on road pavement performance, in the design and management of road pavements.

The current MPW&T Roadworks Standards explain the traditional pavement design relationship between axle loading and road pavement damage for paved roads [2].

Pavement damage has been empirically related to axle loading measured in Equivalent Standard (80kN single axle – dual tyre wheel) Axles, or ESA, according to the following table of axle types and groups, and formula (from Cambodia Road Design Standards 1999):-

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1 The Control of Axle Loading in Tanzania, R C Petts, IRF Conference, Cairo, 1986

2 There are no relationships established for axle load related damage to gravel or earth roads, although it is clear that overloaded vehicles do a disproportionate amount of damage to these surfaces. The US Forest Department have derived gravel road thickness designs based on axle loading.

Table 2.5.1 Axle Loads Which Cause Equal Damage

Axles Configuration	Single Single	Single Dual	Tandem Dual	Tri-axle Dual
Load (kN)	53	80	135	181

$$\text{No. of standard axles for same damage} = \left(\frac{\text{Load on axle group}}{\text{Appropriate load from Table 2.5.1}} \right)^{\text{EXP}}$$

The exponent in the formula will depend on a number of factors relating to the pavement, its condition and 'environment' and the spectrum of vehicle traffic. However, for relatively light bituminous pavements in developing countries an exponent of 4 is usually taken to be appropriate.

The effect of overloading can be conveyed by the following examples for a single dual-tyre-wheel axle based on this exponent.

Axle Load (tonnes)	Number of equivalent standard axles (ESA)
8.0	0.9
12.0	4.6
15.0	11
20.0	35

Table 9.2 Effect of axle load on assessed pavement damage

9.2 Uncertainty of Performance

It is important to appreciate the situation with respect to loading and road pavements in Cambodia. Nearly all of the research on axle loading and pavement damage has been conducted in developed countries. Factors such as climate, flooding, range of loading, road user discipline and control, construction techniques, construction quality control and maintenance regimes etc. can have a significant effect on pavement performance.

Therefore there is considerable uncertainty regarding the prediction of the effects of any particular level of loading in Cambodia.

Furthermore, there is the basic problem of predicting traffic growth[3], the mix and loading of vehicles, and even vehicle technology well into the future, to assess what the particular level of loading will be through the design period of a road pavement.

In consequence of the foregoing there is a fundamental problem in the accurate prediction of the axle loadings and their effects over the 'design life' of the road pavement in Cambodia.

3 Normal, diverted and generated traffic and growth.

9.3 Available Information on Axle loading

There is very little information available regarding axle loading in Cambodia. It is however evident that overloading is common with examples of survey weighings of over **20 ESA** per 2 or 3 axle truck [4] (a legally loaded 3 axle truck would have a maximum axle load equivalence of **3 ESA**).

Investigations under the PRIP design phase and the Puok Market trials investigations have since shown the overloading problem to be serious and widespread in Cambodia. Truck loadings of up to two and a half times the legal limit have been monitored.

During the 2003 mid year wet season and continuing during the October field surveys, the Puok Trial sections were subjected to significant numbers of sand haulage trucks. It was apparent during the field survey work that these trucks are heavily overloaded, hauling wet sand, and were using the road on a regular daily basis, Figure 9.1.

Figure 9.1 – Overloaded truck on the Puok Trial Road.

These trucks were not weighed, however from physical measurements and manufacturers' specifications the following assessment of axle loading has been made. The standard haulage trucks are modern 3 axle tippers (Hyundai, Hino, Daewo etc.). The bodywork on the trucks has been extended (as most materials haulage trucks are in Cambodia) to a struck capacity of $20m^3$. However the trucks often transport the material in a heaped condition, which is equivalent to an additional $4m^3$. Therefore total material load can be $24m^3$ for a 3 axle truck. The unladen weight of these trucks is about 9 tonnes for the chassis and cab, plus about 2 tonnes for the tipping body and fuel, i.e. approximately 11 tonnes. The wet sand being transported would have a specific gravity of more than 1.6. The total operating weight of the loaded trucks can therefore be up to about 50 tonnes. This compares with the current legal limit of 20 tonnes for 3 axle trucks on secondary roads. It is clear that axle load control is not practiced.

