

Improving Vietnam's Sustainability

Key priorities for 2014 and beyond

Rural Road Pavement and Surfacing Design Options

Key Messages

1. Rural roads that are designed to be compatible with their task and their local environment are more effective in terms of whole life costs than those that are not.
2. Poorly or inappropriately maintained rural roads are very likely to fall short of design life performance targets.
3. Current Vietnam rural road design and construction procedures are, in many instances, out of step with current National and Regional research and International practice.

Key Actions

1. Final assessments of the conditions of the trial pavement, particularly with respect to climate impacts.
2. Upgrade of Vietnamese rural road standards, specifications and design guidelines to take into account recent research and potential climate threats.
3. Increased focus on meeting the challenge of funding effective rural road maintenance.

Research Background

Recent research in S E Asia and Vietnam in particular, funded by the World Bank and DfID since 2003, has focused on improving rural community access through more sustainable low volume rural road design. More appropriate design ensures that roads built are cost effective in terms of whole life performance.

Because of increasing recognition that gravel surfacing was not always the best solution for rural roads in Vietnam, the initial research focused on the performance of existing unsealed roads and the identification of sustainable alternatives. Subsequent research has focused on the relative performance of the alternative option trials and their role in providing a more climate resilient rural infrastructure. In general, this work has concentrated on a range of pavements to establish the best performance within a range of physical and socio-economic environments.

This note highlights the findings of the Rural Road Gravel Assessment Programme (RRGAP) and the Rural Road Surfacing Trials (RRST phases I, II and III) undertaken within Vietnam under the umbrella of

the Ministry of Transport Rural Road Surfacing Research (RRSR) committee. Outcomes were enhanced by information from complimentary projects within Lao PDR and Cambodia.

It is increasingly appreciated for Low Volume Rural Roads (LVRRs) that a range of factors, collectively known as the “Road Environment”, needs to be taken into consideration when selecting and designing 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 Rural Road Surfacing Research Programme

The Rural Road Gravel Assessment Programme (RRGAP)¹ comprised the evaluation of a representative selection of 269 WB-funded road links from 16 provinces. The road lengths covered a range of physical and climatic environments (flat deltas, coastal hills, moderate hills, high plains and mountainous terrain) by recovering visual, in situ

¹ Cook J R Petts R C, 2005. SEACAP 4 The RRGAP Final Report.

strength and laboratory test data from 766 spot locations.

Analysis concentrated on the amounts and variability of apparent gravel losses in relation to the impacting road environment factors.

Between 2003 and 2012 three phases of trial road selection, design and construction were undertaken under the RRST programme. The objective was to

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compare new pavement options in terms of construction and in-service performance against a number of standard Vietnamese “control” sections, Table 1.

Table 1. RRST Pavement and Surfacing Layers

SURFACING OPTIONS
Bituminous Seals
Double emulsion chip seal
Double hot bitumen chip seal
Emulsion sand seal & single chip seal
Single emulsion sand seal
Double emulsion sand seal
Unsealed granular surfaces
Gravel Wearing Course (GWC)
Water-Bound Macadam (WBM)
Block Surfacing
Stone Setts
Cobble Stone
Fired Clay Brick
Concrete Brick
Concrete Surfaces
Steel Reinforced
Bamboo Reinforced
Non-Reinforced
BASE & SUB-BASE LAYERS
Water-Bound Macadam (WBM)
Dry-Bound Macadam (DBM)
Emulsion Stabilised Sand
Cement Stabilised Sand
Lime Stabilised Clay
Armoured Gravel
Graded Crushed Stone
Natural Sand
Natural Gravel

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

- Designs should be appropriate to the road environments.
- Local construction materials should be used where possible.
- Maintenance requirements must be closely matched to local community arrangements and resources.
- Construction techniques should be suitable for small contractors and encourage local employment.

RRST Phase I comprised of a number of short sections (100m to 200m) of different trial options constructed on single roads. In the second and third phases two or three options of longer length (0.5-2km) were constructed on each road.² An almost complete coverage of road environments within Vietnam has now been achieved³.

RRST Phase I construction was completed in 2005; Phase II in 2006; and Phase III in 2012. Monitoring of the trial sections commenced as soon as construction was completed. 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. The last round of monitoring was undertaken in 2012.

