MAINSTREAMING LOW VOLUME RURAL ROAD RESEARCH IN S E ASIA

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ABSTRACT

Between 2004 and 2009 SEACAP (South East Asian Community Access Programme) initiated or extended a series of Low Volume Rural Road (LVRR) pavement trials in Vietnam, Cambodia and Laos. The great majority of this research was undertaken in Vietnam with DFID financing and in association with the World Bank and Ministry of Transport. This work continued with funding by the World Bank's Vietnam Rural Transport Programmes. In total some 140 separate lengths of trial road sections, totalling over 170km, have been constructed and subsequently monitored up to 2012. Central to the work in all three countries was the trialling of a wide range of pavement and surfacing options appropriate to the governing physical socio-economic conditions. The Vietnam Rural Road Surfacing Research (RRSR) database now comprises a unique historic record of rural road performance in the tropical and sub-tropical rural environment. The focus is now on mainstreaming this work to the benefit of vulnerable rural communities.

1 INTRODUCTION

Because of increasing recognition that gravel surfacing was not always the best solution for low volume rural roads in S E Asia, surfacing trials on alternative surfaces were initiated in Cambodia in 2001 and extended to Vietnam (2003) and Laos (2006). The initial research focused on the performance of various bituminous and non-bituminous surfaces in comparison to unsealed gravel options [1]. Subsequently, particularly in Vietnam, their role in providing a more climate resilient rural infrastructure became more prominent. In general, this work has concentrated on identifying the best performing pavements and surfaces within a range of physical and socio-economic environments and within a whole-life cost context. The bulk of the research was undertaken between 2003 and 2010 in Vietnam where three phases of trial road selection, design and construction were undertaken under the Vietnam Rural Road Surfacing Trial (RRST) programme, under joint DFID-World Bank funding in cooperation with the Ministry of Transport (MoT) [2] [3].

Under the three phases of RRST a total of 156 km of trial roads have been constructed within a range of road environments in 16 provinces, from which a representative 123 sections of between 80m to 200m in length have been selected for ongoing performance monitoring. Rural road condition data in Vietnam were collated within the Rural Road Surfacing Research (RRSR) database under the ownership of the Department of Science and Technology, MoT. In RRST I short sections (100m to 200m) of different trial option were constructed on single roads whilst in the second and third RRST phases longer sections (0.5km to2.0km) were constructed with less variation on each road. Each trial road had at least one Control Section built to standard Vietnamese design and construction norms.

In Vietnam, the RRST programme was accompanied by a parallel Rural Road Gravel Assessment Programme (RRGAP), which studied gravel loss from over 700 rural roads sites [4]. This research found serious constraints to the use of gravel throughout Vietnam in most of the studied 16 provinces due to factors relating to material quality, material availability, climate, terrain, drainage provision and maintenance. Overall gravel loss figures indicated that around 58% of the surveyed sites were suffering unsustainable deterioration (>20mm/year), while 28% were losing material at twice that sustainable rate. The research on gravel roads in Vietnam raised serious questions about their sustainability and whole life cost and hence the capacity of authorities to maintain a predominantly gravel road rural road network. The RRGAP was a valuable complement to the RRST programme.

In Cambodia SEACAP took over the rehabilitation and monitoring of 10 short sections of pavement and surfacing options on a rural road in Siem Reap province constructed under the DfID funded KaR programme [5]. In Lao SEACAP funded the design, construction and some limited monitoring of 26km of LVRR trials, constructed under ADB funding, consisting of eight options within one northern hill region [6].

Table 1 summarise the range of physical road environments that the trials have covered and Table 2 list the range of surfacings, bases and sub-bases that have been trialled.

Table1 - General trial environments

Region	**Trial Terrain**	**Numbers of Trials**		
		Bituminous Trials	**Concrete Slab**	**Other Non-Bituminous Trials**
Vietnam				
Mekong Delta	Flat deltaic	**8**	4	1
South Central Coast	Flat coastal	8	3	5
North Central Coast	Flat coastal-small hills	18	12	2
Central Highlands	Rolling hills	18	11	3
Red River Delta	Flat coastal-deltaic	29	11	3
North East	Rolling hills – High hills	16	6	0
Lao PDR				
North West	Rolling hills	4	2	2
Cambodia				
Central	Flat inland plain	6	1	3