Two assumptions have been made regarding the weight distribution on trucks in this extreme loading condition to derive equivalent standard axles (ESA) for each fully loaded truck in the following tables. The equivalences are based on an exponent of 4 normally used in the formula for lighter duty pavements.

4 Project Preparation TA for Primary Roads Restoration Project, Final Report, SMEC 1999.

Axle (Group)	Assumed Weight	Equivalent esa
Front Steering (2 tyres)	9 tonnes	8
Rear tandem pair (8 tyres)	41 tonnes	79
VEHICLE TOTAL	**50 tonnes**	**87**

Table 9.3 Calculation of Axle Equivalence for a loaded construction materials haulage Truck: Scenario A

(1 tonne = 9.807kN)

Axle (Group)	Assumed Weight	Equivalent esa
Front Steering (2 tyres)	12 tonnes	24
Rear tandem pair (8 tyres)	38 tonnes	58
VEHICLE TOTAL	**50 tonnes**	**82**

Table 9.4 Calculation of Axle Equivalence for a loaded construction materials haulage Truck: Scenario B

It is expected that the actual maximum loading will typically lie between these two scenarios. It is clear that the overloaded materials haulage trucks can have an equivalence of more than 80 esa. This is over **25 times** the pavement damaging power of a truck loaded to the current legal limit for secondary roads.

However, this level of loading is well beyond the limits of researched knowledge of pavement damage by vehicular traffic, and established pavement deterioration relationships based on fatigue. The excessive stresses induced in most pavements and foundations by this level of overloading will cause rapid failure by shear strain with very low numbers of vehicles passing. This appears to be a common problem on the Cambodian road network.

Overloading of bridges is also a serious problem in Cambodia. There are a number of instances of recent collapses of bridges due to overloaded vehicles.

9.4 Cambodia Government Initiatives

Cambodia is cooperating with the People Republic of **China**, the **Lao** People's Democratic Republic, The Union of **Myanmar**, The Kingdom of **Thailand** and the Socialist Republic of **Vietnam** to achieve a common regional regulation of vehicles, their sizes and loading.

The latest draft of the regional agreement (November 2003) contains proposed regulations for loading limits for road vehicles shown in Table 9.5.

The proposed regulations will **REDUCE** the permissible axle loadings on vehicles in Cambodia.

Of particular interest for axle loading and pavement damage considerations is that the proposed regulations will not apply to *"road building contracting equipment"*. As these are the vehicles which cause serious damage to haul routes while constructing/rehabilitating other roads, these proposed regulations will have little effect on the serious axle loading situation and road pavement damage in

Cambodia.

AXLE CONFIGURATION	Proposed Regional maximum Loading GVW	Current Cambodia Main Road Regulations GVW
3 axle rigid truck	21 tonnes	25 tonnes
4 axle rigid truck	25 tonnes	-
4 axle articulated	32 tonnes	-
5 axle articulated	36 tonnes	40 tonnes
6 axle articulated	38 tonnes	-

Table 9.5 Proposed South East Asia Regional Axle Loading Regulations and current Cambodia Main Road Regulations.

GVW = Gross Vehicle Weight

There seems to be little consideration of the actual and feasible axle load control situation in Cambodia, and the consequences for road pavement design and performance.

A Cambodian Road Law is currently being drafted. However, review of the latest version of the document shows that there is no recognition of the axle loading situation and consequences for road pavement damage. There is no effective provision for the rational monitoring, control, penalisation and deterrence of axle overloading.