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

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

The condition monitoring of the Vietnamese trials has resulted in the assembly of a significant amounts of data on the performance of a wide variety of pavement and surfacing types. The RRST database was developed as a means of managing and analysing this wide range of data on rural road

² Mot-DfID, 2006. SEACAP 1: Final Report – 3 Volumes

³ J R Cook 2013. Technical Report to WB Hanoi.

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surfaces and pavements in Vietnam. The database includes information on:

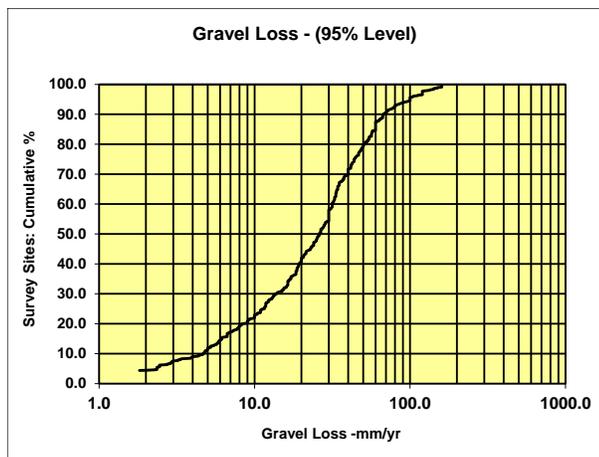
- Trial pavement designs.
- Construction costs.
- As built condition.

Research Outcomes

Sustainability of Gravel Wearing Course Surfacing

The RRGAP studies that showed unsealed Gravel Wearing Course (GWC) is not a sustainable option in many of Vietnam’s road environments. More than 60% of the analysed road sections indicated gravel loss of greater than the 20mm/yr taken as the limit of loss sustainability, Figure 1. Losses greater than 20mm/yr imply a need to re-gravel at 4 years or less for a normal 15-20cm design thickness. In some particularly vulnerable environments, for example high rainfall and /or steep hill terrain, all analysed road sections could be defined as unsustainable.

Figure 1 Overall Gravel Loss for 740 road sections



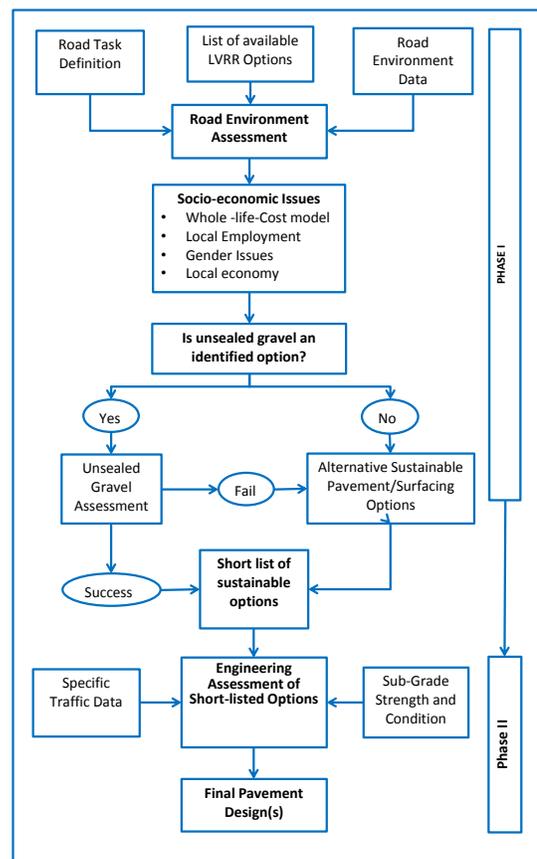
Pavement and Surfacing Selection and Design

A two-phase pavement selection and design approach has been developed, based on the

- Change of condition with time.
- Traffic.
- Physical and climatic environments.
- Historic climate

experience gained with the RRST programme, Figure 2.

Figure 2 An Approach to Pavement Selection and Design



Phase I comprises the identification of appropriate pavement types compatible with the road environment and may be considered as a progressive screening operation aimed at identifying one or more options that are compatible

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with the road task and its environment. The second phase is the detailed design of the selected pavement option compatible with engineering requirements; primarily traffic, axle load and sub-grade strength.

The identification of suitable pavement options can be considered as a filtering process whereby unsuitable or unsustainable options are removed from consideration.

Apart from road environment factors, other issues such as involvement of local groups in construction, local employment, development of local resources and social safeguard considerations can also be addressed. This process should highlight those options that are most suitable to take forward to final design.