Table 2 - Trial Pavements and surfacing types

	Cambodia	Vietnam			Lao
Type of Surface/Roadbase	**SC 2**	**SC1, 27**		**WB RT3**	**SC17, 17.2**
	Sim Reap 1	RRST-I	RRST-II	RRST-III	
SEALS					
Double emulsion chip seal			√	√	
Double hot bitumen chip seal	√		√	√	
Emulsion sand seal over single chip seal		√			
Single emulsion sand seal	√	√			
Double emulsion san seal					√
Otta Seal					√
UNSEALED SURFACES					
Gravel Wearing Course	√	√	√	√	√
Water-Bound Macadam (WBM)		√	√		
Hand Packed Stone	√				√
Engineered Natural Surface					√
SEALED BASES & SUB-BASES					
Water-Bound Macadam (WBM)	√	√	√	√	√
Dry-Bound Macadam (DBM)		√	√	√	
Emulsion Stabilised Sand		√			
Cement Stabilised Sand		√	√	√	
Lime Stabilised Gravel				√	
Lime Stabilised Clay		√			
Armoured Gravel		√	√	√	
Graded Crushed Stone				√	
Natural Sand		√			
Sand-Aggregate Mix	√				
Natural Gravel	√	√	√	√	
BLOCK SURFACES					
Stone Setts	√	√			
Cobble Stone			√		√
Fired Clay Brick		√	√	√	
Concrete Brick		√	√	√	√
CONCRETE					
Steel Reinforced		√	√		
Bamboo Reinforced	√	√	√		√
Non-Reinforced	√	√	√	√	
Cast in Situ Blocks (Hysen Cells)					√

Notes **2005 etc** **Year of original construction**
1 **Puok Trials upgraded in 2005 under SEACAP**

The following sections of this paper concentrate on the regularly monitored trial options in the more comprehensive Vietnam trials. Conclusions are supported by evidence from the more limited monitoring from Cambodia, Lao and the follow-on mainstreaming under World Bank rural road rehabilitation programs.

2 THE SURFACING TRIALS PROGRAMME

2.1 Aims and design principles

It has become increasingly appreciated for LVRRs that a range of factors, collectively known as the “Road Environment”, needs to be taken into consideration when selecting and designing low traffic rural road pavements. The road environment was, therefore, a basic consideration in designing, initiating and analysing the RRSR programmes. The key factors in the road environment are as follows.

- Construction Materials
- Climate.
- Surface and sub-surface hydrology.
- Terrain.
- Sub-Grade.
- Traffic
- Construction regime.
- Maintenance.
- The “Green” Environment

The selection of trial options was based on the following guiding principles:

1. Designs should be appropriate to the road environments.
2. Local construction materials should be used where possible.
3. Maintenance requirements must be closely matched to local community arrangements and resources.

In addition construction techniques should be suitable for small contractors with limited capital or equipment resources, and encourage local employment

2.2 Construction,

Construction of the trials was undertaken using local contractors operating under a normal contracting regime in order to model market practice as much as possible. The only departures from normal practice were:

- Construction supervision was to international standard for the initial RRST sites (2005); for later sites (2006, 2010) trained local supervisors were utilised.
- Some initial training for contractors was undertaken in new techniques, eg bitumen emulsion, cobble stone etc.
- Quantified as-built quality audit surveys were undertake on the RRST sites in order to be able to relate performance to possible variation in construction quality.

2.3 Trial monitoring and data management

The monitoring of the completed RRST trial pavements involved the systematic collection of the following data:

- Visual condition: using numeric coded sheets.
- Roughness: using low cost simple apparatus (MERLIN).
- Strength correlations derived from in situ DCP tests.
- Gravel loss (where appropriate): cross-sectional leveling.
- Traffic: 12 hour traffic counts (3 or 6 day).
- Photographic records.

Table 3 - Monitoring activities

Deterioration Mechanism or Parameter	Techniques and Equipment	Application to Trial Options
Surface condition	Standard visual condition survey. Photographic record	All trial options
Roughness	MERLIN	All trial options
Deformation	2m straight edge	All trial options excluding concrete surfacing
Erosion	Engineering Level	Unsealed carriageway sections
Layer/ pavement strength	Dynamic cone penetrometer, DCP	Gravel and sealed stabilised base options. All shoulders
Moisture	Small disturbed samples	Gravel and unsealed options. Unsealed shoulders

Key to the conclusions discussed in this paper has been the collection of surface condition data in numeric coded form which has allowed surface deterioration to be analysed in a quantifiable manner. Condition data for the RRST has been collected in a series of surveys between 2005 and 2010, Table 4. The initial data was collected by the ongoing Consulting Team and then since 2006 by trained local engineers or university researchers with oversight and cross-checking by the Consulting Team. The condition monitoring of the Vietnamese trials has resulted in the assembly of significant amounts of data on the performance of a wide variety of pavement and surfacing types over a 6-7 year period.