9.5 Initial Conclusions on Axle Loading

The following conclusions are drawn from the investigations to date:-

- Overloading is common on all categories of road in Cambodia. This can be up to two and a half times the current legal axle load limit.
- Light or sub-standard road pavements can be quickly destroyed by overloaded trucks. Bridges are also vulnerable to collapse by overloaded trucks.
- Pavement design processes in Cambodia do not take adequate account of the serious axle overloading situation and Cambodia-specific conditions.
- Currently there is no effective control of overloading in Cambodia.
- Experiences from other developing countries suggest that axle load control is extremely difficult to achieve.
- The proposed common regional axle loading regulations will reduce the allowable vehicle loading in Cambodia on main roads. However they will probably have very little effect on the loading situation and road pavement damage in Cambodia.
- The draft proposed Cambodian Road Law does not recognise the serious axle overloading situation, nor does it provide for an adequate framework to control axle loading.

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10 WORK PROGRAMME

The proposed work programme is presented as Figure 10.1. This programme is broadly in line with that originally proposed, although some adjustment has had to be made to allow for the rainy season impacts on construction.

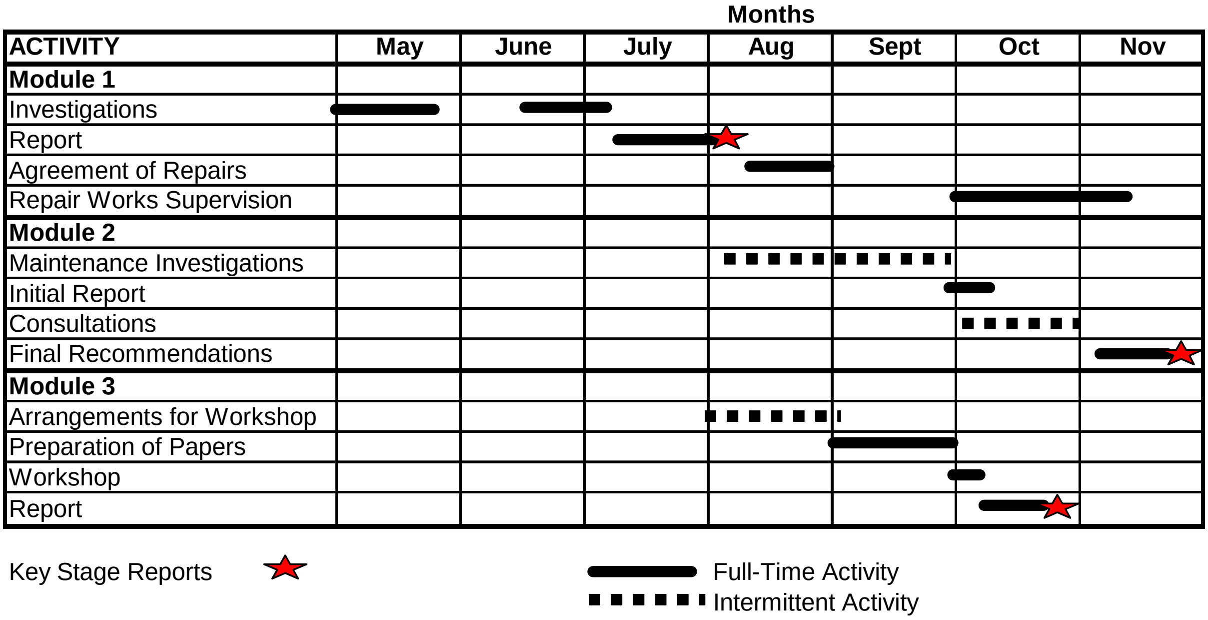


Figure 10.1 SEACAP 8 Programme

References

1. Ministry of Public Works and Transport, Cambodia Road Design Standards, 1999
2. Robert Petts, The Control of Axle Loading in Tanzania, IRF Conference, Cairo, 1986
3. Cambodia Draft Road Law, 2004.
4. Draft Regional Agreement for Facilitation of Cross-Border Transport of Goods and People, 13 November 2003.
5. Heng Kackada, LCS Working Paper No 17, Pouk Market Trial Road Initial Pavement Monitoring, April- May 2003
6. Fergus Gleeson, Low Cost Surface (LCS) Options Trials, Conclusion of Construction Phase, Intech Associates, 2002.
7. Fergus Gleeson, Low Cost Surface (LCS) Options Trials, Initial Maintenance Report, October 2002, Intech Associates, 2002.
8. TRL, Overseas Road Note 18, a guide to the pavement evaluation and maintenance of bitumen-surfaced roads in tropical and sub-tropical countries, TRL, 1999.
9. TRL, Overseas Road Note 40, a guide to the measurement of axle load in developing countries using a portable weighbridge, 1995.
10. TRL, Report 229, The MERLIN road roughness machine User Guide by M A Cundill, 1996.
11. Indian Roads Congress, Guidelines For Strengthening Of Flexible Pavements Using Benkelman Beam Deflection Technique, 1997
12. ILO, CMB/97/M02/SID The Upstream Project, Road Inventory