Phase II of the selection and design process involves the detailed design of the general options identified under Phase I.

The Comparison of Engineering Performance

The rural road performance database allows comparative analysis to be made of different pavement and surfacing options. For example, Figures 3 and 4 compare options performance on a single road in a high rainfall environment

Figure 3 Performance of Different Options on a Single Trial Road: Visual Assessment.

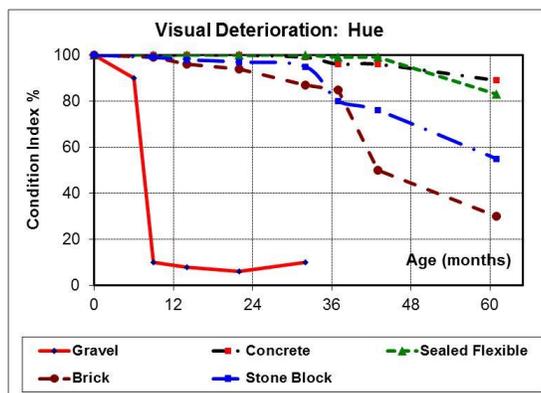
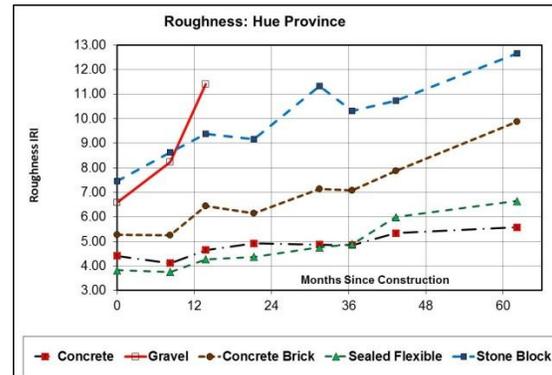


Figure 4 Comparative Performance of Different Options on One Trial Road: Roughness



Environmentally Optimised Design

The research has supported the concept of Environmentally Optimised Design (EOD) as an over-arching principle applied to pavement selection and design. Its application requires that the selection and design of pavements must take into account the full range of road environment factors that impact upon pavement performance along the road corridor.

The logical extension of this principle allows for the adoption of variable surfacing options along the length of rural road links, including using gravel or leaving “as-is” (optimising the use of in-situ or existing materials) and focusing on critical areas (SPOT improvements). EOD includes consideration of appropriate drainage structures at watercourse crossings. The adoption of this strategy allows a more focused use of limited construction resources where budgets are severely constrained.

Spot Improvements can be prioritised according to defined criteria, such as gradient, flood-prone areas or a dust-free road through a village⁴. A section of unformed road that provides access and is not dangerous may be left, while other sites are

⁴ S Done, J Cook. 2009. Low volume rural road environmentally optimised design manual. For DfID and MPWT Lao PDR

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improved. It is perfectly feasible, therefore, to balance low-cost surfacing solutions such as gravel or even engineered natural surfaces for low-risk areas with higher-cost solutions for the most-at-risk areas.

Specifications and Quality Control

The RRSR programme has prepared a library of relevant rural road pavement specifications in English and Vietnamese. These have been modified based on experience gained during RRST construction and monitoring phases. In addition, some further specifications have been developed from research in Lao and Cambodia.

One of the outcomes from the RRST work is the recognition that the standard of contractor compliance with specifications is variable and that poor quality control can be directly related to poor in-life service performance, and increased the vulnerability to climate impact. Existing supervision arrangements in the rural road sector do not appear to be sufficiently effective. Areas of particular concern are:

- Inadequate testing of materials prior to construction.
- Inadequate testing of as-delivered materials.
- Lack of required in situ testing.
- Poor control on cross sectional shape.
- Poor maintenance of site records.
- Use of inappropriate construction equipment

Pavement Drainage

Although drainage was not a direct component of the pavement trials its impact on the performance of the pavements was assessed and the following general conclusions arrived at:

- Side drainage was often poorly constructed and frequently omitted altogether.

- Missing or ineffective drainage could be directly linked to poorly performing or failing pavements.