The RRSR database was developed as a means of managing and analysing this wide range of data on rural road surfaces and pavements in Vietnam. The database includes information on:

- Trial pavement designs.
- Construction costs.
- As built condition.
- Change of condition with time.
- Traffic.
- Physical and climatic environments

Associated with this database are large sets of data collected on the gravel loss and deterioration of unsealed surfaces under the RRGAP initiatives Vietnam and in Laos. Some more limited, but still valuable, condition data is available from the less regularly monitored trials in Laos and Cambodia.

Table 4 - The RRST monitoring programme

Trial Phases	Provinces	Trial road completed	Monitoring times									
			SEACAP I				SEACAP 27			RT3	RT3 AF	
Monitoring survey round			AS built	I	II	III	IV	V	VI	VII	As built	I
RRST-I	Hue	May-05	Jun-05	Jan-06	Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Tien Giang	May-05	Jul-05	Jan-06	Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Dong Thap	Jul-05	Jul-05	Jan-06	Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Monitoring survey round				As built	I	II	III	IV	V		
	Da Nang	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
RRST-II	Tuyen Quang	May-06			Jul-06	Mar-07	Jan-08	May-08	Jan-09	Jul-10		
	Ha Tinh	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Quang Binh	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Ninh Binh	May-06			Jul-06	Mar-07	Dec-07	May-08	Jan-09	Jul-10		
	Hung Yen	Jun-06			Jul-06	Mar-07	Dec-07	May-08	Jan-09	Jun-10		
	Gia lai	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Aug-10		
	Dak Lak	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Aug-10		
	Dak Nong	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Aug-10		
RRST-III	Cao Bang	Mar-12									Mar-12	Sep-12
	Thai Nguyen	Mar-12									Mar-12	Sep-12
	Thai Binh	Apr-12									Apr-12	Aug-12
	Thanh Hoa	Apr-12									Apr-12	Sep-12

3 DATA ANALYSIS

3.1 Performance Indices

The analytical procedures have been predominantly based around the numeric assessment of the visual deterioration of the trial sections with time. To simplify the assessment two indices were set up; the Road Condition Deterioration Index (RCDI) and the Deterioration Extent Index (DEI). The Calculation of a Road Condition Deterioration Index (RCDI) for each trial section, based on key deterioration factors, allows assessment of the level of deterioration on a percentage basis relative to the as-built condition. The calculation of the Deterioration Extent Index allows assessment of the extent of deterioration for each trial section by summing all 5m blocks of the trial length of road showing any deterioration with respect to the key indicators. Table 6 below lists these key factors for each trial road group.

Table 5 - Key performance indicators

Trial Group	**Indicative Factors**
Concrete	Joint condition Crack extent Surface condition Potholes
Bituminous seals	Crack extent Ruts Potholes
Blocks	Block condition Joint Condition Ruts Potholes
Control Group	
Unsealed	Erosion Ruts Potholes

The Road Condition Deterioration Index of a trial section is the ratio of Road Condition Deterioration (RCD) to the as-built Road Condition Deterioration (RCDmax). This index shows the level of deterioration on each trial section for the features mentioned above. Individual Condition Deterioration Indices (CDIs) for individual factors can also be established. For example, in the case of the concrete slabs, assessing an individual CDI for slab seals has proved to be a useful step [8].

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

The combination of RCDI and DEI allows a rapid assessment for maintenance of deterioration, seriousness, and extent; for example,

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

These indices can be used to establish comparative relationships between the performance of the trial surfacing options within a series of road environment. Figure 1 presents an example of plots of RCDI and DEI. These simplified indices have also been used to estimate whole life maintenance costs.