13. ILO, Provincial And Rural Infrastructure Project (PRIP), Main Technical Report July 2003
14. Robert Petts, LCS Working Paper No 1, Rationale for the Compilation of International Guidelines for Low-cost Sustainable Road Surfacing, second edition, March 2002.
15. Azam, Al-Fayadh, Gleeson & Petts, LCS Working Paper No 7, Bamboo Reinforced Concrete Pavement, Road Construction in Cambodia, June 2002.
16. Dr Jasper Cook, LCS Working Paper No 18, Puok Market Trial Road Investigation: October 2003.
17. Bach The Dzung & Tran Tien Son, LCS Working Paper No 16, Clay Brick Paving Investigations in Vietnam, First Edition, April 2004.

APPENDIX A - TRIALS REPAIR BUDGET

Section	Trial Paving Description	Estimated Cost Rehabilitation & Repair in US$	Remarks	Unit Cost US$ per Square Metre of trial section	Recommended
ILO	Bamboo Reinforced Concrete Pavement	**178.3**		14.9	
Transition	Laterite	**492.4**		12.3	
Trial Section No 1	Bamboo Reinforced Concrete Pavement	**5.4**		0.1	
Trial Section No 2	Sand-Aggregate Roadbase & Single Bitumen Stone Chip Seal	**882.9**		2.2	
Trial Section No 3	Dressed Stone with Bitumen-Sand Sealed Joint	**773.6**		3.9	
Trial Section No 4	Armoured Laterite Roadbase & Single Bitumen Stone Chip Seal	3,840.7	Option 1		sand+chip seals + sand aggregate RB
		3,523.6	Option 2		sand+chip seals + armoured laterite RB
		4,423.3	**Option 3**	11.1	sand+chip seals + haqndpacked stone RB. Expected best overloaded traffic performance
Trial Section No 5	Dressed Stone Pavement & Bitumen-Sand Seal Joint	**790.7**		4.0	
Trial Section No 6	Sand-Aggregate Roadbase & Single Bitumen Stone Chip Seal	**294.8**		0.7	
Trial Section No 7	Telford Water Bound Macadam & Single Bitumen Stone Chip Seal	**197.9**		0.5	
Trial Section No 8	Water Bound Macadam & Double Bitumen Stone Chip Seal	**316.9**		0.8	
Trial Section No 9	Armoured Laterite Roadbase & Sand Seal	1,049.3	Option 1		Partial rehabilitation
		2,266.3	**Option 2**	11.3	sand+chip seals + haqndpacked stone RB. Expected best overloaded traffic performance
Trial Section No 10	Hand-Packed Stone & Laterite Wearing Coarse	**450.0**		2.3	
Total for Rehabilitation and Repair works with recommended options (US$)		**11,072.6**			
Contingency @ 5%		**553.6**			
Total Works Budget for Rehabilitation and Repair works with recommended options		**11,626.2**			
Contribution from Haulier		1,300.0			
Total Financing Budget required for direct works costs (US$)		10,326.2			
Financing and handling fee @ 5%		516.3			
Total Financing Budget required for project costs (US$)		10,842.5			
Equivalent Sterling Financing Budget required for works		**£6,195.7**	1.75	= Exchange rate	

APPENDIX B

RURAL ROAD SURFACING GUIDELINES

Using Local Resource Based Methods
Focusing on the use of local labour, materials, enterprises and the community themselves.