Construction Costs

There was considerable regional provincial variability in constructions cost of the trialled option. Table 2 summarises some typical costs relative to specification-compliant unsealed GWC

Table 2 Typical Relative Construction Costs

Pavement options	Vietnam Region		
	Coastal	Northern Mountain	Centre Highland
GWC (20cm)	1	1	1
DBST/GCS Base-sub-base	3 to 4	2.5 - 3	4.5-5
DBST/lime or cement stabilised base- sub-base	3	6	n/a
NRC/sub-base	5	4	7
Stone block/Sub- base	5	n/a	n/a

One significant problem was noted as being the tendency for contractors cost and to then use cheap non-compliant GWC material.

Whole Life Costs

The significant difference in the initial construction costs per kilometre between unsealed and sealed, block paved or concrete roads is a major issue in the budget-constrained rural infrastructure sector. This is commonly exacerbated by the unrealistically low pricing of surfacing gravels based on the use of cheaper sub-standard, non-compliant materials. These prices make the gravel option seem falsely more attractive in terms of initial cost, when in fact the use of sub-standard materials will have significant negative impacts on pavement

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performance, with consequent social and local economic impacts.

A simplified Whole Life Asset Cost (WLAC) approach, assessing both maintenance and

construction costs over road design life period, has been developed for use in the RRSR programme and is included in the final RRST reporting.

Maintenance

The lack of routine or periodic maintenance undertaken on the RRST roads since 2005 reflects the general position in the rural road sector as a whole in Vietnam. However, by analysing the deterioration patterns of the trial options over 6-7 years it has been possible to assess the relative maintenance costs and to arrive at some overall conclusions regarding rural road maintenance in Vietnam.

Table 2 indicates general relative maintenance cost levels of pavements including both routine and periodic maintenance and surfacing averaged out over a 12-year design life. These costs will vary depending on the road environment.

Table 2. General Levels of Maintenance Costs

Pavement Maintenance Costs	Pavement Option	Relative Construction Costs
Very High (US\$2-3000/km/yr)	Unsealed granular	Low
Moderate-Low (US\$ 1500/km/yr)	Sealed Flexible	Moderate
Low (US\$ 500-1000/km/yr)	Stone block and mortared brick	Moderate to high
Very Low (US\$200-300/km/yr)	Non Reinforced Concrete	High

Concrete pavements: This is a low-maintenance option, not a “no-maintenance” option. Maintenance of joint seals is a major requirement and this will be greater in the case of pavements with a central joint. Cracked slabs are expensive to repair.

Sealed Flexible Pavements: If well-constructed this can give generally a “window” of 3-5 years before significant maintenance other than routine edge and occasional pothole repairs and minor sealing is required. Unless a system maintenance regime is then functioning, high rehabilitation costs associated with the repair of failed road sections will start to become significant.

Stone Block Pavements: This is a low-maintenance option. Costs for block pavements with joints filled with sand/fine chippings are higher than the cost for block pavements with mortared joints and are almost exclusively associated with replenishing the fine material, which should be done every 2 years.

Brick-Block Pavements: The rehabilitation costs of mortared joints in block pavements are relatively low. Indications are that the sand emulsion seals should be rehabilitated after 2 years of operation.

Unsealed Granular Pavements (GWC and WBM): These are high maintenance options. If left unmaintained, the rehabilitation costs in many regions after 24 months of operation are very high and can be equivalent to 50% of the construction cost.

Pavement and Surfacing Performance

Unsealed Granular Pavements

Analysis of the trial control section data confirmed the conclusions from the separate gravel studies (RRGAP) that unsealed GWC or water-bound macadam (WBM) surfacings are not sustainable options in areas of flood, high rainfall, or steep gradient. Monitored trial sections in the lower rainfall, flatter, regions in the Vietnam Central Plateau in similar traffic environments, have shown satisfactory performance when well-constructed with appropriate materials. Important issues include:

- The regular maintenance of cross-sectional shape is essential.
- Gravel materials must reasonably comply with specified grading and plasticity requirements.
- There must be sufficient gravel resources for maintenance as well as construction.
- Gravel loss is likely to be excessive where annual precipitation is greater than 2000mm/yr.
- Gravel should not be used on gradients greater than 6% in medium to high rainfall areas (1500-2000mm/yr). Gravel erosion may be significant on long gradients of more than 4%.
- Even in simple combinations of some of the above factors, gravel can be lost from the road surface at a rate of more than 30-40mm per year, leading to the need to re-gravel at frequent intervals.