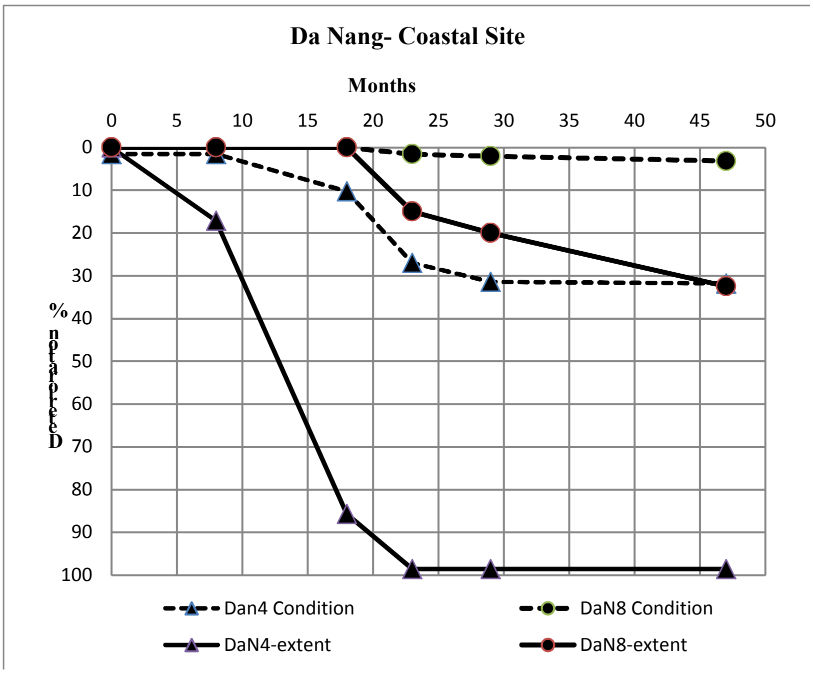

Figure.1 - Typical RCDI and DEI plots with time

3.2 Traffic

Traffic input to the design and evaluation of the RRST road pavements has followed a standard procedure of assessing traffic counts, firstly in terms of AADT and then in terms of equivalent standard axles(ESA). Table 6 presents outline data in terms of vehicles (motorised and non-motorised) and pedestrians and adjusted ADT.

Table 6 Traffic data for road sections discussed in this paper

Monitoring Sections	Survey Date	Traffic Volume									ADT	
		Truck≤5T	Truck≥5T	Bus	Car	Cong Nong	Motor-cycle	Cycle	Animal Cart	Walker		
	ADT Factor	2.5	5	2	0.8	1	0.1	0.05	0.2	0.02	12(hrs)	24(hrs)
Da Nang (DaN)	Nov. 2004*		0	2	0	22	206	426	0	260	74	89
	Oct. 2006		0	0	0	13	312	88	9	58	52	62
	Jan. 2008		0	2	1	13	141	90	0	67	39	46
	Aug. 2008		0	0	1	1	143	117	0	138	25	30
Hue (H)	Nov. 2004*		0	0	1	1	69	193	0	263	24	28
	Oct. 2006		0	0	3	17	578	588	0	565	118	141
	Jan. 2008		0	4	4	0	346	693	0	609	95	114
	Aug. 2008		0	6	3	0	426	296	0	218	79	95
Hung Yen (HY2	July 2005*		2	31	9	66	147	191	40	168	196	236
	Jan. 2008		0	37	16	0	280	206	48	216	158	189
	Aug. 2008	4	0	29	3	0	215	165	7	97	116	139
Hung Yen (HY3	Sept. 2006**		2	3	2	30	258	404	35	507	112	135
	Jan. 2008		0	7	3	0	148	145	26	164	50	61
	Aug. 2008	1	5	15	9	51	472	1046	97	863	260	312
Tuyen Quang TQ1	July 2005		21	23	15	25	756	854	18	587	333	400
	Aug. 2008	3	12	14	5	29	826	454	21	281	249	299
	July 2005		1	5	4	7	222	605	5	554	92	111
Tuyen Quang TQ2	Sept. 2006		92	4	7	20	1041	1087	8	279	661	793
	Jan. 2008	4	14	24	13	18	740	722	9	178	274	329
	Aug. 2008		3	6	13	2	706	530	0	80	141	169

Notes: * = Prior to construction. “Cong Nong”= Local “tiller-tractor” based vehicles

Some pertinent factor with regard to the traffic counts are:

- The high regional variability in traffic patterns
- General volumes of traffic axle loads are below “standard axle”level.
- The high volume of two-wheel vehicle traffic in some locations

- Variability of heavier traffic – due in some cases to intermittent quarry/construction activity.

4 LOW VOLUME SURFACING TRIALS DATA

4.1 LVRR surfacing performance.

The RRST programme and the supplementary work in Lao PDR and Cambodia has produced a large set of information on the performance of LVRR surfacings and associated structural layers, under a variety of road environments. The following figures are examples of typical analysis plots to illustrate surfacing and pavement performance with time in a selection of road environments.

Figuress 2 and 3 show the relative performance of two bituminous options, (PMac, S-SBSTe) compared with non-bituminous options, including unsealed gravel. The key road environment factors are high rainfall (3000mm/yr); poor gravel sources; flat terrain subject to severe flood; low traffic (100 ADT) mainly motor cycles and cycles; little or no carriageway maintenance over the 5years of monitoring. During the monitoring period the road was subject to 1 major overtopping flood event. .