Number	Type of Surface or Road base	SUITABILITY FOR TRAFFIC As a Road Surface		
		Light	Medium	Heavy
1	Engineered Natural Surface			
2	Soil Stabilisation			
3	Gravel / Laterite			
4	Water Bound Macadam			
5	Dry Bound Macadam			
6	Crushed Stone Macadam			
7	Hand Packed Stone			
8	Telford Paving			
9	Cobble Stones			
10	Stone Setts or Pavé			
11	Dressed Stone			
12	Mortared Stone			
13	Stone Chippings			
14	Slurry Bound Macadam			
15	Bituminous Sand Seal			
16	Bituminous Chip Seal			Note 3
17	Slurry Seal			Note 3
18	Ottaseal			
19	Penetration Macadam (Bitumen)			
20	Pre-Mix Macadam (Bitumen)			
21	Burnt Clay Brick			
22	Concrete Brick			
23	Un-reinforced Concrete			
24	Steel Reinforced Concrete			
25	Bamboo Reinforced Concrete			
	Type of Roadbase			
26	Sand Aggregate			
27	Armoured Laterite			

Definitions

Traffic
Light: Mainly non-motorised, motorbikes & less than 25 motor vehicles per day, with few medium/heavy vehicles
Medium: Up to 100 motor vehicles per day including up to 20 medium (10t) goods vehicles
Heavy: Accessible by all vehicle types including heavy and overloaded trucks

Notes
1. Assumes that adequate specifications, thickness & foundations are provided for each surface type.
2. Engineered Natural Surface suitability depends on soil type and environment
3. Suitable for Heavy Traffic in Multiple Seal applications

Puok Trials: Construction Material Sites Visited January 2004

1 Phnom Dei (Q1)

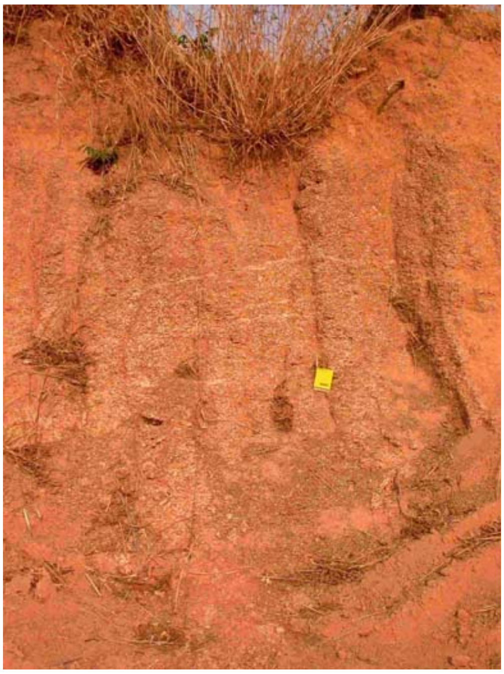
Location: 30-35 km NNE of Siem Reap.

N 13^0 35.51’,
E 103^0 58.98’

A Laterite borrow area of variable quality on the footslopes of Phnom Dei (Plate1). Composed of plinthite, honeycomb (vermiform) and some hardpan materials (Plate 2). Engineering Character varies from weakly cemented plinthite with abundant kaolinite to locally moderately strong hardpan with included nodules (Plate 3).

Existing excavations in the area are small scale and randomly situated. Acceptable wearing course laterite is available within the area but good quality control on excavation would be required to ensure that weaker and friable material is excluded.