Concrete Pavements

The concrete trial roads are generally performing well. Even on the sections exhibiting some cracking, the great majority of the pavement slabs are still performing adequately in a zero-maintenance

regime. The exceptions are where significant problems with the quality of concrete were recorded during construction and the slabs have now significantly deteriorated.

Other important factors include

- Poor construction and curing procedures and sub-standard sub-base are factors in the premature cracking of the concrete slabs.
- Bamboo reinforcement has been shown to have no advantage over properly constructed non-reinforced concrete.
- Poor shoulder maintenance and consequent erosion and under-cutting of concrete slabs give rise to cracking and eventual failure.

Sealed Flexible Pavements

A major outcome from the RRSR is evidence that the combination of emulsion double chip seal on dry-bound macadam base/sub-base is performing as well or better than the Vietnamese standard option of hot bitumen seal over water-bound macadam base/sub-base. Other key points are:

- Penetration macadam trials are amongst the best performing options. However some evidence from monitored sections indicates it is susceptible to shallow potholing or ravelling deterioration under heavy truck traffic and once this occurs the subsequent deterioration is likely to be 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.
- The single sand emulsion seals are showing distinct signs of erosion. However most of these seals are now over 5 years old and

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current international advice recommends a second layer of sand seal should be laid within six months of construction.

- The performance of a significant number of the poorly performing sites is being influenced by underlying structural issues in the road base and/or sub-grade related to axle overloading.
- Surface reflection cracking associated with lime or cement stabilised bases is evident in some sections.
- Cement stabilised bases and sub-bases have, however, performed well and analysis of structural strengths have shown them continuing above the required design strength over the monitoring period.
- Analysis of the structural strength of the lime stabilised base and sub-base trials in the Mekong Delta, has shown a significant and on-going deterioration in strength since the initial surveys. This is considered to be related to seasonal water level movement within the embankment and pavement immediately following construction.
- The trial flexible sealed options have been shown to be the most vulnerable to traffic and axle loads over and above the design criteria.
- Mechanical mixing of two granular components (eg clay and gravel or aggregate) was not trialled in Vietnam but is known to be an effective regional option.

Stone Block Pavements

The performance of the two stone cobble or stone sett trial pavements is good and they have been shown to be highly resistant to rain-storm and flood erosion. The inherently high roughness of this option has, however, been shown to increase significantly without maintenance, leading to a tendency for two-wheeled traffic to try to use the shoulders.

The pavement is effective in providing a sustainable surface/road-base in mountainous areas, albeit with high roughness consequences.

Brick Pavements

In general, the performance of fired clay or concrete block pavements appears to be variable. However, this conclusion should be further considered in terms of the scale and types of defects, as follows;

- The single sand seals overlying brick options have performed very poorly. Although despite this the brick pavements themselves have continued to perform satisfactorily with little or no maintenance.
- The use of mortared joints appears to have some advantages over sealed sand joints in high erosion environments; however, there could be a disadvantage in the loss of inter-block flexibility.
- Joint and surface deterioration are the dominant defects. Significant block damage was found where compliance with brick strength specifications was an issue.

Carriageway Shoulders

Road shoulders were constructed with a variety of materials in the following general groups:

- Unsealed Water Bound/Dry Bound Macadam.
- Sealed Water Bound/Dry Bound Macadam.
- Gravel.
- Quarry run – usually a coarse granular quarry waste product.
- Lime or cement stabilised local materials.
- Local soils.

Based on the visual assessment of the shoulders over the 4-5 year monitoring period the following conclusions were reached:

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- In general the shoulders were not maintained and were in a poor condition.
- In many cases the erosion of shoulders was impacting on the performance of otherwise sound pavements.
- Coarse quarry-run materials were clearly the best performing shoulder materials with sealed WBM/DBB a second best.
- There was a significant increase in shoulder deterioration after about 2 years with no overall maintenance.
- Full-width construction should be considered where the additional costs are justified.

Key Recommendations

A number of important technical lessons have either been learnt or re-affirmed by the RRSR and related programmes in S E Asia.

1. The design and construction of rural road networks should be founded on a four key principles:
 - Roads must suit their function.
 - Design must be suitable for the local environment Table 3.
 - Locally available materials should be used except where neither technically nor financially feasible.
 - Roads should be constructed with whole life costs that will not place excessive burdens on the local management budgets.
2. It is not possible for local authorities, designers or contractors to accept research-based outcomes their adoption by Ministries. This is an essential pre-requisite for effective take-up of the RRSR research.
3. An appropriate classification for rural roads is a necessary step in providing the context and control framework within which local resource-based pavement options may be assessed and selected for appropriate use.
4. For rural roads a key initial question should be “What roads can I build with the locally available materials?” rather than “Where can I find materials to meet general specifications”.