Significant points are:

- Good performance of bituminous seals, with signs of deterioration increasing after 3 years without maintenance
- Very poor performance of unsealed gravel
- Adequate performance of concrete blocks for 2-3 years
- Good resistance of cobble to climate impact, although roughness a significant issue with road users.
- Very good performance of concrete surfacing, however the early deterioration in the inter-slab joint seals is a significant feature in the cost-performance review of these options

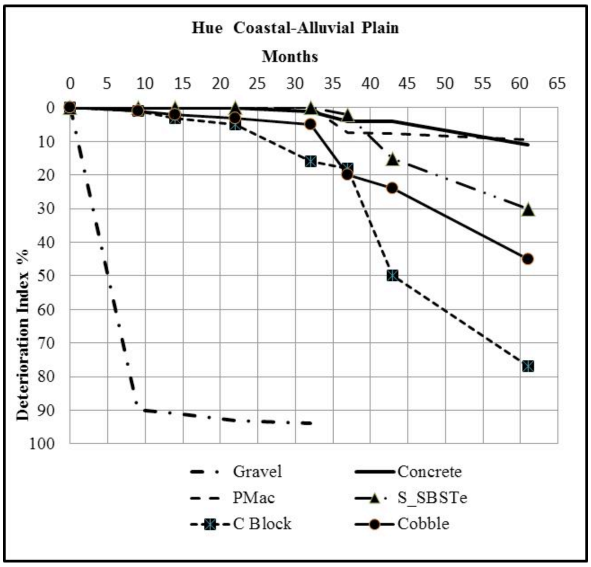

Figure 2 - Deterioration comparison of trial options

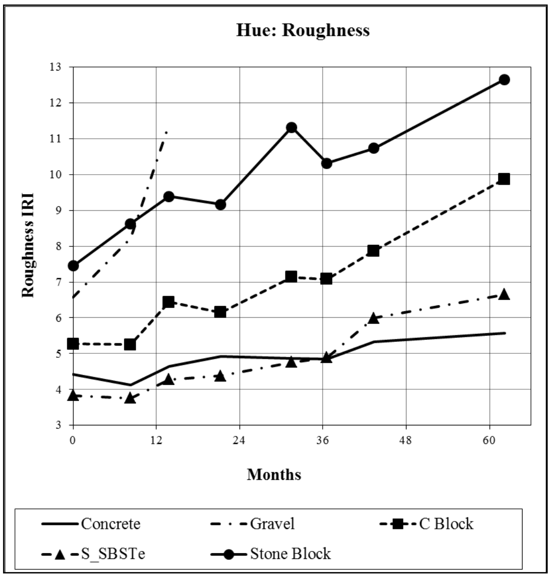

Figure 3 - Comparison of IRI roughness

Figure 4 presents the poorer relative performance of DBST seals over cement stabilised sand base (CSB) as compared to DBST over macadam and bitumen emulsion stabilised base. The road environment is characterised by very high rainfall (up to 4000mm/yr), flat coastal floodable terrain, and very low, farm-based, traffic (ADT 30) comprising mainly motor cycle, cycles and local small pick-ups (con nongs). No carriageway maintenance was undertaken during the monitoring period. In addition to the probable influence of cement modified base cracking this trial had a low construction quality assessment.

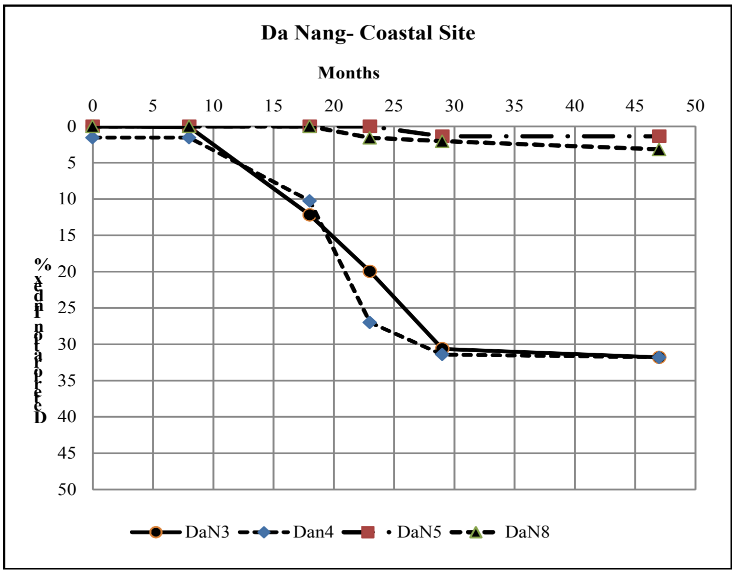

Figure 4 - Performance of cement stabilised base relative to other options

DaN3	S/SBSTe over cement stabilised sand base and sub-base
DaN4	S/SBSTe over cement stabilised sand base and emulsion stabilised sub-base
DaN 5	Penetration Macadam/WBM
DaN8	S/SBSTe over emulsion stabilised sand base and sub-base

Figure 5 illustrates the very poor performance of single bitumen emulsion sand as a seal over concrete block and clay bricks. The Road environment at this site is characterised by low-lying deltaic terrain, moderate to high rainfall (around 2000 mm/yr) and moderate farm traffic (around 200 ADT) with some buses and occasional trucks.