Plate 1



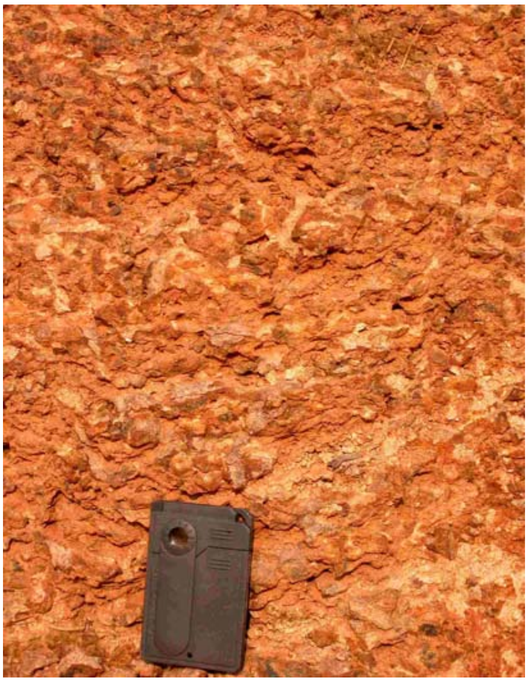


Plate 2 **Plate3**

2 Phnom Tuch (Q2 & Q3)

Different operations working the same hill area composed of bedded indurated sandstones and fine conglomerates (greywacke) with possibly some intruded igneous beds (andesitic rock with small feldspar phenocrysts?)

Location: 20-25 km NE of Siem Reap – but accessed onward from Phnom Dei.

N 13^0 30.62'
E 104^0 04.35'

LocationQ2 is a small drill and blast operation working along the strike of the stronger rock beds (Plate 4), and feeding a small portable jaw crusher with revolving screen (Plate 5). Secondary crushing and sorting is a manual labour-based activity. Current small stockpiles comprise nominal 10-20mm ($9/m^3) and 6-8mm ($8/m^3) materials composed of reasonably clean and apparently strong particles, however the shape of the aggregate is poor and consequently so is the size control (Plate 6). The material however is perfectly adequate for low volume rural roads construction.

Plate 4

Plate 5

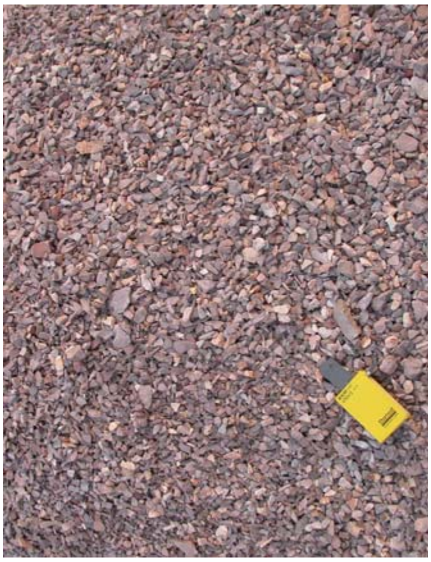


Plate 6

Source Q3 is located close to Q2 on the same hill, but is a larger operation with a greater production capacity (Plates 7 and 8). Cost 10mm aggregate $7.5/m^3 at site, $11.7/ m^3 at Puok Market.

Plate 7

Plate 8

Source Q3 also has the potential to produce a mixture of colluvial gravel and lateritic gravel from overburden on the adjacent hill-slopes. (Plate 9).

Plate 9

3 Phnom Troyng (Q4)

Location 40km West of Siem Reap, 1km South off the N6 highway.

N13^0 35.16'
E103^0 20.98'

Moderately thickly to thickly bedded quartzite sandstone with some conglomerate being manually excavated by wedging and barring off 1-2m spaced joint planes and 30-40^0 dipping bedding planes (Plates10 & 11).

Plate 10

Plate 11

Plate 12

Several small concessions are working the same hill currently producing hand crushed aggregate ($8/m^3) and small 250mm blocks ($5/m^3).- (Plates 12 & 13). A suitable source for hand packed stone materials.

Plate 13

4 Puok Sand Sources (Q5)

Fine to medium alluvial sand sources, 5km north of Puok market, (Plate 14)

Plate 14