Table 3 Pavement Option for Typical Physical Environments

Typical Road environment	Potentially Suitable Options
Flat terrain adequate supplies of good quality gravel	Sealed armoured gravel (very thin aggregate base layer)
	Sealed gravel base/sub-base
	Sealed cement/lime modified gravel base/sub-base
	Unsealed gravel wearing course
Flat deltaic or coastal terrain subject to potential flooding. No gravel or aggregate nearby, some sand deposits	Non-reinforced concrete on cement stabilised sand sub-base
	Mortared concrete or fired clay bricks on cement stabilised sand sub-base
	Sealed DBM/WBM over cement stabilised sand sub-base
	Sealed cement stabilised sand base-sub-base
Rolling terrain to hilly terrain with variable quality hill gravel	Sealed lime stabilised gravel base/sub-base
	Sealed WBM or DBM base/sub-base
	Sealed WBM or DBM base, gravel sub-base or lime stabilised gravel sub-base.
	Unsealed gravel wearing course
River valley, abundant alluvial sands, gravel, cobble	Sealed WBM or DBM base/sub-base
	Non-reinforced concrete on DBM/WBM sub-base
	Stone sett/cobbles on gravel sub-base
	Mortared concrete or fired clay bricks on DBM/WBM or gravel sub-base

5. The use of technical standards and specifications that are focussed on up-to-date

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- regional or national requirements is essential, such as those developed for the RRST trials
6. The RRSR has shown that unsealed GWC roads are not a sustainable option in many road environments in Vietnam.
 7. Composite construction using different pavement designs along a road link can be appropriate.
 8. Spot Improvement solutions may be effectively applied in cases where there is insufficient budget to supply a sustainable whole road link solution.
 9. Effective pavement drainage, cross-pavement drainage and earthwork drainage are essential elements of a sustainable rural road. Apparent cost-saving on drainage will inevitably lead to poor performance and higher whole life cycle costs.
 10. WLAC assessment of pavement options must be part of the overall design approach.

Some Practical Outcomes of the RRSR Programme

Under SEACAP and subsequently under World Bank the outcomes from the RRSR work have been disseminated through technical papers and workshops. Practical outcomes from the RRSR may be summarised as follows:

1. Strategic change in pavement option selection between RT2 and RT3 in Vietnam; under RT2 the roads were approximately 80% unsealed whilst in RT3 the roads are approximately 85% sealed.
2. ADB have adopted a policy of promoting sealed or non-reinforced concrete pavements (rather than as previously adopting unsealed gravel) for irrigation project roads in their rural road programmes in Vietnam and in Lao
3. Outcomes from the RRSR work were incorporated into aspects of the World Bank funded Ethiopian Low Volume Road Design Manual and are included in the DFID-funded South Sudan Low Volume Road Design Manual.
4. RRSR outcomes formed part of the recommendations on Appropriate Standards and Specifications to the relevant Cambodian and Lao PDR ministries between 2007 and 2009.
5. The RRSR principles with respect to the Road Environment and Low Volume Road design have been included in a current ADB climate resilient infrastructure projects in Bangladesh and Laos.
6. RRSR recommendations on the road environment and pavement design have been included in the current Lao Poverty Reduction Fund programme (PRF-II, funded by World Bank).
7. The incorporation of RRSR content within teaching and research modules at the University of Transport and Communications (Vietnam).

What needs to be done?

As noted previously it is unreasonable to expect executing agencies to accept research-based pavement solutions without their adoption by the regulatory authorities into formal standards and operational manuals. In addition to completing the monitoring and analytical work on the trial roads in a logical manner, the development of the RRSR work should further mainstream the research outcomes and to work closely with the relevant departments or institutes under the MoT to produce updated practical rural manuals and guidelines.

There is in addition a need to take on board the impacts from increasingly severe climate events and incorporate these in a much more flexible and regionally focussed framework of standards and specifications.

At recent World Bank workshops in Vietnam there has been a growing request at provincial level for the adoption of more flexible and rural road standards. Much, therefore, remains to be done therefore in terms of championing the updating of Low Volume Road National Standards, Specifications and Guideline documents. .

Further Discussion

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