Figure 6 compares the performance of DBST and DBSTe on two trial roads of the same design (macadam base) in similar road environments characterised by rolling hill terrain, moderate to high rainfall (2000 mm/yr); no maintenance and moderate to high rural traffic (normally up to 400 ADT) mainly farm-based but including a significant number of small trucks and buses. The data indicate the DBSTe performing significantly better than the standard Vietnamese hot bitumen DBST design. It should be note however that the DBST lengths were designated as “control sections” and as such were built under normal rural road condition of contract and supervision, whilst the DBSTe sites benefited from appropriate training in DBSTe procedures.

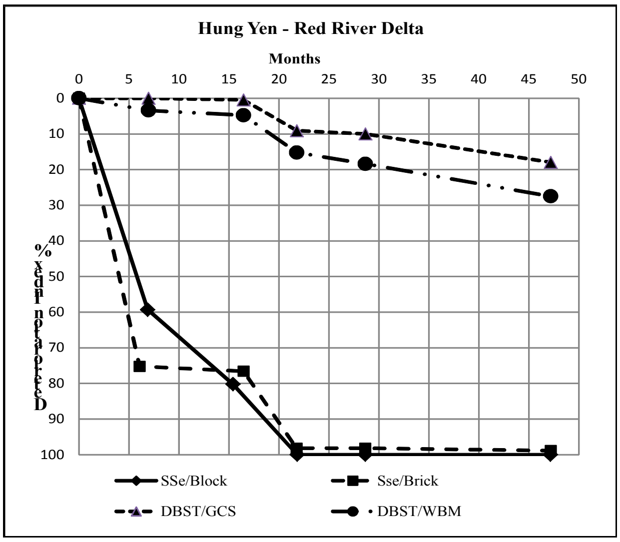

Figure 5 - Single sand seal performance

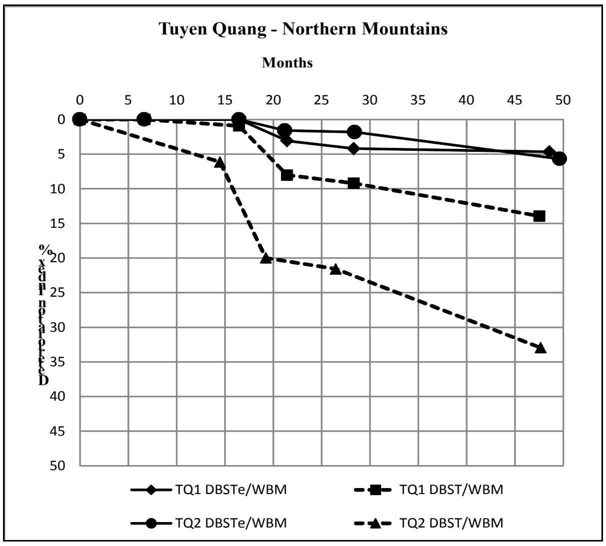

Figure 6 - Comparison of DBST and DBSTe.

For concrete pavement options, the primary of manifestation of failure is cracking of the concrete slabs themselves, although early deterioration in concrete joint seals was also noticed. An analysis of the surveys up to 2008 showed that in a total of 385 concrete slabs in the monitored sections representing 15 distinct experimental sections of road in 12 provinces, only 17 slabs showed some form of cracking.

The requirements for maintenance of low volume rural roads can also be initially assessed with the aid of the RRST RCDI and DEI analytical tools. ..

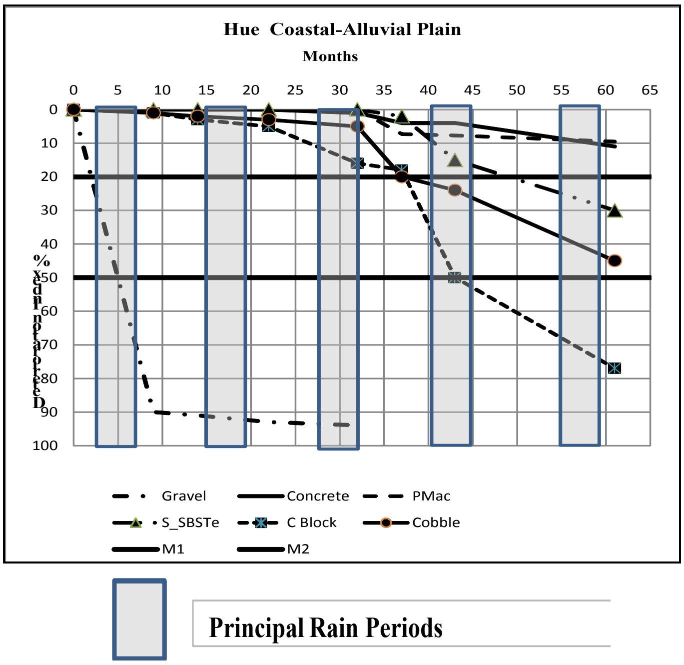

Figure 7 - Comparative maintenance requirements.

Figure 7 illustrates the comparative maintenance requirements for a number of trial options within a single road environment using these indices and assuming 20%

deterioration (M1) requires routine procedures and greater that 50% (M2) would require significant periodic procedures. The RRST maintenance analyses for all the trial sections highlighted the following points:

- There were very high rehabilitation requirements associated with repair of structurally failed roads due to excessive axle loads in some sections. These cannot be considered as maintenance costs, but they do serve to highlight the penalties associated with poor road management.
- There is evidence that districts or provinces that protected their LVRRs from truck overloading by use of physical barriers had reduced deterioration and hence reduced repair or maintenance costs.
- Apart from structural problems, particular issues such as the cracking over stabilised bases, the defects associated with the sealed flexible sections are generally occurring on a wide area (high DEI), but with low severity (low RDCI index).
- Where poor construction technique was identified it had a significant influence on the performance of the bituminous seals.
- Whilst sealed roads can withstand the typical Vietnamese “low” or “no maintenance” regimes for up to 2-4 years, the consequences thereafter are increasingly severe.

5 SUMMARY OF TECHNICAL CONCLUSION

5.1 Unsealed LVRRs

The RRGAP has shown that unsealed gravel roads are not a sustainable option in many of the road environments of Vietnam, especially so if no effective maintenance programme is in place. The costs and environmental implications of an effective re-gravelling programme are of considerable concern in whole-life management terms.

5.2 Bitumen Sealed LVRRs

1. The local contractors have significant experience in constructing penetration macadam (PMac) pavement and they were generally constructed to a reasonable standard. The data indicates that the penetration macadam option is performing better than either DBST or DBST(e) seals. However there is evidence that they are susceptible to shallow potholing or ravelling deterioration under heavy truck traffic and once this occurs the subsequent further deterioration is rapid. Penetration macadam consumes a high quantity of bitumen per unit area and is not an efficient use of this expensive and high-carbon-footprint material.
2. DBSTe seals are performing at least as well as the Vietnamese standard hot bitumen DBST seals. It may be truer to say that the combination of DBSTe over DBM is performing better than the Vietnamese standard option of DBST over WBM. The former combination is therefore considered preferable.
3. The single sand emulsion over SBST(e) seals generally deteriorated significantly within 1-2 years. However it is worth noting that current international advice recommends a second layer of sand seal should be laid within six months of construction. It is apparent that the sand-sealing is not a suitable option within the high rainfall - low maintenance road environments such as commonly exist in Vietnam, Cambodia and Lao PDR.
4. Apart from the cracking over cement stabilised bases and sub-bases the modified pavement layers have, essentially performed well and analysis of structural strengths

have shown them continuing above the required design strength over the monitoring period.

5. DBST sealed bitumen emulsion stabilised sand base and sub-base trials have performed well, although the cost and need for specialised training for local contractors mitigate against this option
6. Poor construction and supervision procedures are major issue with the bitumen seal sections sites.

5.3 Concrete slabs

1. Concrete trials roads are generally performing well. Even on the sections characterised in the review as “poor performers”, the pavement slabs are still performing adequately in a zero-maintenance regime. The reason is that although there may be cracking present on the pavement; its severity (width and depth) is low.
2. The early deterioration in the inter-slab joint seals is a significant feature in the cost-performance review of these options.
3. Poor construction technique and poor sub-bases have been shown to be major factors whenever the performance of the slabs is poor.
4. Bamboo reinforcing for concrete slabs has been shown to have no advantage over well-constructed non-reinforced concrete. Its continued use is not recommended.

5.4 Blocks and stone

1. The single sand seal on block options have a poor performance. The addition of a second sand seal would add to the cost without any guarantee of improvement in high rainfall and flood environments.
2. The use of mortared joints appears to have advantages over sealed sand joints in high erosion environments; however, there could be a disadvantage in the loss of inter-block flexibility.
3. It is found that on the poorly performing sections, the overall DEI% is high but the RDCI is less than 20%, i.e. the defects are widespread but not yet significant. Hence the sections classified with a high DEI% in fact are still performing well as their deterioration condition is not serious.
4. Joint and surface deterioration are the dominant defect in concrete block or brick surfacing. Significant block damage was found only on one section where there were recorded problems with compliance with brick strength specifications. . The minimum strength requirement of 20-25MPa for manufactured engineering quality bricks is therefore important.
5. Based on the RRSR evidence, these block options cannot be described as low maintenance options. However, if the relatively cheap maintenance is carried out timely and regularly then good performance can be retained for a long time.
6. Stone cobble, stone set or hand-packed stone options have performed very well in terms of resisting climate impacts however their inherent roughness is a problem for cycle-based traffic. They are potentially very useful option in steep difficult road sections.

5.5 General LVRR issues

The design and construction of rural road networks should be founded on a five key principles:

1. Roads must suit their function or task.
2. Design must be suitable for the local environment.
3. Optimum use should be made of local materials.
4. Local contracting capacity should be developed through appropriate training, certification and supervisory arrangements.
5. Design options should be selected with whole life costs that will not place excessive burdens on the local asset management budgets, local physical resources or communities.
6. Roads subject to high climate impact risk should be considered for a Spot Strengthening approach that utilises two or more options based on the road environments governing individual road lengths.
7. For LVRRs the key initial question should be- “What roads can I build with the locally available materials?” rather than “Where can I find materials to meet inappropriate specifications?”

6 LESSONS ON DISSEMINATION AND EFFECTIVE UPTAKE

Resistance to the implementation of new techniques remains a major challenge to the transfer and application of new knowledge in the transport sector. This is at least partly due to the inherently conservative nature of the civil engineering profession, but primarily due to normally lengthy path from research to full implementation, which typically requires a much longer length of time than the timescale of most donor-funded research initiatives. The value of constructing pavement or surfacing trial “demonstrations”, for example, is strictly limited without the additional time being put into their monitoring and evaluation. It is also essential that there is a framework within which they can be mainstreamed. For example, suitable rural road standards are essential to provide the context within which local resource-based pavement options may be assessed and selected for appropriate use [9].

The RRST monitoring has so far spread over 5 to 6 years and has delivered a significant body of data on LVRR performance and lessons from that work are now being applied in Vietnam, S.E Asia and other regions [10].

Lessons on timescale may be drawn from the overall phasing of the RRST programme:

Research need identified	2000
Research scoping	2001
Funding secured	2002
Research initiated	2003
First trials completed	2005
Monitoring	2005-2010
Feedback into World Bank programmes	2007
Feedback into regional programmes	2007-2015
Feedback to Further trials	2011-12
Input to new Vietnam Local Road Standards	2014

These timescales are considerably in excess of what used to be normal timescales for in international funded research. . It is essential to consider the whole research-uptake chain, Figure 8. Traditionally LVRR research has delivered well in terms of output and adequately in terms of dissemination; it has performed less well thereafter further down the chain.

The key lesson to be drawn from the multi-funded RRST work is that it is both essential and possible to achieve good “down-chain” success provide a longer view is taken of research aims and objectives both by donors and research promoters. The current DFID funded African and Asian Community Access Partnerships (AFCAP and ASCAP) have taken this lesson on board and clearly see achieving uptake and embedment of applied research as the “end-game” rather than just research dissemination.

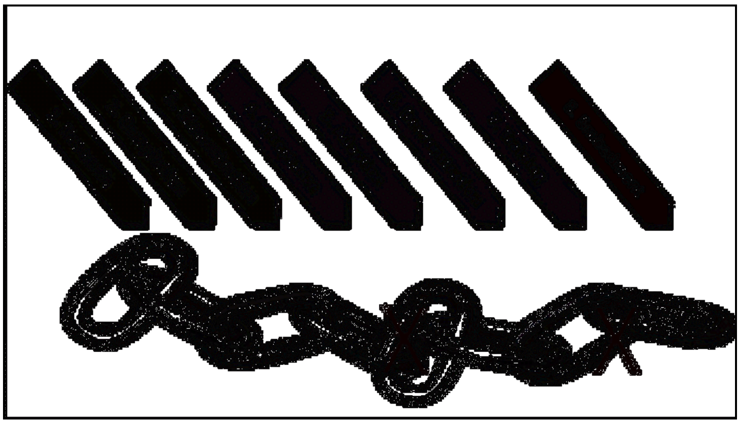

Figure 8 - The project chain – A key lesson to take on board

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